your Home

TECHNICAL MANUAL

FOURTH EDITION






REPRINTED WITH MINOR UPDATES






Australia's guide to environmentally sustainable homes

This is a collaborative project of the government and the building and design industry. The project was managed on behalf of the *Your Home* Steering Committee by the Department of Climate Change and Energy Efficiency.

Australian Government
Department of Climate Change and Energy Efficiency

1st Edition 2001
2nd Edition 2004
3rd Edition 2005
4th Edition 2008
4th Edition 2010 (reprinted with minor updates)

ISBN 978 1 921299 20 9

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The choice of materials used in the case studies in this publication are based on the judgements of the people and designers involved.

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(BOTTOM L-R)
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2. Subiaco Sustainable House
3. Dick Clarke
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2. Mirvac Lend Lease Village Consortium
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PRINTING

XXX

your Home

TECHNICAL MANUAL FOURTH EDITION











Australia's guide to environmentally sustainable homes

Preface

This project is the result of the combined efforts of a large number of committed people. At the last count there were some 30 principal authors, 15 contributing authors and 30 photographers, plus the people who have undertaken the energy ratings and others who have provided their input as members of the steering committee, technical advisers, industry and community representatives, commentators and reviewers of the various texts as they have evolved.

No other widely available Australian publication covers as much ground in quite the way achieved by the *Your Home* Technical Manual. As a resource for people aiming to build, buy or renovate a sustainable home it has proven its value time and time again. As water shortages and energy costs have increased along with awareness of climate change, the *Your Home* Technical Manual has become more and more relevant.

HISTORY

The *Your Home* Technical Manual was originally published in 2001. It was the first Australian publication to provide a comprehensive guide to sustainable building aimed at ordinary householders and occupiers as well as builders and building professionals. It has always been intended to keep the manual up-to-date, with the first two editions published in a ring binder format. From the outset, the printed version of the manual has been published in parallel with a website that makes the material readily available to people who don't need or want the full printed version.

There have been significant changes in the building industry since publication of the first *Your Home* Technical Manual. Basic thermal insulation requirements for housing were promulgated nationally in the Building Code of Australia for the first time in 2003 (although some states already had their own requirements) and these were upgraded to '5 Star' requirements in 2006. During the last five years or so the construction industry has openly embraced the idea that 'green is good' and there are now a number of industry programs promoting sustainable approaches to building.

In the future we can expect to see further upgrading of sustainability requirements in the Building Code and an increasing sophistication on the part of industry in delivering environmentally responsible buildings and products, meanwhile *Your Home* continues to provide a timeless tool for sustainable design.

CHANGES

This edition of the *Your Home* Technical Manual incorporates a number of revisions, all of which are responses to feedback garnered over the last few years. These changes range from reorganising the chapter structure, to adding page numbers and reconstructing the index. Some new fact sheets have been added and others rewritten to better reflect emerging concerns or provide more information on certain topics, such as adaptable housing and bushfires. All fact sheet material has been checked for its currency, and references to codes and standards have been updated. The climate zone references in this edition now employ the same descriptions and map used in the Building Code of Australia.

The case studies in this manual provide diverse examples of some of the best attempts to produce sustainable homes in Australia. Case study authors were given the opportunity to provide updates, including new images, and there has been an overall effort to ensure more consistency in the scope and presentation of case study information. Earlier editions of the *Your Home* Technical Manual gave performance ratings for the case study projects derived from a variety of sources. In this edition all the case studies have been rated against one building envelope performance system, *AccuRate*.

SUPPORT

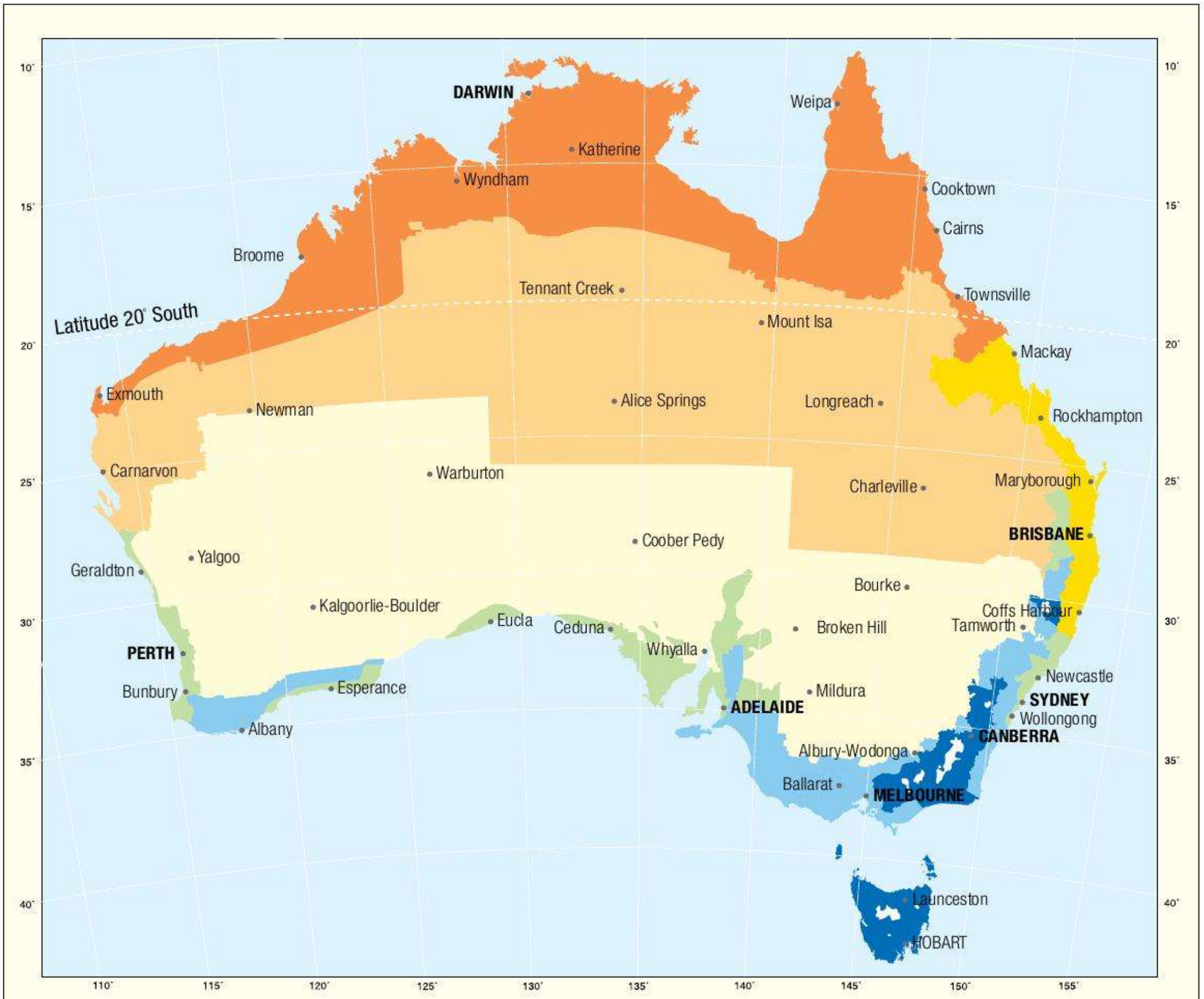
Industry and cross-sectoral support for the development of *Your Home* has been part of the project since its inception and crucial to its success. Originally shaped by the work of Chris Reardon and his crew at the Institute for Sustainable Futures and forged in the crucible of the Steering Committee and extensive peer review, *Your Home* has always been a particularly informative and robust work – as editor, I was fortunate to inherit an extremely well-constructed document. The design of the manual has been managed by Damian Monaghan with unfaltering attention to detail and astonishing reserves of patience! And I particularly want to acknowledge the invaluable and extensive assistance of the gracious, dedicated and well-informed staff managing the project.

Welcome, to the Fourth Edition of the *Your Home* Technical Manual – the continuation of a long-standing, concerted effort to maintain a current and effective tool for everyone interested in building homes for a sustainable future.



Paul F Downton
Adelaide, December 2007

Australia's Climate Zones



ZONE	DESCRIPTION
1	High humid summer, warm winter
2	Warm humid summer, mild winter
3	Hot dry summer, warm winter
4	Hot dry summer, cool winter
5	Warm temperate
6	Mild temperate
7	Cool temperate
8	Alpine

Note: The Building Code of Australia descriptions have been used throughout the Technical Manual for consistency. Individual jurisdictions may also use their own nomenclature to describe climate zones such as tropical (zone 1) and sub-tropical (zone 2).

1.0 INTRODUCTION

1.1 Introduction 2
1.2 Historical Perspective 6
1.3 Common Myths 8
1.4 Carbon Neutral 11
1.5 Rating Tools 15

2.0 SUSTAINABLE COMMUNITIES

2.1 Introduction 21
2.2 Choosing a Site 24
2.3 Streetscape 29
2.4 Sustainable Landscapes 32
2.5 Biodiversity On-site 35
2.6 Transport 38
2.7 Noise Control 41
2.8 Sediment Control 45
2.9 Challenging Sites 48

3.0 DESIGN FOR LIFE

3.1 Introduction 51
3.2 The Adaptable House 52
3.3 The Healthy Home 57
3.4 Safety and Security 62
3.5 Bushfires 65

4.0 PASSIVE DESIGN

4.1 Introduction 69
4.2 Design for Climate 71
4.3 Orientation 76
4.4 Shading 81
4.5 Passive Solar Heating 86
4.6 Passive Cooling 93
4.7 Insulation 101
4.8 Insulation Installation 108
4.9 Thermal Mass 114
4.10 Glazing 119
4.11 Skylights 127
4.12 Apartments and Multi-unit Housing 130

5.0 MATERIAL USE

5.1 Introduction 134
5.2 Embodied Energy 136
5.3 Waste Minimisation 140
5.4 Biodiversity Off-site 144
5.5 Construction Systems 147
5.6 Mud Brick (Adobe) 151
5.7 Rammed Earth (Pisé) 154
5.8 Straw Bale 157
5.9 Lightweight Timber 162
5.10 Clay Brick 166
5.11 Autoclaved Aerated Concrete (AAC) 169
5.12 Concrete Slab Floors 172
5.13 Green Roofs and Walls 176

6.0 ENERGY USE

6.1 Introduction 180
6.2 Heating and Cooling 184
6.3 Lighting 190
6.4 Appliances 193
6.5 Hot Water Service 197
6.6 Renewable Energy 205
6.7 Photovoltaic Systems 208
6.8 Wind Systems 211
6.9 Batteries and Inverters 213
6.10 Home Automation 216

7.0 WATER USE

7.1 Introduction 218
7.2 Reducing Water Demand 220
7.3 Rainwater 223
7.4 Wastewater Re-use 227
7.5 Stormwater 231
7.6 Outdoor Water Use 234
7.7 Low Impact Toilets 237
7.8 Water Case Studies 240

8-11 CASE STUDIES

Case Studies Introduction 243

8.1	Little Green Island QLD	NEW HOME	244
8.2	Rockhampton QLD	NEW HOME	247
8.3	The Gap QLD	NEW HOME	251
8.4	Gold Coast QLD	NEW HOME	255
8.5	East Perth WA	NEW HOME	258
8.6	Subiaco WA	NEW HOME	261
8.7	Perth Hills WA	NEW HOME	265
8.8	Tanja NSW	NEW HOME	269
8.9	Sunbury VIC	NEW HOME	274
8.10	Bairnsdale VIC	NEW HOME	278
8.11	Yarra Junction VIC	NEW HOME	281
8.12	Dandenong Ranges VIC	NEW HOME	285
8.13	Kangaroo Island SA	NEW HOME	289
8.14	Canberra ACT	NEW HOME	292
9.1	Clayfield QLD	MEDIUM DENSITY	295
9.2	City of Adelaide SA	MEDIUM DENSITY	298
10.1	City of Adelaide SA	HIGH DENSITY	303
11.1	Mt Ommaney QLD	RENOVATION	307
11.2	Northern Beaches NSW	RENOVATION	310
11.3	Chippendale NSW	RENOVATION	317
11.4	Clovelly NSW	RENOVATION	321
11.5	Marion SA	RENOVATION	326
11.6	Hawthorn VIC	RENOVATION	329
11.7	Surrey Hills VIC	RENOVATION	333

12.0 *YOUR HOME* CHECKLIST 338

13.0 INDEX 340

Introduction

If you are building, buying or renovating, this Technical Manual has been developed to show you how to design and build a more comfortable home that has less impact on the environment – a home that will also be more economical to run, healthier to live in and adaptable to your changing needs.

This Technical Manual contains specific information and practical solutions that you can adapt to your budget, climate and lifestyle.

The ideas and principles outlined in each fact sheet can be applied to any home. Suggestions cover new or existing homes and include villas, units, apartments and freestanding houses anywhere in Australia.

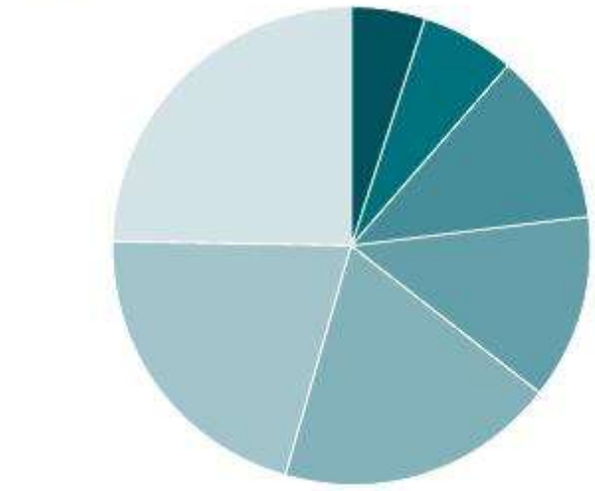
Always remember that whatever you do – no matter how small – it will contribute to your own health, comfort and lifestyle. It will also contribute to the health and wellbeing of the environment which sustains us now and which will sustain future generations.

Our behaviour and the way we build our environment are interconnected. Well designed homes perform best when used in a way that makes the most of their sustainable features.

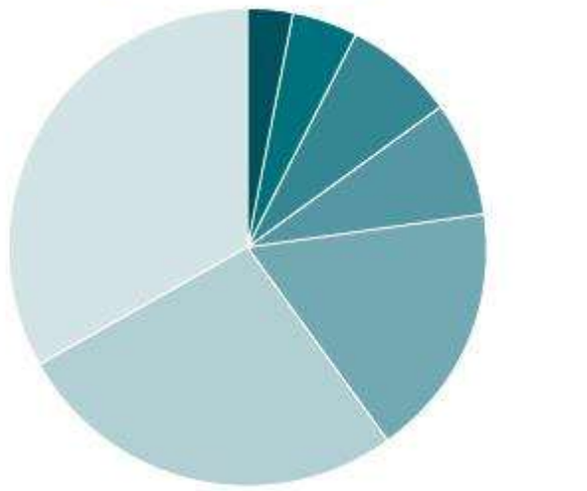
Adopt a lifestyle that minimises your use of energy, water and resources.

The most important action you can take now is to make a commitment to do all that you can within your budget. Little things, when done by enough people create enormous change.

Greenhouse gas emissions from home energy use (Baseline Energy Estimates, 2008)



Home energy use (Baseline Energy Estimates, 2008)



The percentage of greenhouse gas emissions from home energy use depends on the carbon intensity of the energy source. For example, the carbon intensity of electricity is much higher than that of natural gas or wood per unit of delivered energy. Therefore, although heating and cooling is the highest energy use in the home, as natural gas is typically used for heating, it is not the highest greenhouse gas emitter.

WHY USE GOOD DESIGN?

The home front

A great majority of Australians live in homes that work against the climate, rather than with it.

These homes are energy inefficient, too cold or too hot and comparatively expensive to run. Most homes use far more water than necessary, and can be made of materials that damage our health and the environment.

Building a home using good design principles can save energy, water and money, while creating a more enjoyable and comfortable home.

The cost of implementing good design ranges from a net saving through to a significant up-front investment that will be repaid throughout the life of the home and increase its value in the future.

The big picture

Australians currently emit more than 550 million tonnes of greenhouse gases each year. About 20 per cent of this is generated through everyday activities such as heating, cooling, cooking, lighting, driving the car, running appliances, travelling and from household rubbish decaying in landfill. In fact, the average Australian household emits around 14 tonnes of greenhouse gases per home each year.

The 'embodied energy' or energy used to create and transport the materials and furnishings in our homes also generate greenhouse gases.

Other impacts of ill considered building design include a loss of community, reduced natural habitat, increased water pollution and continuing soil erosion.

It now seems likely that the local patterns of our climate will shift and that we will need to adapt our homes and lifestyles to changing conditions.

One manifestation of climate change is an increasing frequency of extreme weather events such as storms, droughts, floods and bushfires.

Sea levels are also expected to rise. All these risks lead to higher living costs including insurance premiums.

These technical fact sheets can help you respond appropriately to any need for adaptation.

USING THE FACT SHEETS

The fact sheets in this Technical Manual describe practical ways in which you can implement principles of good design, whether you are a property owner, home buyer, builder, architect, designer or developer. All are important and all will make a difference.

The fact sheets are arranged into broad categories or chapters, each addressing specific aspects of home selection, design, construction and renovation.

1. **Introduction** includes this description of the Technical Manual. It then gives an overview of the issues including some of the history and myths associated with sustainability, and introduces some key concepts and tools.
2. **Sustainable Communities** covers ways to deal with a range of issues that are site related, such as streetscape, community, landscape and biodiversity. It highlights ways to minimise your home's impact on its building site and the impact of your site on the broader environment, as well as how to deal with transport, noise, sediment control and the problems of challenging sites.
3. **Design for Life** is about how to make your home safe, secure, protected from fire, and able to adapt to your changing needs.
4. **Passive Design** deals with design or modification of a home to make it more comfortable and reduce energy consumption in all climates by taking advantage of natural heating and cooling methods.
5. **Material Use** explains the environmental and health impacts of the materials used to build and furnish a home. Choosing environmentally preferred materials can reduce harmful health effects, minimise waste, reduce embodied energy consumption and minimise or eliminate other off-site issues.
6. **Energy Use** will show you how to reduce power consumption in your home and how to take advantage of renewable energy systems.
7. **Water Use** shows how to reduce the water you use inside and outside your home through improved water use efficiency, by using rainwater and wastewater and by designing your garden to need less water.

8-11. **Case Studies** presents real life examples of homes from all over Australia where good design principles have been applied. The studies are arranged in four categories:

> **New Homes** from remote islands to inner-city townhouses.

> **Medium Density** includes a range of building types that deliver sustainable solutions.

> **High Density** shows that even the most compact inner-city apartments can be sustainable.

> **Renovations** demonstrates that almost any existing home can be upgraded to deliver more sustainable, efficient and comfortable lifestyles.

12. ***Your Home* Checklist** covers the main points that need to be addressed in the search for a more sustainable home.

Use the *Your Home* checklist as a guide to make a list of the things you most want to achieve. Then find out more about them and how to implement them in these fact sheets.

BUILDING A NEW HOME

The fact sheets will help inform your decisions about where you want to live, how you should orient your home and other important design features. The decisions you make at this stage will determine everything else about your home.

Look at the issues covered by all the fact sheets and think about which are important to you. Make a list of priorities to take to an architect or designer for discussion.

Your choice of architect or designer is important. Make sure their views are compatible with your own.

Once you have agreed on an initial house design, use the fact sheets to take an imaginary walk through your home. Think about being in the kitchen and apply the fact sheets to water use and energy use. Can further improvements be made to the plans? Going through this process for all facets of your design will help you create a comfortable, economic and environmentally sustainable home.



Renovation of a suburban house in Marion, SA has achieved lower water and energy use, natural lighting and high occupant satisfaction.

BUYING AN EXISTING HOME

Look at the property and how the home sits on the block.

> Do the main living areas of the house face north?

> Is your potential purchase close to the facilities you want and need such as shops and schools, or will it force you to drive more and therefore cost you more over time?

> Does it look like it could be passively heated and/or cooled?

> Does it have potential for improvement?

Use the fact sheets to assess whether there is scope for enhancements using good design.

PLANNING A RENOVATION

Prioritise the things you want to achieve with the renovation, such as more space, a better kitchen, more sunlight, reduced energy and water consumption.

Read the fact sheets to find out about what materials might be suitable, what type of glass would be best in your windows, what sort of lighting you will require and how you might reduce your energy bills with better design.

Think creatively. Do you need to extend or could you achieve what you want just by modifying what you already have? A simple deletion (such as opening up a wall) rather than an addition can often provide the solution you're looking for.

HOME IMPROVEMENTS

These fact sheets contain plenty of information that will help you improve an existing home. Use the fact sheets to find ways to reduce water and energy consumption.

> Would a different garden use less water?

> How can the energy bills be reduced?

> Can you fit solar panels or replace inefficient appliances with better ones?

> Is the home well insulated?

> Can passive cooling or heating be improved?

This process will give you many great ideas about making your home more comfortable, cheaper to run and better for the environment.



PRIORITISING YOUR CHOICES

Cost is usually the main consideration when choosing what to include and what to leave out. The fact sheets contain advice to suit all budgets and lifestyles.

Creating the perfect sustainable home is beyond many budgets but there are effective options that are free or actually save money. Some low cost actions will rapidly repay a small initial extra investment.

Your Home does not prioritise one action or strategy over another. Each is important and can increase comfort or reduce the environmental impact of a home.

We can never be sure what the future may bring, but an adaptable home will be able to accommodate changes in lifestyle as your circumstances change.

Energy efficient, sustainable homes are rapidly increasing in value due to their greater comfort levels and lower running costs. Your home will be in existence for at least 50 years. Its re-sale value will be increasingly linked to the features described in this Technical Manual.

The following considerations are helpful when faced with the many decisions that must be made when designing, buying, building or renovating a home:

> Reducing energy consumption is an urgent priority. Climate change is already becoming apparent. This will inevitably lead to rising prices for energy from non-renewable sources. [See: 4.0 Passive Design; 6.0 Energy Use]

> Water is in critically short supply in Australia. Rising demand for household water supply is competing with the needs of agriculture and both are reducing the environmental flow required to keep our rivers and waterways healthy. [See: 7.0 Water Use]

> Australian soils are fragile. Soil loss and degradation from inappropriate vegetation clearing and excavation is accelerating. [See: 2.1 Sustainable Communities]

> Air quality is essential for health. Outdoor air quality is declining rapidly in most cities. Indoor air quality is dependent on outdoor air but has the added burden of toxins and gases emitted from the materials and furnishings in our homes. [See: 3.3 The Healthy Home]

> Conservation of biodiversity is essential to maintain the ecological systems that sustain us now and into the future. These systems produce the food we eat and purify the air and water we need to survive. [See: 2.5 Biodiversity On-site; 5.4 Biodiversity Off-site]

> Waste is an unnecessary consumer of precious resources and can poison our environment when disposed of. It can easily be avoided or minimised. [See: 5.2 Waste Minimisation]

SUSTAINABILITY & THE BUILDING SECTOR

The generally accepted definition of sustainable development is 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (WCED, 1987, Brundtland Report).

In practice this means living in harmony with the natural environment, considering the social, environmental and economic aspects of decisions, and reducing our footprint through a less energy, water and material intensive lifestyle. Social sustainability is also important and working towards a healthy and safe community is often interconnected with economic and environmental endeavours.

The building sector which comprises consumers, builders, architects, designers, manufacturers, government regulators, marketing agents and developers all face the challenge of developing sustainability in the built environment.

The built environment has in the past and in some cases continues to:

> Consume significant amounts of the earth's resources (especially energy).

> Generate polluting toxins and waste.

> Create conditions leading to a loss of soils and biodiversity.

> Interfere with life support systems (eg. the water cycle, soil systems and air quality).

> Exacerbate urban sprawl, traffic pollution, social inequities and alienation.

The building sector is working to identify and implement avenues of reform that will reduce its environmental impact and improve social cohesion.

If economic and social development is to continue without destroying the environment that sustains us, each and every member in the building sector must play their part in finding new pathways to sustainable futures.

Consumers

Consumer demand for housing has a significant influence on the market and the finished product provided by architects, designers, builders and developers.

Consumers are usually the building operators. Many adverse environmental impacts of housing arise during operation. This is particularly true of energy consumption and waste generation.

A clear understanding of how to operate a home and adopt the lifestyle options recommended in this Technical Manual will significantly reduce the operational impacts of a home whilst improving comfort, health and finances.

Consumers have a major role in making housing more sustainable. Awareness of environmentally sustainable design principles and expressing these preferences to marketers, architects, designers and builders will create great change.

Builders

Australian builders and trades people have demonstrated time and again their ability to adapt to new trends, regulations and technology. Building more sustainable houses is but one more challenge to which many builders have already risen.

Building is a very cost competitive industry. A 'level playing field' is essential to support the builder's role in creating more sustainable housing. Quotations should itemise things such as insulation levels, shading details, window performance and durability of materials and appliances – these are essential elements of a home just like the roof and walls and should not be treated as optional extras.

Architects and designers

Architects and designers of buildings bear much responsibility for the sustainable performance of the whole industry. They are the first link in the construction chain. The majority of important decisions affecting lifetime performance of buildings are made during the design stages.

Architects and designers have a leadership role in implementing sustainable reform. This Technical Manual provides guidance and tools to create practical, affordable and sustainable solutions.

Manufacturers

Manufacturers, like builders, provide products to meet regulatory standards or demand driven by consumer preferences.

Many manufacturers are discovering that they gain a distinct market advantage over their competitors by developing and marketing more sustainable products. The same is true for designers, builders and developers.

Governments and regulators

All levels of Government are working hard to implement sustainable reform. In our democratic society, elected representatives require clear mandates and support from the community to achieve this effectively.

By raising awareness and providing solutions, this Technical Manual will help create the platform for such mandates and encourage community support for reform agendas.

Marketing agents and developers

Marketing agents and developers respond to market needs. Their success depends on their ability to gauge the needs and wants of consumers and meet them with cost competitive products.

Experience with Newington Olympic Village and many other similar ventures across Australia have shown that the market is more than ready to embrace sustainable housing and that developers and marketers can supply it.

Developers and marketers also have a strong leadership role in implementing sustainable reform in the industry.

The *Your Home* Technical Manual will support this role by raising consumer awareness and demand and providing guidelines and technical information on implementation for architects, designers, builders, and you the consumer.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on building sustainability and energy efficiency, including what rebates are available.
www.gov.au

Australian Council of Built Environment Design Professionals. *Environment Design Guide.*
www.environmentdesignguide.net.au

Australian Greenhouse Office (2005), *National Greenhouse Gas Inventory 2005.*
www.greenhouse.gov.au/inventory/2005/pubs/inventory2005.pdf

Department of the Environment, Water, Heritage and the Arts (2008), *Australian Residential Sector Baseline Energy Estimates 1990 – 2020.*

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Historical Perspective

WHAT CAN BE LEARNED FROM HISTORY?

Sustainable design is not a recent concept – it's a recently lost one.

The reason we make buildings today is much the same as the reason we have always built – to make safe, healthy shelters that protect us from wind and rain, keep us warm when it's cold, and keep us cool and shaded when it's hot. Over long periods of time, by trial and error, people have evolved the tried and proven solutions that we call vernacular building – and these solutions all contain elements of sustainable design.

Since the time when humans lived in caves and enjoyed the benefits of stable temperatures and natural ventilation with zero mortgage and environmental impact, we have been refining our use of resources to provide improved shelter.

Until very recently in human history, this refinement occurred within sustainable principles because it was dependent on available resources and technologies. These limitations meant that solutions had to be effective yet still work with the environment and available materials rather than transforming and dominating them.

Cheap, accessible, fossil energy sources and the proliferation of technology and new materials have encouraged us to solve building problems differently.

Unfortunately, many of these new methods are compromising the ability of our planet home to sustain us in the long or even medium term.

Despite our technological advances, our housing needs have remained similar – albeit with increased levels of comfort and technology. This is because in the last few thousand years, humans have evolved very little physically. It is our technology that has changed and it has changed the way we build – not always for the better.

The new challenge is to use our technology to minimise environment impacts, whilst continuing to improve the comfort and performance of the homes we create.

Indigenous Australians have used common sense siting principles for many thousands of years. Australia's original inhabitants understood the need for lightweight shelter that provided shade whilst allowing air flow, yet in the hottest climates of the country we still build sealed boxes that trap the heat and then require massive amounts of energy to drive machinery to cool them down.



Struggling to find its place in an unfamiliar landscape – Blacksmith's Cottage at Wilpenna Station, SA.

We have become used to the idea that buildings can be heated or cooled as we choose simply by burning energy. Without that option, you would start to look at how to keep warm air in during winter and how to vent warm air out during summer, and that's what our predecessors did.

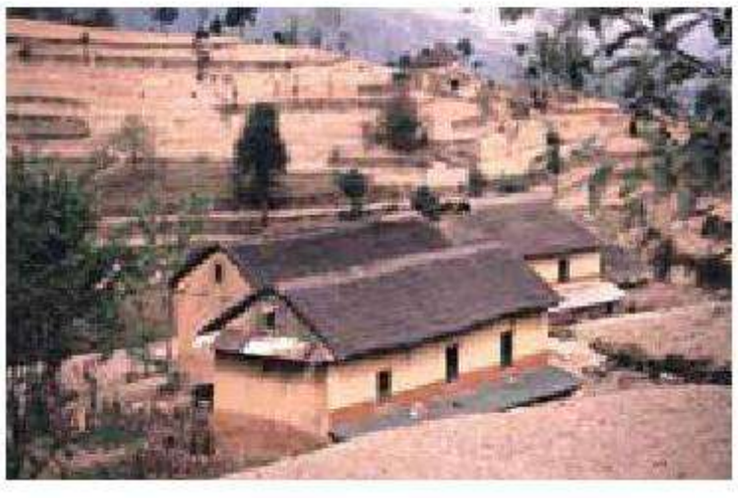
If you look carefully at some of the buildings that have survived from the early days of colonisation, you can often identify elements that are clearly design responses driven by climate, even if they are as simple as roof vents, or verandahs designed with vented gables so that the achievement of shade doesn't also trap hot air.

Early colonial buildings in this country often included elements of passive design in response to climate, often borrowing from the experience of other cultures. The ubiquitous verandah that is now so strongly embedded in the culture of Australian building originally came, along with its name, from India. Every culture that has brought its thread into the multicultural weave of Australia has a deeper history that can be drawn on for inspiration and example.



Colonial cottage with vents to main roof and gabled verandah.

The following examples of sustainable vernacular buildings illustrate how many simple principles of sustainable design remain as relevant today as they were thousands of years ago. Many of these principles have been incorporated into Australian vernacular buildings with great success.



Timeless Nepalese dwellings are built to a tried and proven formula that produces affordable, comfortable, easily maintained dwellings with minimal embodied energy, that endure century after century. Passive solar orientation and shading maximises solar gain. East and west windows are omitted. Roofing is lightweight, high insulation thatch of reeds grown on site (estimated R3.0 or better). Walls of rock are high in thermal mass and blend with the landscape. Rendering each year with mud guarantees longevity and prevents heat loss by caulking cracks and crevices. Early Australian settlers used similar building methods. [See: 4.5 Passive Solar Heating]

In Cappadoccia, Turkey, soft volcanic rocks were hollowed out to form 3000 year old thermally efficient homes that are literally part of the landscape. Durable, adaptable, and taking up no valuable productive land, many are still occupied today. These dwellings possess ultimate levels of thermal mass and earth coupling ideal for evening out the diurnal extremes of the region. They are well ventilated via thermal flues in summer. They store the heat from wood fires in winter and have extremely low embodied energy. Dwellings in Coober Pedy in Australia use the same principles. [See: 4.2 Design for Climate; 4.9 Thermal Mass]



In Wales, similar construction to the Nepalese example above was used for centuries where it also suited the climate. The open first floor windows in the photograph show convective ventilation at work allowing hot air to rise and escape from the house during the brief Welsh summer, drawing in cooler air at lower levels. In winter, the small windows reduce heat loss and the high mass fireplace and hearth absorbs radiant heat from open fires, re-releasing it later to keep the occupants warm during freezing nights. [See: 4.2 Design for Climate; 4.0 Passive Design]

Ancient cliff dwellings of American Indians in the south western desert country at Mesa Verde exploit a cliff overhang for passive solar control to not just walls and windows, but the whole village. Natural updrafts provide ventilation. Buildings are set into the cliff face and made of adobe and rock – high in thermal mass, low in embodied energy. The whole village is passive solar shaded and in summer provides ideal, cool sleeping spaces. [See: 4.2 Design for Climate]



Indonesian vernacular buildings use thatch as high level insulation to deal with heat gain in a tropical climate. Open gables allow cross ventilation of the hottest air that would otherwise accumulate in the roof space. Generous eave overhangs shade the building, further reducing heat gain. These principles are employed in the traditional 'Queenslander' which is also an excellent example of climate responsive architecture. The structures employ low thermal mass materials everywhere above floor level allowing the buildings to respond quickly to cooling breezes. [See: 4.2 Design for Climate; 4.6 Passive Cooling]

The Romans developed the first greenhouses as well as solar-heated bath-houses and access to the sun was made a legal right under the Justinian Code of Law adopted in the sixth century AD. In ancient Pompeii (Italy) the courtyard homes were built with high thermal mass, used adjustable shade and often supported roof gardens. [See: 4.2 Design for Climate]

The earliest green roofs we know of date back thousands of years and include the Hanging Gardens of Babylon (Iraq) which were what we now call 'intensive' green roofs with deep soil. Earth sheltered buildings have been part of the Chinese landscape for centuries and during those same centuries Europe's Vikings were building their homes with what we now recognise as 'extensive' (thin soil) green roofs. [See: 5.14 Green Roofs and Walls]

These sustainable principles of vernacular architecture stand in stark contrast with the principles employed in the majority of contemporary high consumption Australian houses built to rely on cheap fossil energy.

Just as the basic principles of sustainable construction are not new, neither is the idea of solar housing but after the first modern solar house was built in the 1930s in Chicago, Business Week magazine described it as a threat to the domestic fuel industry!

Meanwhile, research and development in climate-sensitive building has continued. There is now a vast amount of information available for building energy-efficient, climate-sensitive structures almost anywhere on the planet. The *Your Home* Technical Manual contains a distillation of that information for use here in Australia.

The urgent challenges we face are to:

> Rediscover these lost principles.

> Select those appropriate to our climatic and cultural context.

> Adapt and combine them with appropriate current technology.

> Use them consistently in the construction of our homes.

Most of the principles here are the same as those in the following fact sheets. Our current technology simply makes it easier to apply these principles with an even better understanding for increased comfort.

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Common Myths

Myths and misunderstandings about environmental design and features have prospered. They exist as the architectural equivalent of 'old wives' tales'. This fact sheet aims to dispel some of the common myths.

PASSIVE DESIGN

[See: 4.0 Passive Design]

Myth: If you can't design the perfect sustainable house there's no point bothering at all.

Fact: House performance varies across a spectrum, from very good to very bad. Incorporating any element of sustainable building practice will make a difference. Simply specifying the optimal eave widths on a project home or renovation may prevent unwanted sunshine overheating your home in summer. This step on its own will improve your thermal comfort and reduce your energy bills. All home design includes compromises, but try to do what you can to incorporate good design features.

Myth: Sustainable design is just for 'Greenies'.

Fact: Everybody benefits from good home design. Occupants from all walks of life now enjoy lower energy bills and improved comfort thanks to good design features. Everybody on the planet will benefit from reduced greenhouse gas emissions and better use of limited resources.

Myth: Sustainable designs are 'weird looking'.

Fact: Any style of existing home can benefit from the application of sustainable design principles and practices. Changes to existing buildings may go unnoticed by the casual observer. Optimum efficiency building design must differ from accepted, inefficient building styles, but a well designed home is usually a good looking home.

Passive solar homes can look like any other.



Myth: Using a 'sustainable' design means that there's no need to do anything more.

Fact: Good design is not a license for bad behaviour. It cannot compensate for an energy and water intensive lifestyle.

COST

Myth: Good design costs more.

Fact: Good design in many cases can cost less than bad design. Good design is nothing new, extra or onerous. Good design is largely about the intelligent use of space and materials. The greatest gains are made in planning and orienting the home appropriately and working with the climate and existing landscape.

Myth: The up-front cost of efficient fittings is too high.

Fact: While efficient products sometimes cost more, most are comparable in cost with standard items of similar quality. They also have lower running costs. Most efficient products are also premium products in terms of features and warranty. In many instances, the most efficient products are not necessarily the most expensive. For example, efficient space heaters which heat only the rooms in use are often a cheaper option than central heating which heats the whole house. An energy efficient house will similarly reduce the size of the heating and cooling systems required.

LIGHTS

[See: 6.3 Lighting]

Myth: Light quality and output from fluorescent lamps is poor.

Fact: Fluorescent lamps are a developing technology that has improved greatly in recent years. However, compared to incandescent lamps there is a much greater range in quality and performance. A range of colour temperatures and wattages are available, and it is important to select a lamp appropriate to the intended application.

The Australian Government is currently developing a Minimum Energy Performance Standard (MEPS) for performance and quality of CFLs. From October 2008 (proposed) all CFLs must meet this standard to be sold in Australia.

Myth: 'Low voltage' halogen lamps and downlights (12V dichroic) are energy efficient.

Fact: These lights are low voltage but not energy efficient. While low voltage lights provide more light than ordinary incandescent light globes for a given amount of electricity, fluorescent lights are far more efficient, delivering over four times more light than incandescent globes using the same amount of electricity. Downlights may also penetrate ceiling insulation, resulting in greater heat losses in winter. Mains voltage CFL Downlights are expected to become available in the near future.

Myth: Fluorescent lamps flicker.

Fact: Older magnetic ballast lamps may have a noticeable flicker. Modern, electronic ballasts operate at very high frequencies and usually have no noticeable flicker.

Myth: Turning fluorescent lights off and on uses more energy than leaving them on.

Fact: There is an 'in rush' current when fluorescent lamps are turned on that is higher than the current drawn during normal operation. As this additional current is only drawn for a fraction of a second, it is always more energy efficient to turn the lamp off when not needed.

Myth: Fluorescent lamps are bad for the environment because they contain mercury.

Fact: All fluorescent lamps contain some mercury but this is being reduced all the time. Maximum mercury content will be mandated as part of the MEPS. Far more mercury (and other pollutants) is released into the atmosphere from burning coal to provide the power for inefficient incandescent lamps.



Myth: Compact fluorescent lamps (CFLs) are heavy and bulky.

Fact: Some older magnetic ballast lamps were heavy and bulky but newer electronic ballast units are more compact and lightweight.

Myth: Compact fluorescent lamps are ugly.

Fact: Many of the early CFLs were not very attractive and were often put into the wrong type of fitting so the tube was visible. There is now a much greater range of shapes available, and they are being designed to look better. There is an even greater range of shapes and sizes of CFLs available overseas, including 'sub-miniature' types to replace small candle lamps – these are becoming available in Australia.

Growing demand for CFLs is increasing the range of choices available.

WINDOWS

[See: 4.10 Glazing]

Myth: Large north windows are always a great idea.

Fact: Poorly designed, inappropriately glazed or shaded north windows can lead to overheating. Moderately sized north windows are a good idea where winter sun is available to warm your home. Since windows and their shading and coverings can be expensive, reducing window area to an appropriate size can reduce the cost of your home.

Myth: Laminated glass is as effective as double-glazing in stopping heat transfer.

Fact: 10mm thick laminated glass is only marginally better than single glazing for reducing heat transfer. It is, however, as effective as double-glazing in reducing noise transfer. If you want to reduce noise and heat flow, double glazing is the best option.

INSULATION AND WEATHER PROOFING

[See: 4.7 Insulation]

Myth: Heavy materials such as brick and earth provide insulation.

Fact: Heavy materials are generally not good thermal insulators. They do not decrease heat flow like reflective or bulk insulation. Heavy materials do slow the passage of heat through the building fabric, and this can be beneficial in both winter and summer where there are large temperature differences between day and night.

Myth: Mudbrick and cavity brick walls don't need insulation.

Fact: Materials with high thermal mass such as earth and brick are generally not good insulators. In most climates these walls will benefit from installing insulation. Check with your designer or architect.

Myth: Bricks are weatherproof.

Fact: Most bricks allow moisture to pass through them. Cavity wall construction was devised to protect the inner wall from being damaged by moisture penetrating the outer brick skin. The outer brick skin is attached to the inner skin with cavity ties to provide strength. Water that penetrates the outer skin is shed via a drip groove. Brick is most useful on the inside where its thermal mass can help stabilise internal temperatures.

Myth: There's no point insulating walls, because all the heat just flows through the windows.

Fact: Adding insulation to one part of a home won't increase the heat losses through other parts. Although windows can be areas of great heat loss and gain, all insulation makes a difference by reducing heat flow. Insulated surfaces stay at a temperature closer to the indoor air temperature and therefore create a more comfortable environment.



Myth: Plastic pipes don't need insulation.

Fact: Many plumbers believe that plastic hot water pipes don't need insulation because plastic feels like an insulator. Although a better insulator than copper pipes, they still lose a lot of heat and need to be insulated.

Insulation is often the most cost effective way to reduce heating and cooling bills.

HEATING AND COOLING

[See: 6.2 Heating and Cooling]

Myth: A few draughts here and there don't make much difference.

Fact: Draught sealing around doors and windows can save up to 25 per cent of heat losses and gains in many climate zones.

Appropriate sizing of heating and cooling equipment can save on purchase and running costs.

Myth: Roof ventilators will keep your house significantly cooler.

Fact: Roof ventilators do not make an appreciable difference to house temperatures if the roof is insulated, particularly if reflective insulation is installed. If your ceiling is uninsulated a ventilator might make a small difference, but insulation is a better investment. There may, however, be other valid reasons for installing roof ventilators such as moisture removal.

Myth: It is much better to have an oversized heater or cooler because it's better to have them too big than too small.

An oversized air conditioner not only costs more to buy but cannot dehumidify air properly. It will only run for short periods and not have time to remove much moisture from the air. Consequently, the occupants feel sticky even when the air conditioner is running. Most air conditioners are less efficient when running at part load, and frequent cycling on and off may shorten their life. Oversized heating systems cost more, and will give bursts of heat, followed by long periods when no heating is occurring. Occupants are subjected to varying levels of heat and cold, especially when sitting near a window, where the temperature falls faster than it does near the thermostat.

Myth: A sustainable house's indoor temperature will be comfortable throughout the entire year without additional heating and cooling.

Comfort is very subjective and varies from person to person. At the height of summer or in a cold winter snap, indoor temperatures may become uncomfortable depending on an individual's tolerance. The sustainable home will be uncomfortable far less often than a standard home and require much less energy for heating and cooling if needed.

Myth: Air conditioning should be set at a constant temperature (eg. 22°C) all year round.

Human physiology enables us to adapt to seasonal and geographic changes in climate. Most people live in houses, drive in cars and spend time outside where the air is not constantly conditioned to 22°C. In winter 22°C may feel too hot and in summer it may feel too cold. People living in hot regions (eg. Darwin) will have a greater tolerance for heat and may find that a much higher temperature than 22°C feels right for them. In winter turn the thermostat down a few degrees, and in summer up a few degrees. Each degree can reduce energy consumption by up to ten per cent.

WATER

[See: 7.0 Water Use]

Myth: Water efficient shower roses don't give a good shower.

While many early models of water efficient shower roses performed poorly, new models with the 3 WELS Star efficiency rating have to meet minimum quality performance levels specified by Standards Australia. The 3 WELS rating is a guarantee that you will get a high quality comfortable shower while using up to 50 per cent less water.

LANDSCAPING

[See: 2.4 Sustainable Landscapes]

Myth: It is always better to plant native trees around the house rather than exotics.

Non invasive, exotic, deciduous trees can perform a vital valuable role in regulating the heating and cooling of a home. When planted to the north of a home they shade in summer and admit sunlight in winter. Try to choose varieties that will attract native wildlife to your garden.

Many people plant 'natives' that are neither indigenous to nor appropriate for their location. Some hardy Mediterranean and South African plants, for example, are often suitable or even preferable to inappropriate native species.



Good design is a design for life, a better quality of life that will directly or indirectly benefit everybody on the planet.

Principal author:
Geoff Milne

Carbon Neutral

Our lifestyles and homes have a significant impact on the environment. To balance and reduce this trend there is a growing interest in carbon neutral, zero energy and carbon positive homes. This fact sheet outlines key considerations for designing such homes.

Steps for moving towards a carbon neutral home:

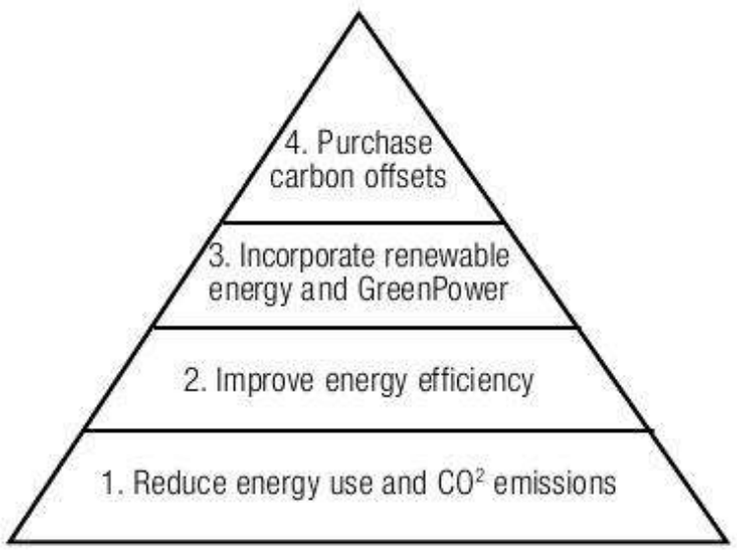
> Calculate the amount of emissions and energy being used.

> Reduce the demand for energy and activities that produce greenhouse gas emissions.

> Improve energy efficiency technologies.

> Incorporate renewable energy and use GreenPower.

> Offset the equivalent amount of emissions in other areas and activities.



WHAT IS CARBON NEUTRAL?

The term 'carbon neutral' aims to balance the overall amount of CO_2 being emitted into the atmosphere, by calculating how much CO_2 is being emitted from an activity and reducing the equivalent amount of CO_2 in another activity.

Carbon dioxide (CO_2) is a naturally occurring gas in the atmosphere. Before the industrial revolution CO_2 levels in the atmosphere were consistently between 260 and 280 parts per million (ppm). Since the industrial revolution human society has become increasingly dependent on burning the fossil fuels of coal and oil and as a result human activities have increased the concentration of CO_2 in the atmosphere to more than 380ppm.

For example:

CO_2 EMISSIONS ARE CALCULATED FOR AN ACTIVITY		OFFSET CREDITS ARE PURCHASED THROUGH AN ACCREDITED SCHEME		OVERALL CO_2 IN THE SYSTEM IS NEUTRAL
If 1 tonne of CO_2 is emitted each year, eg. through transportation or the burning of fossil fuels for electricity generation	+	1 tonne of CO_2 is absorbed by planting trees or other sequestration measures	=	the net result of CO_2 being emitted by the activity is deemed to be carbon neutral

Activities that we think of as quite ordinary, like driving a car or heating a house with a gas or electric heater, continue to contribute to the release of CO_2.

Although CO_2 is a small part of the atmosphere's composition it plays a major role in creating the greenhouse effect, which enables the atmosphere to trap solar energy and make the planet hospitable to life as we know it. Increased levels of CO_2 have been shown to relate to global warming and climate change, and while reduction of CO_2 to pre-industrial levels is considered difficult to achieve, any reduction is likely to help slow down climate change and every householder can contribute.

The goal of becoming carbon neutral may be achieved by carbon offsets. By purchasing offset credits that reduce CO_2 by an amount equal to that being produced, the overall amount of CO_2 being emitted into the atmosphere can be effectively zero, hence carbon neutral.

There are many carbon neutral or carbon offset schemes available in the market that offer to balance or offset the CO_2 emissions created by our lifestyles and homes. These schemes generally involve three steps:

1. The off-set scheme attaches a cost to emissions by working out how much it will cost them to carry out a project that is specifically set up to provide a greenhouse savings or benefit. (eg new tree plantings or stopping greenhouse gases from landfills).
2. The off-set scheme calculates the amount of CO_2 emissions produced by an activity.
3. The cost calculated in step 1 is applied to step 2 to give a cost to offset the activity.

In the following example, a cost is attached to carbon to show how an off-set scheme determines a dollar figure to offset the CO_2 emissions of a domestic flight.

For example:

1. If one tonne of carbon costs $13.75.
2. And one seat on the average short domestic return flight (up to 2600km) generates 0.399 tonnes of CO_2 emissions.
3. Then 0.399 tonnes of CO_2 emissions from the domestic flight would therefore cost $5.50 to offset.

Carbon offsets need to sequester carbon and take it out of the atmosphere to contribute to a carbon neutral result. They may also have other benefits, eg. trees not only absorb carbon dioxide while they grow and trap it for years to come, they can also help to combat salinity, reduce soil erosion, clean underground water systems and provide habitat for wildlife.

Reducing energy use is not the same as taking carbon out of the atmosphere – it only reduces the amount of CO_2 released.

Before considering a carbon offset scheme, ensure that the offset scheme is credible, and has undergone independent auditing.

Although carbon offsetting can provide a way to assist in balancing the amounts of CO_2 being emitted into the atmosphere as a whole, a long-term sustainable solution to environmental problems requires reductions in the amount of CO_2 being emitted in our homes and appropriate changes to our lifestyles.

BECOMING CARBON NEUTRAL

The first step in becoming carbon neutral is to reduce the demand for energy and the amount of CO_2 being emitted. After reductions have been made offset credits can be purchased equivalent to the remaining emissions.

Reducing CO_2 emissions from our homes can be achieved by adopting many of the techniques and procedures described in the *Your Home* Technical Manual, eg.

> Reducing the use of electrical appliances and switching off lights, appliances and equipment at the plug when they are not needed – especially a second refrigerator. [See: 6.4 Appliances]

> Selecting smaller energy efficient appliances with low standby power use and avoiding unnecessary purchases. [See: 6.4 Appliances; 6.10 Home Automation]

> Reducing water use (it takes energy to treat and pump water to a home) and reducing hot water heating by installing water efficient showerheads, taking shorter showers and using cold water for washing clothes. [See: 7.2 Reducing Water Demand]

> Draught-sealing and weather-stripping to reduce unnecessary heat loss and heat gain and setting thermostats appropriately. [See: 4.7 Insulation]

> Installing curtains and pelmets, external blinds and shading to reduce the need for additional heating and cooling. [See: 4.4 Shading]

> Changing the fuel source of hot water systems and home heating. For example switching from electric hot water systems to gas or solar hot water systems. [See: 6.2 Heating and Cooling; 6.5 Hot Water Service]

> Improving the energy efficiency of the home when building, renovating, renting or buying through methods such as:
  – ensuring effective orientation and layout to maximise solar-passive strategies [See: 4.2 Design for Climate]
  – adding or increasing insulation [See: 4.7 Insulation]
  – sizing and orientating windows appropriately [See: 4.10 Glazing]
  – providing double-glazing to windows [See: 4.10 Glazing]
  – using materials that enhance passive solar strategies [See: 5.0 Material Use]

> Adopting and developing a zero energy home – *see next section*.

Reducing CO_2 emissions in our lifestyles can be achieved by:

> Switching to low greenhouse impact transport options like walking, cycling or public transport – or use the telephone or email. If a car is essential, use a fuel-efficient one.

> Considering the time and cost of travel from your home location to work, school, shops and leisure activities. [See: 2.6 Transport]

> Diverting food and garden wastes from landfill to composting – when food and garden wastes break down without fresh air they create a mixture of gases including the very damaging greenhouse gas, methane.

> Purchasing food, products and other services that have not travelled long distances.

> Minimising waste of packaging and materials – 'refuse, reduce, re-use, recycle'.

> Reducing the purchase of non-essential products – ask "do I really need it?"

> Holidaying closer to home rather than flying to distant destinations.

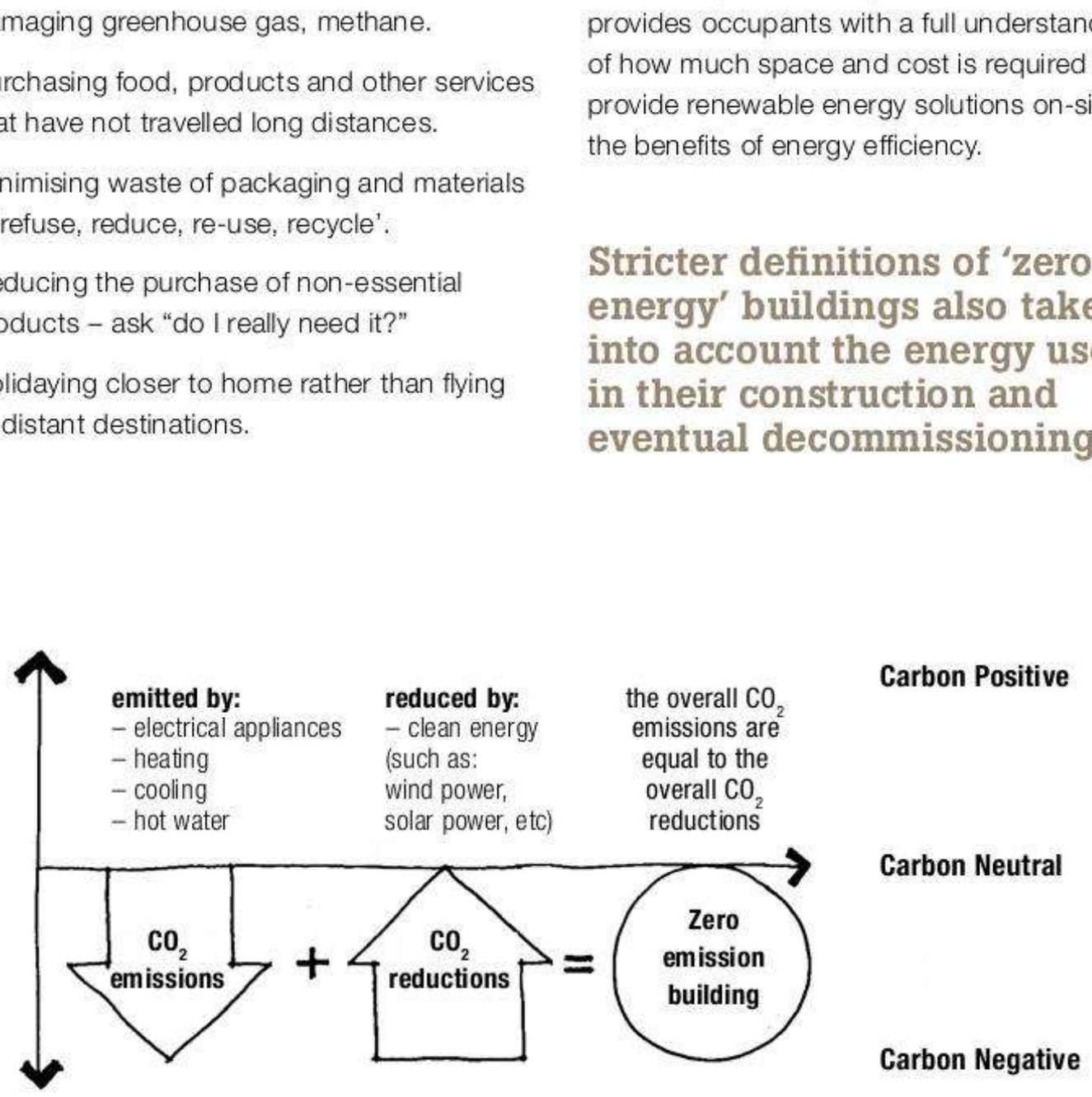
WHAT IS A ZERO ENERGY HOME?

The terms 'zero energy', 'zero carbon' or 'zero emission' are applied to buildings that use renewable energy sources on-site to generate energy for their operation, so that over a year the net amount of energy generated on-site equals the net amount of energy required by the building.

For example, a home that uses 5000kWh of electricity for a year may incorporate photovoltaic panels that generate 2160kWh of electricity in winter. This may not be enough electricity for what is needed during winter, but in summer 2840kWh of electricity could be generated, which would be more electricity than is needed at this time. If the combined result of electricity generated on-site for the year is equal to the amount of energy used for the year (2160 + 2840 = 5000kWh), the building can be considered to be zero energy. Nevertheless, it should be noted that in winter the additional energy needed would still result in carbon dioxide being released to the atmosphere unless it is also sourced from renewables.

Zero energy homes set out to use renewable electricity generated on-site. Although obtaining electricity from the grid through accredited green electricity providers should be used and could be considered as having net zero CO_2 emissions, the intention of zero energy homes is that they are relatively self-contained. This provides occupants with a full understanding of how much space and cost is required to provide renewable energy solutions on-site and the benefits of energy efficiency.

Stricter definitions of 'zero energy' buildings also take into account the energy used in their construction and eventual decommissioning.



Limitations of zero energy homes as described here, are that they only include the energy to operate the home and not other CO_2 emitting areas associated with our homes, such as the manufacture and transportation of building materials and energy used during construction.

Major benefits of creating zero energy, zero carbon or zero emission homes come from the increased energy efficiency strategies that are necessary to make on-site renewable energy sources viable and the immediate awareness and better understanding of energy use they encourage for their occupants.

DESIGNING A ZERO ENERGY HOME

Designing a zero energy, zero carbon or zero emission home can be complex, as each design solution must be tailored to the specific location.

This includes designing to the features and qualities of the site, designing for the requirements of the building's use, designing with an understanding of how to incorporate renewable energy sources on-site and designing with consideration of actual energy use – which is affected by occupant behaviour.

The basic principles that can be followed for designing zero energy homes are described in the *Your Home* fact sheets and include:

> Incorporating energy efficiency strategies with renewable energy options from the outset of the project. [See: 6.0 Energy Use]

> Choosing a site or location that allows for renewable energy opportunities and reduces transportation and food production needs. [See: 2.0 Sustainable Communities]

> Maximising passive design strategies in the design of the home to reduce energy demand. [See: 4.0 Passive Design]

> Reducing water use in conjunction with reducing the demand for hot water. [See: 7.0 Water Use]

> Selecting materials use appropriately, by incorporating materials that enhance the passive design strategy and have a low embodied energy. [See: 5.0 Material Use]

> Reducing energy use in all areas of the home. [See: 6.0 Energy Use]

Maximising energy efficiency allows energy needs to be met with reduced amounts of energy needing to be supplied. Renewable energy opportunities then become:

> Physically viable with reduced space requirements.

> Economically viable with a reduced amount of renewable energy source being required; and

> Environmentally viable with less resources being used to manufacture the renewable energy source.

For example:
In the early 21st century a typical Sydney household uses about 5,000kWh of electricity per year. Table 1 indicates the types of reductions that could be made to a typical home to reduce energy demand based on an all-electric household with a 2 star rating.

There are a range of opportunities for reducing the energy demand of a home, but these depend on the specific household. The energy efficiency measures in Table 1 are indicative only.

After reducing the energy use of the home, renewable energy opportunities can be reviewed as seen in Table 2.

Table 1

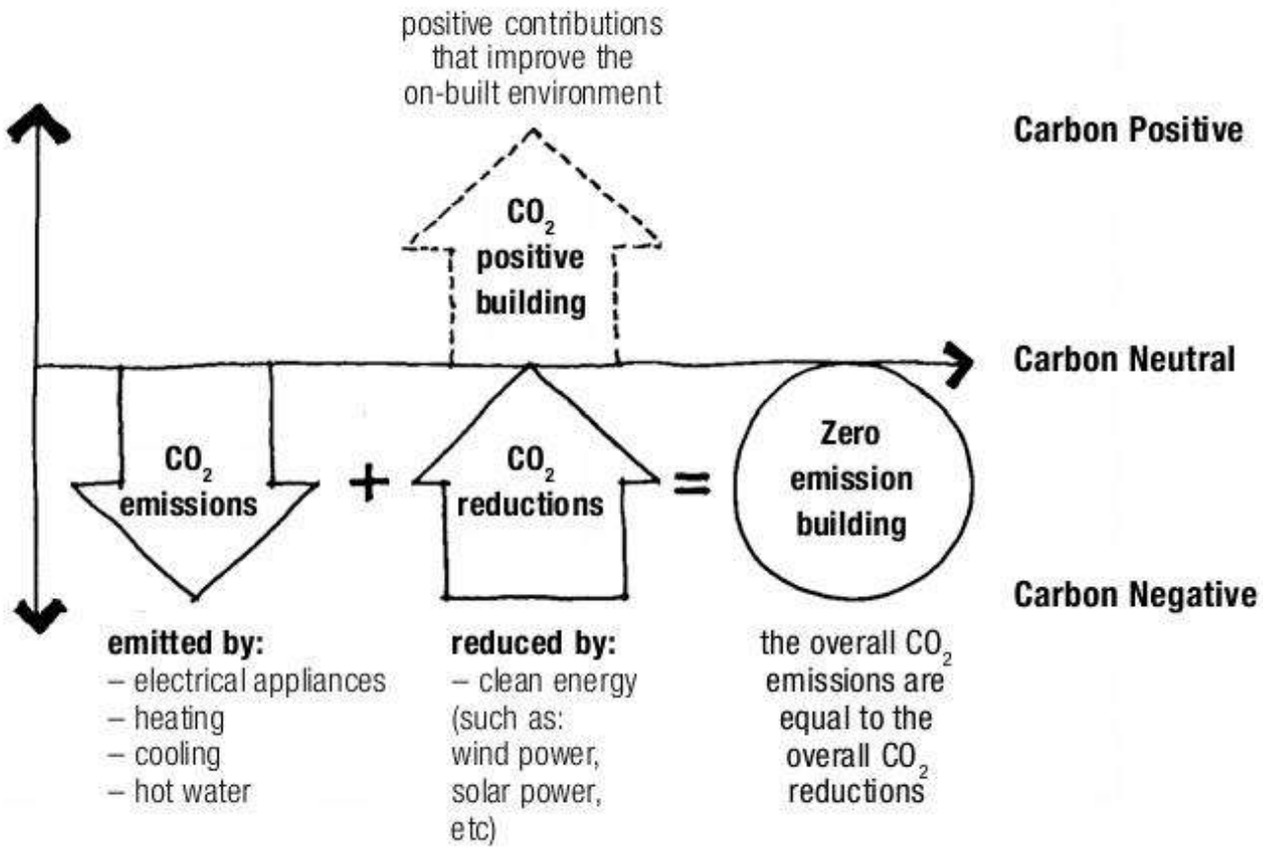
REDUCING DEMAND							
ENERGY USE OF AN AVERAGE AUSTRALIAN HOME EACH YEAR	INITIAL LOAD (kWh)	APPROX COST ASSUMING $0.15c/kWh	CARBON EMISSIONS	ENERGY EFFICIENCY MEASURES	APPROX. ENERGY EFFICIENCY SAVINGS	NEW LOAD (kWh)	APPROX. SAVINGS ASSUMING $0.15c/kWh
Heating / cooling 38%	1900	$285.00	20%	Improve house energy rating from 2 to 5 star	35%	1235	$99.75
Water heating 25%	1250	$187.50	23%	Change to solar hot water system	50%	625	$93.75
Other electrical appliances 16%	800	$120.00	24%	Improve efficiency and reduce use	10%	720	$12.00
Lighting 7%	350	$52.50	11%	Change to compact fluorescent lighting	75%	88	$39.38
Cooking 4%	200	$30.00	5%	Improve efficiency by using a microwave	30%	140	$9.00
Refrigeration 7%	350	$52.50	12%	Improve efficiency by 2 stars	30%	245	$15.75
Standby 3%	150	$22.50	5%	Turn off most appliances at the plug	90%	15	$20.25
Total	**5000**	**$750.00**				**3068**	**$209.88**

Note: This example is based on a typical Sydney household which is situated in a temperate climate. These prices are indicative only and will vary depending on location, price and use of electricity.
Source: Global Warming Cool it, (Australian Greenhouse Office, 2007). Baseline Energy Estimates, 2008. www.nathers.gov.au

Table 2

INCORPORATING RENEWABLE ENERGY SOURCES (APPROXIMATE AMOUNT OF RENEWABLES REQUIRED)				
RENEWABLE OPPORTUNITIES	INITIAL LOAD OF 5000kWh	APPROX. COST ($)	NEW LOAD OF 3068kWh	APPROX. COST ($)
Photovoltaics – Grid connected	32m²	$38,265.00	20m²	$23,480.00
Photovoltaics – Stand alone	44m²	$52,887.00	27m²	$32,451.00
RENEWABLE OPPORTUNITIES	5000KWH = APPROX. 3500kWh	APPROX. COST ($)	3068kWh = APPROX. 7900kWh	APPROX. COST ($)
Wind – Average wind speed = 7m/s	2 x 1kW turbines	$14,000	1 x 1kW turbines	$7,000

Note: Costs are indicative only and provide a comparison for the base renewable source only. They do not include installation, inverter (which may cost $3,000 or more), batteries, connections etc. Costs are based on a 165W panel costing $1,800 and 6 panels being required to produce 1kW peak. Obtain advice from accredited designers for actual amounts of renewable energy required and costs.



The incorporation of renewable energy is site specific and as the tables highlight, the more energy that can be reduced from the outset, the more viable incorporating renewable energy sources become. To determine actual amounts and costs for any system, advice from accredited designers should be obtained.

If a zero energy home is achieved and the net amount of operating energy is reduced to zero, measures to become carbon positive could be considered and incorporated.

WHAT IS CARBON POSITIVE?

Carbon positive aims to move beyond carbon neutral or zero energy and use human activities to improve the environment by making additional 'positive' contributions.

For example, this could be achieved by:

> Producing more energy on site than the building itself requires and feeding this back into the power grid.

> Improving a damaged environment and leaving it in a better condition.

> Releasing water or air from a building that is cleaner than when it entered.

> Planting on or over a building to a greater amount than was removed by the building itself due to its construction.

The contributions that carbon positive projects can make for the built environment as a whole are significant, especially because there will often be situations where zero carbon or carbon neutral homes are not possible.

Carbon positive projects can also help to address the carbon intensity and damaging impacts of past building practices and our lifestyles up to this point.

Becoming carbon neutral and achieving zero energy and carbon positive homes would reduce some of the impact from our homes and lifestyles and significantly reduce greenhouse gas emissions. However it is only part of the solution. Other sustainability aspects – social, economic and environmental – along with other impacts in the building process need to be considered in a holistic way, if a progression toward a sustainable future is to be achieved.

ADDITIONAL READING

Beddington Zero Energy Development, UK
www.peabody.org.uk/bedZED
www.bioregional.com/programme_projects/ecohous_prog/bedzed/bedzed_hpg.htm

Carbon Neutral Emissions Calculator
www.australia.gov.au/climateclever

Department of Climate Change, Australian Government
www.greenhouse.gov.au/greenhousefriendly

Global Warming Cool It
www.greenhouse.gov.au/gwci

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Rating Tools

To reduce the environmental impact of a building it is useful to be able to measure and quantify its performance and compare different options. There is a wide range of rating schemes and assessment tools that measure different aspects of building sustainability.

WHY WE NEED RATING SCHEMES

Rating schemes allow us to compare the environmental performance of similar products, whether they be fridges or houses. This allows us to make more informed choices as consumers and provides a means to measure progress in reducing our environmental impacts.

Rating tools are used as part of rating schemes designed to establish agreed levels of environmental performance. Australia is part of a growing international movement in the development of environmental rating schemes and tools for buildings. These range from single issue schemes, such as appliance energy ratings, to whole building environmental assessments.

Most people are familiar with the energy and water efficiency star ratings found on many appliances. These help purchasers choose the most efficient products in the marketplace and are examples of rating tools that measure a particular aspect of environmental performance.

Currently most rating tools focus on one key aspect of environmental performance, but some consider more than one.

Rating tools have an important role to play in helping us achieve more sustainable buildings.

Rating tools provide assessment methods and benchmarks that can be used to set minimum regulatory standards and can encourage better levels of practice that goes beyond those minimum standards. Some rating tools help us to understand better how human behaviour affects a building's environmental performance.

The energy rating of new single dwellings can be determined by computer software provided that it complies with the relevant Australian Building Codes Board (ABCB) *Protocol for House Energy Rating Software*. State and Territory Building Control Administrations should be contacted to ascertain the suitability of a particular type or version of software.

The Building Code of Australia (BCA) provides an excellent example of how rating tools can help improve the environmental performance of homes. In most areas of Australia the BCA now requires a minimum energy star rating for new single dwellings of 5 stars as assessed by the Nationwide House Energy Rating Scheme. While this standard of 5 out of the 10 stars available is not best practice, the standard is considerably higher than the average performance of homes built prior to the regulation.

Minimum standards play an important role eliminating worst practice but consumers play an equally important role in demanding better practice.

Mandatory Disclosure:
Recent studies demonstrate that mandatory disclosure of energy efficiency in the ACT shows a very strong correlation between star ratings and house value – something in the region of 3 per cent for each star. So a $400,000 house increases value by $12,000 per star which makes energy efficiency a very good investment.

A good rating scheme should:

> Encourage innovation by providing flexible compliance paths and not be overly prescriptive.

> Have the capacity to benchmark higher performance.

> Be able to measure both minimum mandated and better performance.

> Integrate the use of current rating tools.

> Allow more impact categories to be added.

Rating schemes and tools allow assessment of progress towards environmentally sustainable buildings with very low or zero impacts.

WHAT TYPES OF TOOLS ARE AVAILABLE

Rating tools fall into two broad types, although some combine both approaches.

1. Those that predict performance at the design stage, such as house energy rating tools.
2. Those that measure the actual performance of the building, including behaviour and appliances.

This distinction between the two types is important because it defines how the tools can be used. Predictive tools that have standardised user profiles may be used for regulatory purposes by providing a comparison between buildings that assumes similar behaviour patterns. These tools attempt to predict the future performance of new or existing buildings by eliminating the influence of current user behaviour.

Tools that provide feedback on how people are actually using a given building are more valuable for examining how occupant behaviour might be changed to reduce a building's impact on the environment, but these tools cannot be readily used for regulatory purposes. These tools are particularly useful at tracking improvements to the environmental management of a building.

Aspects of building environmental performance that can be rated include:

> Performance of individual appliances and fixtures such as refrigerators, shower heads and gas heaters.

> Performance of individual building elements such as windows.

> Performance of a combination of elements such as the building envelope.

> Performance of a whole building including all building services.

Building rating tools may cover specific environmental impacts in great detail such as energy or water efficiency or greenhouse performance. Other tools cover a wider range of aspects including waste reduction, the availability of sustainable transport links, building material ecological footprints, and land use impacts, but often at a lower level of detail. Users should select the tool that best suits their need for design or behaviour feedback.

HOUSE ENERGY RATING TOOLS (HERS)

House Energy Rating Schemes (HERS) in Australia such as the Nationwide House Energy Rating Scheme (NatHERS) have traditionally only assessed the thermal performance of residential buildings. HERS tools calculate the heat energy gains and losses associated with the design of the building in a particular location, and determine how much artificial heating and cooling may be required to maintain human thermal comfort. NatHERS is managed by the Department of the Environment, Water, Heritage and the Arts. HERS software accredited under NatHERS can be used to assess compliance with the BCA and other regulations.

Currently available HERS do not include the energy use of appliances or the embodied energy of building materials, although work is underway to broaden Australian HERS tools to cover other energy impacts such as lighting, hot water, and major fixed appliances.

The actual amount of gas or electricity used for artificial heating and cooling is influenced by the behaviour of the occupants and efficiency of appliances, in addition to the thermal performance of the building.

HERS tools are typically computer based due to the millions of individual calculations necessary. Shorthand scorecards have been trialed in Australia but do not have sufficient rigor or sophistication to provide accurate assessments of environmental performance.

The main software tools in use are:

> AccuRate.

> BERS.

> FirstRate.

These tools are based on a HERS calculation engine developed by CSIRO that enables assessment of a building on an hour by hour basis for a whole year. Included in the calculations are regional climate data and the individual design of the building, as well as thermal properties of all major materials.

To enable comparison of the building performance, distinct from variables such as occupant behaviour, ratings are based on standardised assumptions about the occupation and operation of the building. Performance can be described in terms of heating and cooling loads or degree hours, hours of discomfort or indoor temperatures. For regulatory purposes, the assessment is often expressed as a star rating. The more stars the better the performance. Star bands are set for each specific climate zone to allow fair comparison of buildings across climates.

Anyone can buy and use the HERS software, but ratings used for assessing compliance with regulations can only be issued by trained and accredited assessors.

Contact details for Accredited Assessors in your area can be found at: www.nathers.gov.au

NatHERS

The original NatHERS branded software, not to be confused with the NatHERS Scheme, was an envelope energy rating tool developed by CSIRO. NatHERS branded software was the most widely used of the early HERS tools but was replaced by the second generation HERS tool AccuRate in 2007.

AccuRate

Use of NatHERS software over several years uncovered limitations in the original software, and the governments of Australia commissioned CSIRO to overhaul both the data input method and the calculation engine.

Designed to address these issues, AccuRate was released in 2006. It now simulates energy performance more accurately in all Australian climate zones, and work is progressing to expand the tool to cover NZ climate zones.

Improvements include:

> Better modelling of the cooling effect of air movement.

> A floor area correction so that smaller houses are not penalised in the star rating.

> Better internal zoning.

> A wider range of construction materials.

> Improved modelling of reflective insulation.

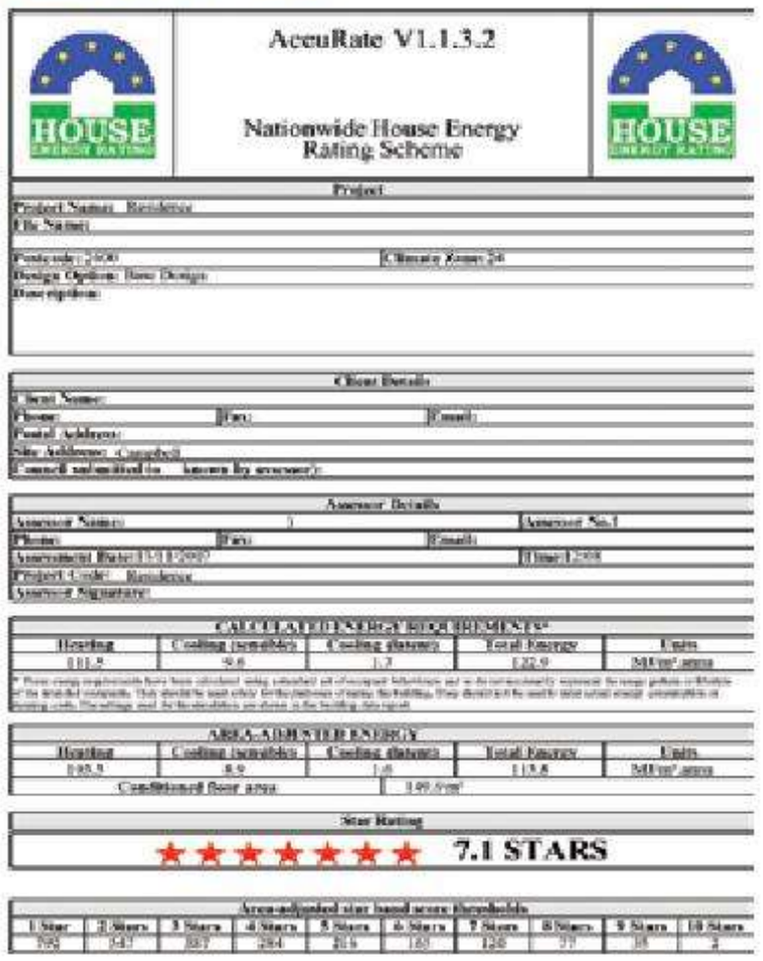
> Integration with the Windows Energy Rating Scheme (WERS).

> Starbands that recognise performance up to 10 stars.

> An easier-to-use interface more suited to newer computer operating systems.

AccuRate has been widely tested, calibrated and verified to produce consistent results for all climate zones.

AccuRate Interface



AccuRate, like all NatHERS family software, requires detailed information about the building such as orientation, construction materials, insulation levels, window size and orientation, shading, overshadowing, ventilation, etc. For an experienced operator, data entry can take from 30 minutes for a simple design to more than an hour for a complex design. AccuRate software can produce detailed information on the building's thermal performance on an hourly, daily and even monthly basis. AccuRate software can also be run without heating and cooling energy inputs to show the hourly internal zone temperatures. These functions can help architects and building designers improve the design.

The basic output is a simple report that shows how much heating and cooling energy would be required to keep the house comfortable, as well as the star rating of the energy performance.

AccuRate provides the benchmark for accrediting other HERS software for use with the BCA requirements.To be accredited to the NatHERS other software packages are required to give results consistent with AccuRate.

The case studies in this Technical Manual have all been rated using AccuRate. See Case Study Introduction on page 243 for more information.

BERS

BERS (Building Energy Rating Scheme) is a NatHERS family software tool based on CSIRO's calculation engine and incorporates many of the same improvements as AccuRate. BERS has the added feature of a graphical data input process that lets designers draw houseplans rather than typing in all the data. Much of the information about the building is selected from pictures displayed on the screen, making data entry quicker and easier.

BERS is most widely used in Queensland but can be used in all Australian climate zones.

FirstRate 5

The FirstRate House Energy Rating software was developed by the Victorian Government to speed up the rating process. It provides a simple and quick method to assess and improve the energy efficiency of house designs and completed homes.

FirstRate was originally developed as a correlating program against NatHERS computations, but the latest FirstRate product incorporates the full CSIRO HERS calculation engine like the AccuRate and BERS branded products.

FirstRate has been the most popular HERS software in Victoria, although other NatHERS family software can also be used. FirstRate is also popular in Western Australia, South Australia and the ACT.

BUILDING COMPONENT RATING TOOLS

WERS

The Window Energy Rating Scheme (WERS) ranks windows for their energy performance in typical housing anywhere in Australia. It will tell you whether a given window is suitable for the climate or not.

> WERS is independent of any one manufacturer and acts as a fair, rigorous and credible system for testing performance claims.

> Rated windows in WERS get from 0 to 5 stars for both cooling (summer) and heating (winter), depending on how they rank against the alternatives.

> WERS rates the performance of a window, not the performance of the amount of windows used in a design.

> WERS complements manufacturer's existing standards for wind, water penetration and safety (AS 1288 and AS 2047).

> WERS enables windows to be rated and labelled for their energy and comfort impact on a whole house, in any Australian climate.

> WERS complements other energy rating and is plugged into NatHERS to provide star ratings for houses.

Rating of a window for energy performance starts with establishment of basic solar, thermal and optical properties of the glazing unit and window frame. These properties are determined by a combination of laboratory measurements and computer simulations.

WERS ranks windows in terms of their whole-house energy improvement when compared to the base-case window (a singleglazed clear window with a thermally unbroken aluminium frame). The rankings are then used to generate star ratings for cooling (summer and solar control performance) and heating (winter performance).

Windows that have been rated will carry a sticker certifying energy rating performance.

The three basic steps to select a window using the WERS rating are:

1. Identify the climate classification for the site (see WERS map on their website).
2. Follow the window selection guidelines for climate type and identify generic window types that might be suitable.
3. Compare the WERS star ratings for the suitable generic windows with products recommended by local distributors and make a selection based on cost and performance.

For more information see www.wers.net

Appliance ratings

Energy and water efficiency ratings are available for many popular household appliances and equipment and provide good guidance to consumers.

Rating schemes for energy and water efficiency of appliances are covered in other fact sheets in this manual. [See: 6.1 Energy Use Introduction; 6.4 Appliances; 7.2 Reducing Water Demand]

OTHER BUILDING ASSESSMENT TOOLS

NABERS HOME

NABERS HOME is an easy-to-use tool for comparing the energy and water use of an existing home to that of an average household. The web-based tool is available for anyone to use. The website also provides diagnostic tools, the Energy and Water Explorer, to provide personalised advice. See: www.nabers.gov.au

Because it focuses attention on the interaction between the occupants and the building, rather than the technical potential for that building, NABERS provides a realistic assessment of how a home is actually performing at a particular point in time as used by those occupants. The design of a home is only one factor in its performance which is also greatly affected by choice of appliances and occupant behaviour.

A NABERS HOME rating analyses 12 months of actual energy or water use, and supplies a rating out of 5 stars, with 2.5 stars representing an average household. A 5 star home is very efficient, while a 1 star home has plenty of opportunities to improve!

NABERS is not a predictive tool. It complements, rather than replaces, other rating systems that focus on the design stage, such as HERS. It can only be used for an existing home that has been occupied for 12 months and provides an opportunity to check whether the home is performing as well as it has been designed to.

The NSW Department of Environment and Climate Change, who are developing and managing the NABERS scheme in agreement with the Australian Government, are also working on waste and transport ratings for homes. See the NABERS Home case study at end of this fact sheet.

BASIX

The NSW government introduced the Building Sustainability Index (BASIX) from 1 July 2005 to establish minimum standards for all new dwellings in NSW.

BASIX is a planning regulation that sets greenhouse gas emission and water use percentage reduction targets for new dwellings when compared to similar sized houses in the same geographical location. The percentage reduction approach provides an easy to understand comparison for users.

BASIX covers the building envelope thermal performance, but when determining compliance also includes a wider range of household energy uses such as heating and cooling appliances, lighting and water heating. In common with many multiple issue tools BASIX uses some existing tools such as NatHERS and appliance energy and water ratings as part of the assessment process.

To assess thermal performance compliance, either:

> The simulated heating and cooling loads predicted by NatHERS family software must be entered; or

> The building fabric must comply with a set of more restrictive 'Deemed to Satisfy' requirements.

The simulation method provides more flexibility in design options. BASIX sets a maximum limit for both the cooling load alone and the total heating and cooling load. The simulation results must be less than these allowable maximums to achieve compliance. BASIX uses the HERS assessment to estimate greenhouse gas emission impact based on the thermal loads and the efficiency and type of heating and cooling appliances selected.

INTERPRETING RATING TOOL RESULTS

In putting the results of rating tools in perspective some things to consider are:

Does the rated performance of an individual building element give a true representation of its performance in the application proposed?

The performance of a building element needs to be considered in context. For example, in a warm climate, an unshaded wall of WERS 5 star cooling rated windows will cause more overheating in summer than a similar sized bank of zero star rated windows with well designed external shading. An AccuRate, BERS or FirstRate assessment would reveal that the window rating alone does not give the complete picture.

Does the rating reflect all the impacts or simply focus on a single issue?

The rating reflects the aspect being rated. For example, an appliance might carry a 5 star energy rating but be inefficient in its use of water.

In which case would a similar product with a 3 star energy rating and high water rating be the better choice if you live in an area where water is in short supply?

There is also the energy used in pumping and treating the water and wastewater to consider. Fortunately, the most energy efficient appliances are usually also the most water efficient.

Does the rating system address relative scale in assessing the impact?

Not usually. A 400m² home and a 150m² home may have the same HERS star rating. However, the larger home will use more resources and embodied energy in its construction than the smaller home. It will also require more heating and cooling energy to be comfortable due to its larger volume. Many rating systems such as NatHERS and BASIX incorporate an area correction factor to eliminate large house surface area to volume bias and to encourage smaller buildings.

Would alternative options beyond those being rated yield equivalent benefits over total lifecycle?

No rating tool can incorporate every environmental impact but better ratings will generally lead to better environmental outcomes. Whilst accepting the limited breadth of environmental impacts covered by a rating tool, try to also consider those aspects important to the environment that may not be easy to measure.

Tradeoffs are a part of every home design and construction process so it is necessary to consider what level of thermal comfortable is desired and what overall environmental impact is acceptable.

For example, it may be better to build a home from low embodied energy materials but have a slightly lower rating, rather than use a high embodied energy but low maintenance fabric on the building envelope and aim for a higher rating. High ratings in one area may not compromise good performance in other areas of environmental impact.

ADDITIONAL READING

Australian Building Codes Board
www.abcb.gov.au

BASIX
www.basix.nsw.gov.au

BEDP *Environment Design Guide*
DES 23 May 2005 Accurate: 2nd Generation Nationwide House Energy Rating Scheme.
PRO 32 Glazing, Windows, Skylights and Atria – Properties and Rating Systems.

BERS Pro
www.solarlogic.com.au

FirstRate
www.sustainability.vic.gov.au/www/html/1491-energy-rating-with-firstrate.asp

NatHERS
www.nathers.gov.au

Windows Energy Rating Scheme
www.wers.net

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NABERS HOME Rating reveals how you can improve your energy and water efficiency

This case study demonstrates how the NABERS HOME Energy and Water ratings can be used to identify opportunities for improving energy and water efficiency around your home.



Alicia and Jason Campbell set out to build a home in Sydney's northern suburbs that would eventually be self-sufficient – collecting rainwater and generating its own electricity. Major investments included a 25,000L underground rainwater tank and an array of 18 photovoltaic panels. The north facing home has been designed to incorporate passive solar principles, and is very cool in summer. Generous thermal mass, good shading, a white roof and a whole-of-house fan ensure it remains a comfortable 25°C throughout the hottest days, without any need for air conditioning.

Unfortunately the home doesn't receive sufficient solar access in winter to heat the thermal mass, leaving it uncomfortably cold during winter. After using the electric underfloor heating last winter, the Campbells were alarmed by the size of their electricity bill and decided to calculate their NABERS rating to see how their household's energy and water use compared to other homes.

The NABERS HOME Energy and Water ratings use a full year's energy and water consumption, plus the number of people in the household and its heating and cooling needs (using data of the particular climate zone), to give the home a rating out of 5 stars. A 2.5 star rating represents the average home, and a 5 star home is extremely efficient.

The Campbells received a low rating of 0.5 stars with their winter heating bills, indicating that their household's energy use and greenhouse gas emissions were in fact significantly higher than the average home. When an estimate was made on the basis of the summer bills alone, a rating of 2.5 stars was received – bringing the Campbell's energy use in line with the average home. Given the extent of Alicia and Jason's efforts to be self-sufficient, and that the summer bills were comparable to that of an average home, these results suggest that there could be areas where the family could adjust their day-to-day choices in the way they use their electric appliances and save energy.

While it is important to build a thermally efficient home, it is ultimately the use of appliances that determines the energy use of a household. A thorough audit of energy use in the home would help to identify where significant savings could be made.



By calculating the household's energy rating with NABERS HOME, identifying where savings could be made and then calculating their rating again in a year's time, Alicia and Jason will be able to see how successful they have been at improving the energy efficiency of their household, and help them to find further opportunities to improve.

On the other hand, the Campbell's efforts to collect rainwater and use the most efficient showerheads and toilets have earned them a 5 star NABERS HOME Water rating, the highest possible score. Alicia and Jason are passionate about saving water, and have not only managed to collect 100 per cent of their family's water needs as rainwater, but have also recently installed a wastewater treatment system to recycle all the water that is used on-site.

Calculating their NABERS ratings has highlighted for the Campbells the importance of not only careful design when planning a home, but also the impact of ongoing, every day choice of appliances, and the way they are used. By also using NatHERS tools, Alicia and Jason could identify possible changes to the building design that may improve the comfort and energy efficiency of the home during winter.

To calculate your own NABERS HOME Energy and Water ratings, go to www.nabers.com.au.

NABERS is a national initiative, managed by the NSW Department of Environment and Climate Change.

Sustainable Communities

Sustainability does not stop at the front door. Your lifestyle will have an impact far beyond your immediate home environment. This section deals with the wider implications of the lifestyle choices you make. Understanding the impact of your choices empowers you to make the best possible decisions about your home and your environment. It is the outcome of these decisions that will contribute to your community and make it a better place.

Site issues, defined as the physical changes to the land that result from building a new home, renovating or landscaping, are also important for the sustainability of your home. Site issues manifest themselves as modifications to the local habitat (biodiversity), soil and relief (topography). Noise impact has also been included here because it examines the impact of surrounding land uses on your site. Design for challenging sites helps address sites that pose structural, environmental and topographical challenges.

Aim to tread lightly and reduce the footprint of your site and lifestyle.

This section contains detailed information about:

> Choosing a Site.

> Streetscape.

> Sustainable Landscapes.

> Biodiversity On-site.

> Noise Control.

> Sediment Control.

> Challenging Sites.

2.2 CHOOSING A SITE

Choosing an appropriate site, or existing home, and developing it to make the most of its natural attributes will yield significant economic, lifestyle and environmental benefits.

The information is in three parts corresponding with the usual stages of choosing a site.

> Choosing a locality and housing type.

> Choosing a site, existing home or block.

> Choosing, designing or altering a home to suit your block.



2.3 STREETSCAPE

When you choose a home you are also choosing a street and a community. A street is more than a collection of buildings and trees. Well-designed and cared-for streets encourage connected, inclusive, supportive and safe communities.

A good community consists of diverse elements, which blend into a vibrant, functional and well connected whole. Diversity of age, ethnicity and means are all essential ingredients. In the same way, a good street consists of houses that have their own character but fit together in a complementary, respectful way. A good street improves quality of life in numerous ways:

> Promotes community interaction.

> Provides a safe environment.

> Enhances the character and comfort of the neighbourhood.

> Encourages people to walk for short trips.

> Increases property demand and resale value.



How to enhance the quality of your street:

> Understand the character of your local neighbourhood and design your home or addition sympathetically.

> Face houses towards streets, parks and open space to improve visual access and security. This needs to be balanced with good orientation for passive heating and cooling.

> Set garages and carports away from the house frontage to minimise their visual impact.

> Limit the width of driveways and use shared driveways where possible.

> Plant trees to enhance the quality of the street.

> Avoid high walls and hedges on the street boundary as they isolate the home from the neighbourhood.

> Be a good neighbour and respect your neighbours privacy, sunlight and views.

2.4 SUSTAINABLE LANDSCAPES

Sustainable landscaping is about putting back much of what was in place before development.

Sustainable landscaping is not only about planting natives. It can include food-producing or permaculture gardens and planting deciduous shade trees to control solar access, provide habitat and shelter.

In dry areas, that were not formerly wetlands, planting low water-use indigenous vegetation (xeriscaping) greatly reduces water consumption.

Indoor plants can be used to filter and improve indoor air quality.

Vegetation can be used for screening, as a windbreak and to frame select views.

The topography of a garden should ideally reflect the original relief to minimise the impact on drainage patterns but bunds can sometimes be created to enhance visual and/or acoustic privacy.


Edwina Richardson

2.5 BIODIVERSITY IMPACTS ON-SITE

Local biodiversity is the variety of life forms, and the ecosystems of which they form a part, that exist on your property. This fact sheet examines ways to minimise the destruction of biodiversity and to retain as much habitat as practicable, while accommodating your home.

Replanting cleared sites is definitely no substitute for leaving native vegetation intact. Once land is cleared it is almost impossible to recover the full suite of indigenous species, remove introduced species and restore ecological processes. To minimise biodiversity impacts:

> Avoid unnecessary disturbance to vegetation and soil.

> Limit clearing outside the building footprint. Vehicle tracks, workers' carparking and rubbish dumps should be concentrated in one area.

> Retain significant habitat trees.

> Rehabilitate disturbed areas with saved topsoil and salvaged plants.

> Use indigenous (local native) species in the garden.

> Maintain links between adjacent bush and your garden.

> Avoid introducing environmental weeds into your garden.

2.6 TRANSPORT

Urban transport is an important national issue. About two thirds of Australia's population lives in capital cities. Decreased motor vehicle use and increased use of public transport, cycling and walking are vital to creating a healthy, liveable city, now and for future generations. A sedentary lifestyle is a health risk. A brief walk to the bus or train each day can improve your health and lower stress levels.


AMB Productions

Some of the problems of car dependency include:

> Urban sprawl.

> Depletion of urban spaces.

> Greenhouse gas emissions.

> Air and noise pollution.

> Depletion of finite oil reserves.

> Loss of valuable bushland and farmland to roads and car parks.

> Communities fragmented by roads.

> Flooding and water pollution from road run-off.

> Death and illness from air pollution, accidents and sedentary lifestyle.

How you can help:

> Avoid car dependency by choosing to live in an established area close to public transport and other services.

> Walk, ride a bicycle or take public transport instead of driving.

> Shop locally and buy locally made goods.

> Lobby governments for improved public transport services and comment on development proposals.

> Work from home.

Do you want to live in an environment designed for you or for your car?

2.7 NOISE CONTROL

Noise is 'disagreeable sound'. The perception of noise is therefore highly subjective.

Noise can be managed through careful site choice such as finding a property that is buffered from busy roads and industry.

Good design can also assist in managing external noise impacts. This can be achieved through site planning and use of appropriate materials and construction techniques.

Some design solutions:

> Locate quiet rooms as far away from noise sources as possible, without compromising passive solar design principles.

> Install windows away from noise sources, if possible.

> Position noisy areas together and away from quiet areas.

> Avoid placing laundries, bathrooms or living rooms next to, above or below bedrooms without adequate sound insulation.

> Provide extra soundproofing for teenagers' rooms and locate them away from adult living and sleeping areas and neighbours.

> Locate driveways/garages away from bedrooms and living rooms.

> Appropriate material selection can reduce noise levels within the home.

Ask for design specifications for noise levels before buying a multi residential unit and ask your solicitor to link them to your contract as a performance measure. This will give you more options if you discover a problem after moving in.

2.8 SEDIMENT CONTROL

Sediment control practices are used on building sites during construction to prevent sand, soil, cement and other building materials from polluting waterways.

Control measures usually require little effort. Benefits include cleaner waterways, healthier aquatic life and reduced clean-up costs to the community. Added benefits to the builder include improved site conditions and wet weather access. Time losses due to waterlogging will also be minimised.

Some sediment control measures:

> Divert uncontaminated water away from the construction site.

> Minimise ersoion by minimising site disturbance, stabilising disturbed surfaces and securing material stockpiles.

> Prevent sediment contaminated water leaving the construction site by using a contained wash area.

> Use diversion devices such as channels and earth banks to divert clean stormwater away from the construction site. This reduces potential for stormwater to become contaminated with sediment.

Most local councils have written guidelines on erosion and sediment control. Ask them for information pertaining to your area.

Developments likely to create sediment pollution to land or receiving waters downhill may need to submit erosion and sediment control plans for approval by your local council before work starts.



2.9 CHALLENGING SITES

Challenging sites is about addressing physical and social factors that may constrain the design of your home and increase the environmental impact. These constraints generally relate to the following areas:

> Structural: topography, natural and artificial structures.

> Environmental: climatic, health, visual and acoustic parameters.

> Spatial: size, shape and volume.

> Location: remoteness, proximity, servicing.

> Ecology: ecological value, landscaping.

It may be environmentally preferable not to build on a challenging site because of the larger impacts that result from addressing its constraints. On the other hand, such sites often provide exciting opportunities for creating a sustainable home and are worth investigating for their design opportunities. A number of approaches are identified that can be applied to address these constraints and achieve sustainable outcomes.

Principal authors:
Chris Reardon
Steve Shackel



Choosing a Site

Where you buy or build your home has a profound influence over your ability to meet your existing and future needs. Where you choose to live will have a significant impact on the environment and your finances. Remember the real estate adage:

'It's location, location and location'.

Choosing an appropriate site for a new house or choosing an existing home and developing it to make the most of its natural attributes will yield significant economic, lifestyle and environmental benefits.

The following information has been divided into three sections corresponding to the usual stages of choosing a site.

> Choosing a locality and housing type.

> Choosing a site, existing home or block.

> Choosing, designing or altering a plan to fit your block.

CHOOSING A LOCALITY AND HOUSING TYPE

Analyse your lifestyle – current and future

The decision to buy or build a new home is often driven by inadequacies in our existing home. These often relate directly to lifestyle. A new home offers many opportunities to alter or change lifestyle. Maximise this opportunity by analysing your existing lifestyle and future needs.

As you start to focus on a particular suburb or locality, visit the local council to investigate the planning controls governing the site (eg. zoning, heritage conservation, and building restrictions such as setbacks and height limits).

The site choice checklist

The following checklist is intended to guide your choice of site. Answer the following questions:

> How does the location suit your lifestyle? Can it continue to accommodate changes over time associated with your employment, financial position, health, recreational focus, family (new and empty nest), retirement and old age?

> Where will the occupants of your home go to work, school, exercise, shop, socialise or get health care? Proximity to these services minimises car trips saving time, money and the environment.

> Can you eliminate the need for a car or second car? This will save you money and help the environment. Access to public transport (rail, ferry, tram and bus) or siting your house within walking or cycling distance of common destinations can eliminate the need for a second car.

> What is the true cost of a location? Cheaper housing on the city fringe is balanced by continuing higher transport costs (car price, fuel, maintenance, time).

> What type of home do you need? Apartments, villas and detached houses offer vastly different prices, lifestyle options and access to facilities. A big garden and four bedrooms may no longer be appropriate.

Remember that a low maintenance, less expensive alternative to a large yard may be a safe park, body corporate gym, pool or tennis court. Shared facilities reduce environmental impact. Smaller yards mean higher housing densities which are usually more energy-efficient because facilities and infrastructure are better utilised. In many areas, vacant land for new homes is scarce. [See: 4.13 Apartments and Multi-unit Housing]

Appropriate re-use of existing buildings will result in energy and materials savings. Avoid demolition and refurbish wherever possible. Save money and the environment. [See: 5.1 Materials Use Introduction]

Work through the above and start the preliminary stages of looking at your home options. A few weekends spent visiting other suburbs or travelling to other areas will consolidate the process of decision making.

CHOOSING A SITE

A site can be where an existing house or apartment is located or where you design or build a new one.

Site evaluation

Planning controls can have a major influence over your design. Check with your local council for easements, setbacks and building restrictions.

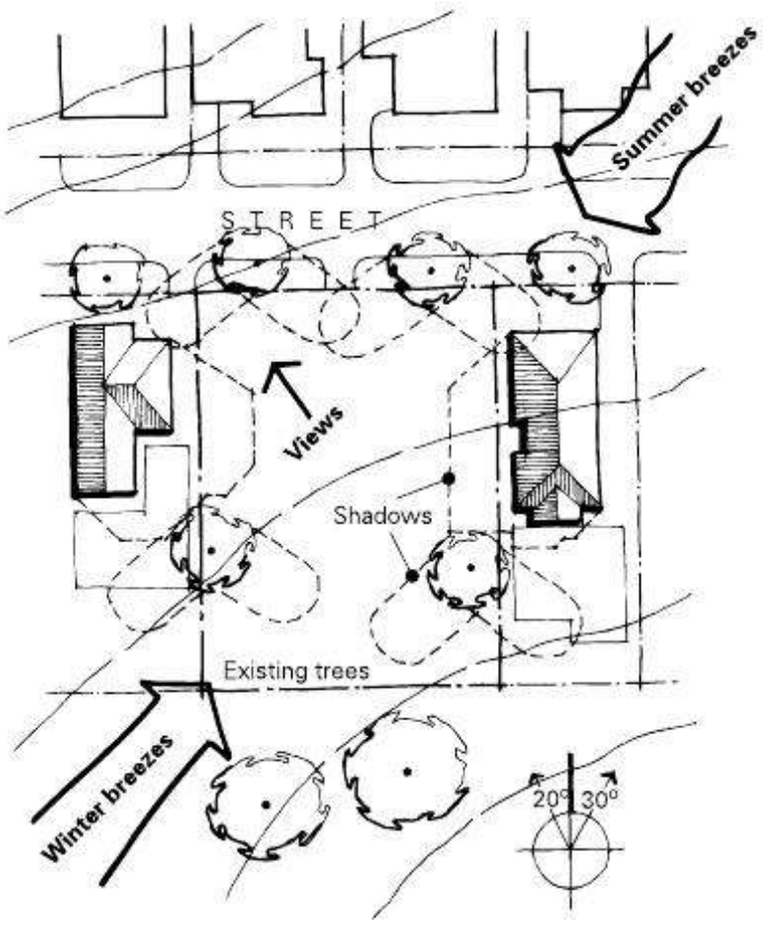
Decide which climatic features need to be taken into account in order of priority. Assess the impact these features will have on your planning.

Determine which climatic features to enhance and which to mitigate in order to increase comfort and decrease energy use. Decide whether solar access or access to cooling breezes takes priority. Is one or the other more important in your climate?

Note the size, orientation and slope of the site. Ensure that the opportunities for solar access are appropriate to the climate. [See: 4.3 Orientation; 4.5 Passive Solar Heating; 4.6 Passive Cooling]



Assess the microclimate (seasonal temperatures, humidity levels, prevailing winds, etc). Observe how the site terrain and vegetation modify air movement and solar access.



Observe the potential for overshadowing, loss of privacy and noise from neighbouring areas. Shadow impact is influenced by latitude, height and spread of trees and may affect the way the house is sited.

Identify vegetation that can be incorporated into open space, used for wind protection or used as part of the site drainage system. Make it a priority to retain native vegetation where possible. [See: 2.5 Biodiversity On-site]

Identify rare or endangered plant and animal species associated with the site. Your local field naturalist society will be able to help with this.

Investigate the geology and topography of the site. Is there a threat of landslide, soil slip or creep?

Assess potential natural hazards such as bushfire risk and flooding.

Identify any natural site drainage patterns and determine how they can be maintained. Steeper sites usually generate more stormwater run-off.

Efficient land use

Efficient planning and land use reduces embodied and operational energy costs for you and the entire community.

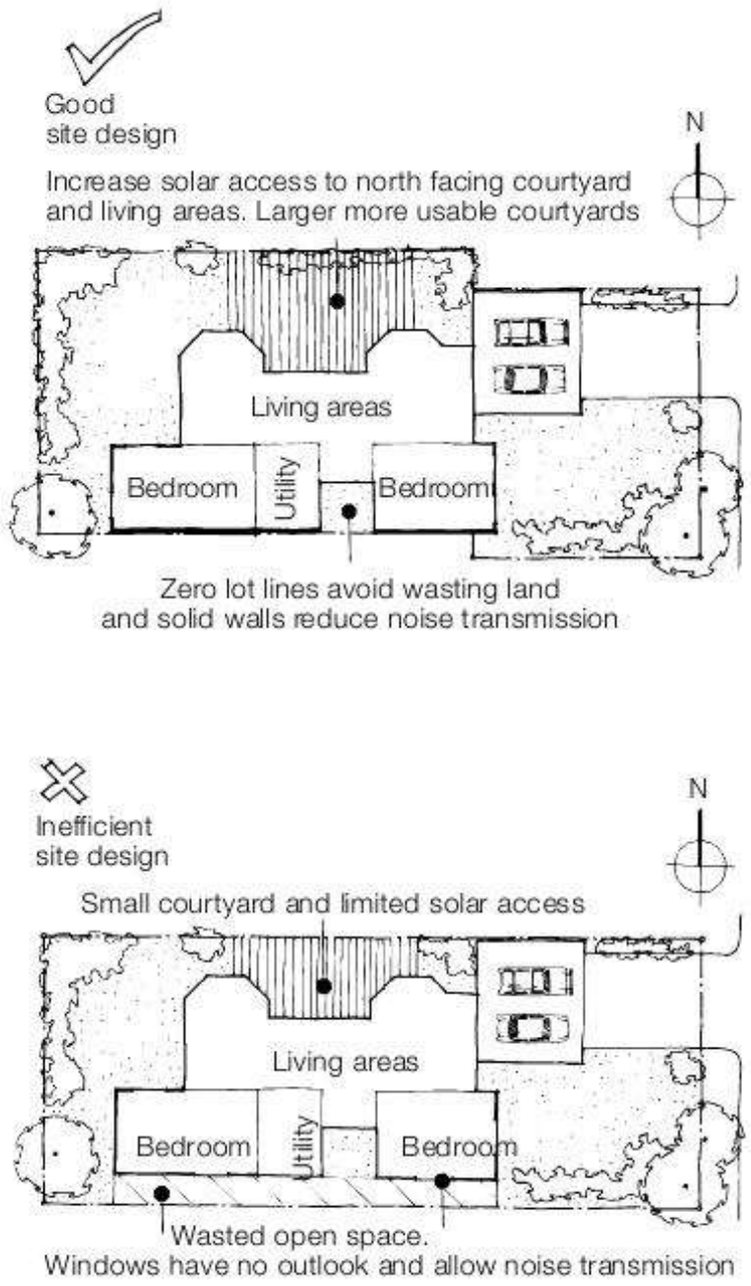
Rectangular lots usually permit the most efficient land use, particularly small lots (less than 300m^2).

Compact housing forms are more energy efficient in cool and temperate climates because there are less exposed external surfaces for heat to escape through.

Longer, narrower housing forms are preferable in high humid climates as they facilitate passive cooling.

Site coverage (building footprint) should be optimised to increase the area available for landscaping. This allows more stormwater to be absorbed on site and generally reduces site impact. [See: 2.3 Streetscape; 7.5 Stormwater]

Building footprint should be balanced with other impacts such as building height.



Building to the boundary (also known as zero lot line) improves efficiency by maximising the amount of useable outdoor space. Wasted space in the form of a narrow side passage can be traded for greater space on the other side of the house. This is particularly beneficial if the house is built on the south boundary as it will increase the amount of open space with a northerly aspect. [See: 2.3 Streetscape; 4.3 Orientation]

Good solar access is desirable in all but tropical climates, but the size, orientation and slope of the block will affect it. Note existing sun and shade patterns in relation to vegetation and adjoining buildings. [See: 4.3 Orientation]

Ensure that a viable plan or housing density can be achieved within the size, shape and topography of the lot. Steep sites often require extensive and expensive excavation and fill. On these sites, pole homes are usually much more environmentally friendly. [See: 2.9 Challenging Sites]

CONSIDERATIONS FOR REMOTE AND RURAL SITES

Protecting, enhancing and repairing the natural and built environment is highly relevant to remote and rural sites. Often the best place to build is a damaged or cleared site.

As you build your garden and home environment, you can 'heal' the landscape.

Before you buy, there are a number of other important considerations:

Services

The cost and availability of power, gas, phone, water supply, wastewater treatment and garbage disposal are often overlooked when buying a rural or remote site. These services often cost as much as the house itself and can cause budget over runs or project cancellation. In such instances, renewable energy based systems for power supply, rainwater harvesting, eco-friendly waste-water treatment and waterless toilets become extremely cost-effective solutions. Failure to allow an adequate budget for services often leads to shortcuts with water supply, wastewater treatment and energy supply. These have serious lifestyle and environmental consequences.

Access

The construction of access roads onto rural subdivisions can be extremely expensive if wet ground, steep slopes or watercourses are encountered. Maintenance of driveways can also be a considerable and ongoing financial burden.

Good road or driveway design and construction will reduce erosion and sedimentation, minimise maintenance costs and guarantee all weather access. [See: 2.8 Sediment Control]

Fire

Bushfire risk is always an important consideration. A reliable water supply is essential. It should not be dependent on grid electricity as this is usually the first thing to fail in a bush fire. A large, permanently filled tank on high ground (for gravity feed) is the best solution. Petrol fuelled water pumps are less reliable and may fail at the critical moment.

[See: 3.5 Bushfires]

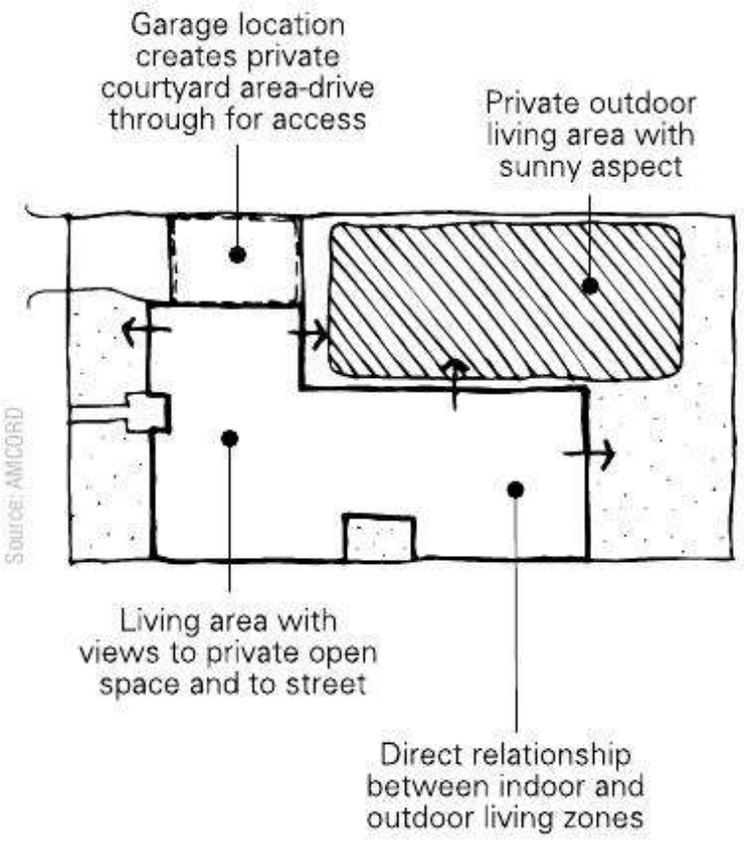
Transport

Motor vehicle costs are often a major drain on household budget for rural dwellers. They also have a major environmental impact.

CHOOSING, DESIGNING OR ALTERING A PLAN

Make a checklist of not negotiable and priority items and do not compromise. Make the real estate agents and sales people aware of your requirements.

Consider how your plan interacts with the site. Orient the home to maximise the benefits of solar access, cooling breezes, summer shading and wind protection. [See: 4.3 Orientation]



Source: AMCORD

A home designed to respond to site conditions can optimise lifestyle, improve energy efficiency and protect the quality of the natural environment.

Carefully consider the relationship between the floor plan and the site, whether building or buying. Good indoor/outdoor relationships are a desirable aspect of lifestyle in all Australian climates.

Where possible, avoid having your windows and outdoor living areas facing those of your neighbours.

SIZE MATTERS

Choosing an appropriate size for your home is the most important step in controlling its economic and environmental cost. Each square metre may cost you $1,200 or more to build and every year will cost more to light and heat. It makes good sense to think carefully about the space you need. Some points to consider are:

> Do you need that extra bedroom?

> Could you add it later if you do?

> Can you design for multi-functional spaces?

> How many living areas do you need?

> Do you need more than one bathroom? Would a well designed three way bathroom suffice?

> How much garage space? Do you want to devote 20 per cent of your house to your car?

Well designed rooms with clever storage and carefully considered furnishing patterns can often allow a reduction in size of up to 30 per cent without loss of amenity.

Poorly designed spaces are often difficult to furnish due to door, window, heater locations and traffic paths. Poor (or no) design is often compensated for by allowing additional space. This costs far more than the services of a professional designer without the added benefits of a professionally designed home.

Ask your designer to consider how your furniture (existing or planned) will fit into each room. Do a scale drawing and experiment with your furniture placements before buying.

Consider combining smaller separate living spaces into one larger multi-purpose space with nooks and crannies for individual activities. This can give a greater feeling of space while reducing floor area.

Build or buy your home for your needs. Avoid the mistake of building for re-sale. Be confident that the home you like will be very saleable to people like you, if and when you sell it.

Be innovative and adventurous but remain sympathetic to the character of the neighbourhood.


David Oppenheim

SENSITIVITY TO NEIGHBOURING DEVELOPMENTS

Visual impact

Minimise your home's visual impact by choosing:

> Appropriate materials.

> A form sympathetic to the precinct.

> Appropriate bulk, height and style.

> Non reflective/low glare materials and finishes.

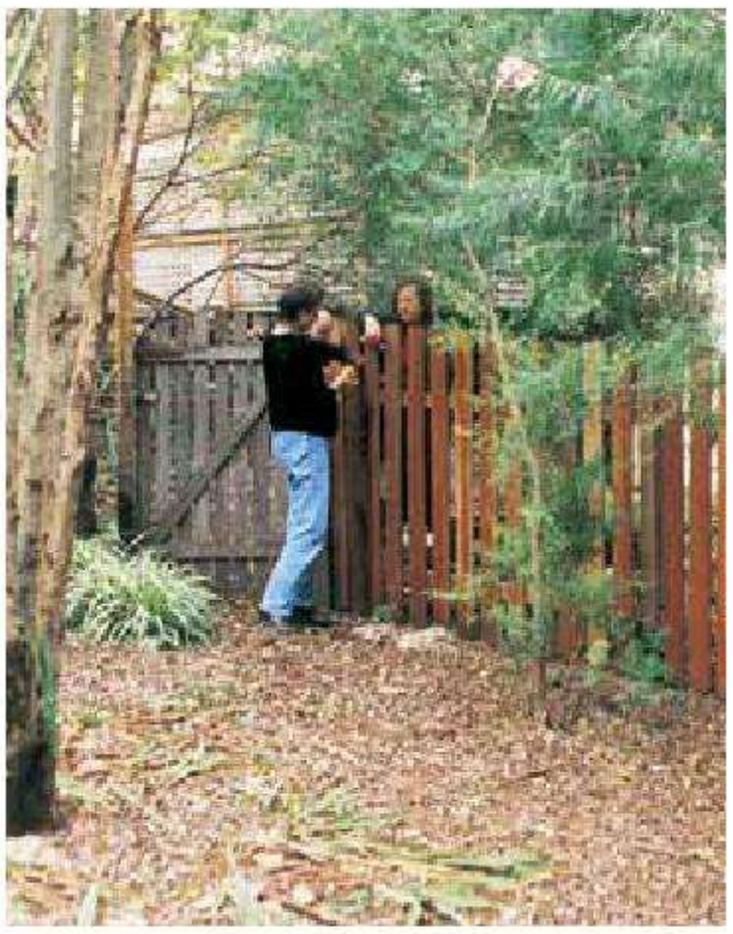
> External colours most sympathetic to the surroundings.

Consider the effect your house will have on your neighbours' solar access, visual and acoustic privacy and views.

Avoid housing designs that significantly overshadow or overlook the main living areas or garden space of neighbours.

Avoid locating noisy areas (such as pools, driveways, service equipment) near the bedrooms or living areas of neighbours.

[See: 2.3 Streetscape; 2.7 Noise Control]



Social impact

A safe home, in a Neighbourhood Watch area, overlooking a well lit street or park can help discourage crime.

Consider how you can achieve visual privacy when you want it while being able to interact with neighbours when you need to.

Though sometimes desirable for noise reduction, building a fortress can cut you off from your community.

Topography

Design or choose your house to respond to the natural topography of the site and minimise the use of excavation and fill. This saves energy, preserves natural drainage patterns and prevents soil erosion.

Excessive excavation can damage the ecological integrity of the site and disturb groundwater zones.

Investigate the underlying geology as it will influence construction costs and energy used in excavation.

A geotechnical report is often requested by your local council or your engineer. If in doubt, obtain one.

Stormwater, particularly overland flows, can create severe problems. Check that the site is not affected by stomwater entering from neighbours' gardens or downpipes before buying. [See: 7.3 Rainwater; 7.5 Stormwater]

SPECIFIC CONSIDERATIONS

Buying a project home

> What is the best plan for your needs on your site?

> How can you alter standard plans to better suit your needs?

> Is the plan oriented on the block in the best way?

> Will flipping or mirroring the plan improve it?

> How can you correct any shortcomings?

> How much will this cost?

Buying an existing home

> Does the plan suit your needs?

> Can it be altered to accommodate your needs? How much will this cost? (Seek professional advice).

> Does it have solar access and access to cooling breezes?

> Can you prune or remove existing vegetation blocking breezes and sun?

> Are outdoor living areas private? Consider adding a courtyard wall and new doors to link internal and external living areas. Consider new planting for visual privacy.

> Consider renovating to achieve passive heating or cooling. (Get professional advice).

> Where will your garbage and wastewater go? Check that the local council has good treatment systems.

> Where will your water and energy come from? Consider adding a rainwater tank or adding a solar hot water service.

> Check that good public transport is available and footpaths are installed and well maintained.

PROTECTING THE NATURAL ENVIRONMENT

Your home can change the nature of a site. Poor siting choices can be destructive. Good choices can enhance or even repair a damaged site.

Well sited housing will:

> Retain habitat so that local flora and fauna flourish.

> Protect waterways from pollution including stormwater run-off.

> Reduce the threat of bushfire to the home.

> Maintain or improve soil and air quality.

> Protect any valuable natural features (vistas, ecosystems etc.).

> Preserve existing culturally significant streetscapes and buildings.



When choosing a place to live, we sometimes visit a place of immense natural beauty, fall in love with it and decide to live there, often with little thought of how this action may alter or even destroy the very features that attracted us.

Consider how your desires and choices influence market forces and planning decisions. Support and guide your planning authorities by participating in development processes.

Minimise the impact of your home on the natural environment by considering its impact on local flora and fauna, water, soil and air quality, natural and cultural features. This need not add cost but simply requires forethought and careful choice of site.

Look for a site where your home will have the lowest impact. Surprisingly, these sites are often under-utilised areas (eg. infill development in backyards) or remediated industrial sites (eg. Newington Olympic Village).

Medium and high density developments are often best suited to sites requiring major remedial work. Higher density means that the cost of remedial work is shared between more owners.

High-impact sites include sensitive bushland areas, flood-prone land, areas with poor social and physical infrastructure, and historic conservation areas.

Choose alternative sites or develop carefully to minimise your impact. Design or choose a plan or construction system that suits the slope and minimises excavation.



Avoid choosing a site where substantial clearing, earthworks or alteration of natural watercourses is required.

Existing native plants and fauna habitat should be retained where possible. Extensive removal of vegetation can result in soil erosion and reduction in soil quality.

Native wild plant rescue services exist in many areas. These groups will come to your site, remove any endangered plant species to a nursery and return them after construction is complete (or sell them to others).

The Wildlife Information and Rescue Service (WIRES) in NSW, and similar organisations, will relocate endangered fauna.

Flora Fauna impact studies are required by many local councils for larger developments. These should be conducted at a reduced scale for smaller projects, especially in areas with high natural heritage values or threatened species and ecosystems.

DESIGN FOR CLIMATE CHANGE

Climate change is caused by an increase in greenhouse gas emissions into the atmosphere.

Scientific evidence has shown that global warming has taken place over the last century, and the most of the warming over the last 50 years is attributable to human activities.

Future changes are projected to include:

> More extreme weather events such as storms and cyclones.

> Temperature increases.

> More frequent droughts and floods.

As homes are designed with a 50 year life expectancy (the best ones last for hundreds), it makes sense to choose and design homes that make allowance for climate change.

General principles include:

> Build well above historic flood levels.

> Design stormwater controls for more intense rainfall.

> Plant gardens that will survive longer dry periods.

> Generally design or choose homes appropriate for warmer and more extreme weather conditions.

ADDITIONAL READING

Contact your local council for further information on choosing a site.
www.gov.au

BEDP *Environment Design Guide*
GEN 1 RAIA Environment Policy (see supplementary document).
DES8 Residential Sites – Analysis for Sustainability.
DES9 Residential Sites – Sustainable Developments.

Commonwealth of Australia, *Australian Model Code for Residential Development* (AMCORD) (1995), AGPS Canberra.

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King, S., Rudder, D., Prasad, D., and Ballinger, J. (1996), *Site Planning in Australia, Strategies for energy efficient residential planning*, AGPS Canberra.

Principal author:
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Streetscape

Streetscape is the term given to the collective appearance of all buildings, footpaths and gardens along a street. The streetscape is the visual identity of a neighbourhood and plays an important role in facilitating interaction between residents and creating a community.

Well designed streetscapes encourage connection, understanding and community spirit among residents.

Houses can be diverse in age, shape or style yet combine to create a community identity. At the same time, a development that is not sympathetic to the existing streetscape can significantly detract from the character of the neighbourhood.



Newington Village.

COMMUNITY, STREETSCAPE AND PLANNING

When designing a new home or renovation there are a number of ways to contribute to an improved community identity:

> Understand the character of your local area, and design your home or renovation accordingly. Your home should look like it belongs in the neighbourhood. Use characteristic attributes (for example building height, street setback, form and materials) to compose your innovative design solutions.

> Face houses towards streets, parks and open spaces to allow improved surveillance and access. This encourages better use of public space, promoting safety and community spirit. The orientation of the house should still account for solar access considerations and compromises may be necessary, particularly on west facing blocks.

> Limit the width of driveways and share them where possible. This allows more of the street frontage to be landscaped and provides a better environment for pedestrians.

> Present the house rather than the garage to the street. Generally, set garages and carports beyond the house frontage to minimise their visual impact. Where possible, use secondary streets or rear lanes for car access. This allows more landscaping at the street frontage and establishes a direct visual connection between the house and the street for security.

> Plant trees to enhance the quality of the street. Good tree cover increases property values and provides improved shade, habitat, windbreaks, air quality and appearance.

> Avoid high walls and hedges on the front boundary as they isolate the home from the neighbourhood. They create a perception of isolation and impede observation of the street.

> Accommodate your neighbour's field of view. Utilise appropriate building setbacks and building height to retain your neighbour's view while maximising your own.

What to look for in a street

Streets should be part of our living space and a common area for the community, equal to the park and the footpath. The road itself is more than a racetrack. A good street is one in which you can chat with your neighbour without having to shout over traffic noise, or worry about your safety and that of small children.

The following features make streets more livable – safer, cleaner and more attractive:

> Unique houses that still fit together in a consistent pattern so that no single house is dominant.

> Consistent alignment of house frontages.

> Regularly spaced tree planting on both sides of the street to give it identity.

> Private garden landscapes that complement the street planting.

> Streets that give pedestrians and cyclists priority and are designed to discourage speeding.

> Streets in which the width of the carriageway relates to traffic volume and is not wider than necessary.



> Garages that don't dominate the street frontage.

> Driveway crossovers of minimum width.

> Fences and walls of an alignment, height and style consistent with others in the street.

> Pavements that are porous or modular where possible to encourage stormwater infiltration.

> Clear sight lines between house entrances and the street, providing visual surveillance of the street to maximise neighbourhood safety.

> Underground services, as this removes unsightly power lines and does not impede street tree growth.

> Solar street lights, as this indicates local council commitment to sustainable infrastructure.


Envirotecture Projects

STREETSCAPE'S VALUE

Attractive and functional streetscapes increase residents' quality of life and their property values.

The streetscape should encourage community interaction and exchange. People who feel isolated from society are more likely to behave in a manner detrimental to the needs of the community.

An effective streetscape should therefore convey a sense of openness and sharing while offering a degree of privacy.

Elements like trees and footpaths encourage pedestrian activity, which reinforces social interaction and provides casual surveillance of the street.

A streetscape that looks inviting is more likely to encourage people to live there, increasing demand and property prices.

Good streetscape design

Creating a sympathetic building design and additions to fit in with the streetscape does not mean that neighbouring house designs must be imitated. It implies being conscious of the area's natural environment, heritage significance, density, style and social and cultural mix.

Good house design allows individuality without detracting from the character of the street or the amenity of neighbours.

Visit your local council for guidelines specific to your area. Council planners understand the features that give a precinct its individual character and are trained to help you find solutions that meet your needs without destroying that character.

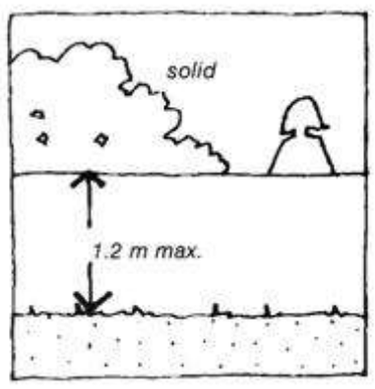
Solutions include:

> Complementary materials and colours.

> Roof pitch to maintain consistency with the neighbouring houses.

> Bulk, form and height sympathetic to the character of the street.

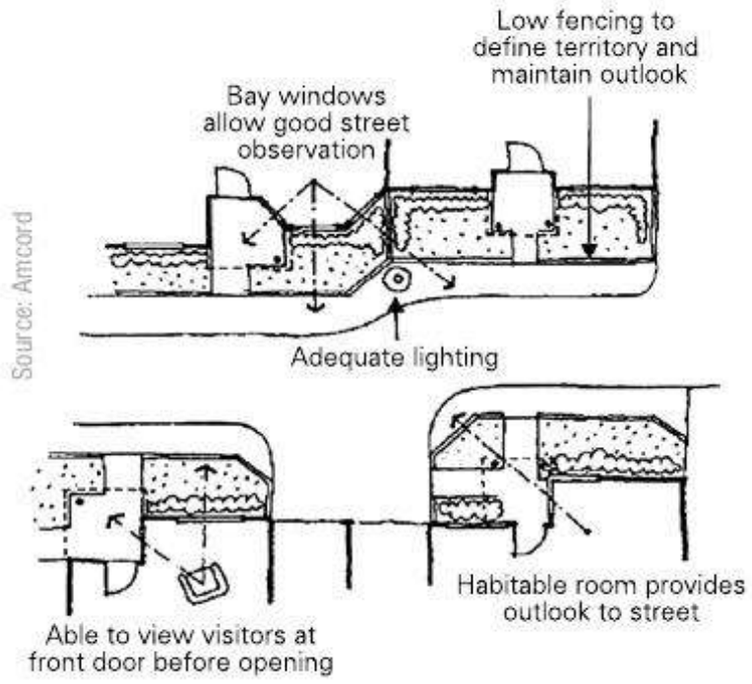
> Passive visual surveillance to discourage crime. Provide outlook over the street and public space from at least one room other than a bathroom or bedroom.



Source: Amcord

> Consistent street fencing, which does not isolate the house from the street. New fences and walls should balance privacy requirements with the need for a visual connection with the street.

> Low walls to integrate mail boxes and shield bins and recycling facilities from the street.



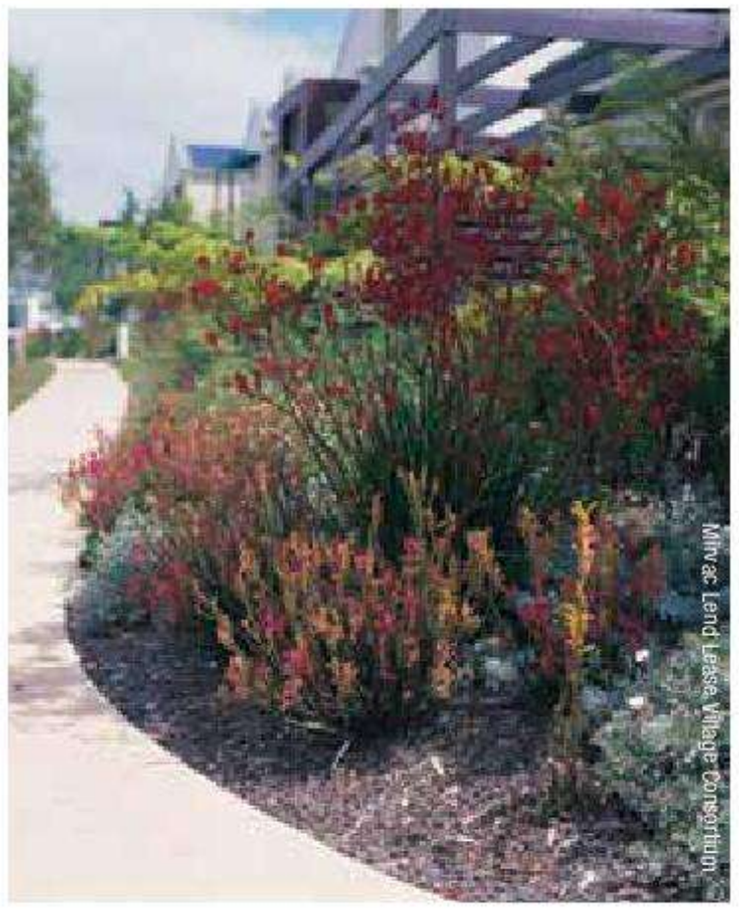
Source: Amcord

> Landscaping to enhance the quality of the streetscape. Plants can be used to screen or direct views, provide shade, clean the air and give visual identity to a street.

> Garden planting which considers the rhythm and proportion of existing street planting (intervals between trees, height and spread). Plant fewer big trees rather than many small trees.

> Planting species that won't damage footpaths, structures or drainage or invade adjacent bushland.

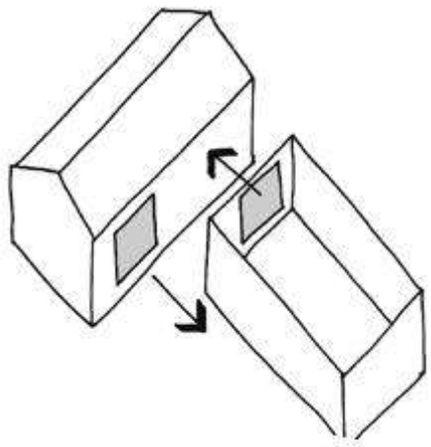
> Planting native species which require less water and provide a habitat for native animals. Many local councils provide lists of local indigenous plant species.


Mirvac Lend Lease Village Consortium

Be a good neighbour

There are a number of ways to be a good neighbour. These include:

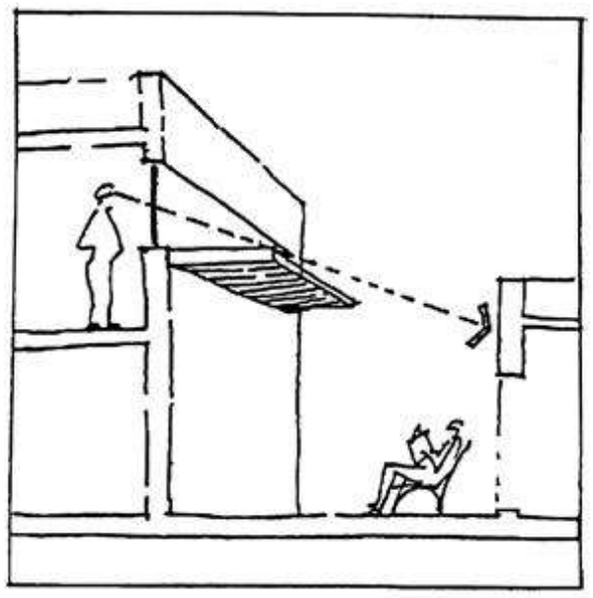
> Offset windows to ensure maximum privacy.



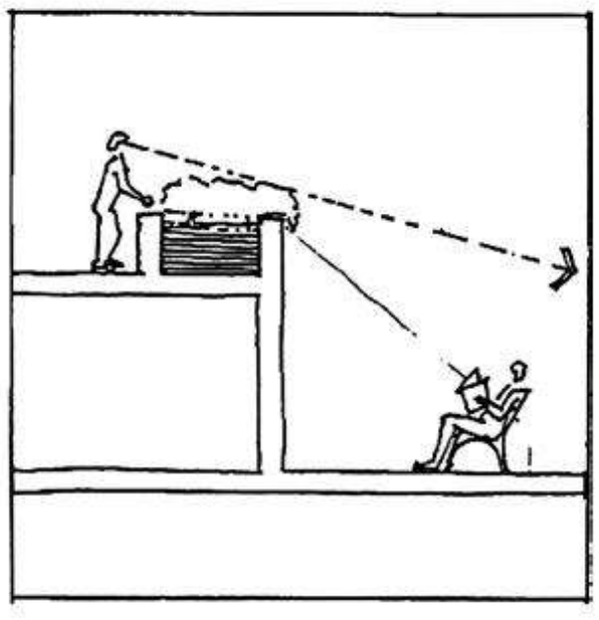
> Use of landscaping and other devices to selectively screen views.

> Protect acoustic privacy by careful siting and internal planning. Locate bedrooms and private open space away from noise sources such as service equipment, busy roads, driveways or active recreational areas.

> Avoid directly overlooking your neighbour's main living areas or garden space by careful location and design of windows and balconies.



Source: Amcord



> Avoid building in a way that significantly overshadows the main living areas or garden space of neighbours.

> Avoid locating noisy areas (such as pools, driveways, and service equipment) near the bedrooms or living areas of neighbours. Driveways and parking areas should be at least three metres from bedroom windows.

> Protect as much as possible any significant views enjoyed by neighbouring properties.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on streetscapes. www.gov.au

BEDP *Environment Design Guide*
GEN 17 Urban Planning for Sustainability.
GEN 55 Mental Landscapes – The Forgotten Element of Sustainable Design.
DES8 Residential Sites – Analysis for Sustainability.
DES9 Residential Sites – Sustainable Developments.

Commonwealth of Australia, *Australian Model Code for Residential Development* (AMCORD) (1995), AGPS Canberra.

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Contributing authors:
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Chris Reardon

Sustainable Landscapes

The great thing about sustainable landscapes is that they can simultaneously address aesthetics and amenity, water management, air quality, passive design, climate modification, biodiversity habitat creation and local food production.

There are literally hundreds of definitions for 'sustainable' but the basic idea is that if something is sustainable it can keep going indefinitely. Natural systems have been operating successfully for millions of years. Nothing made by humans can do that.

Sustainable landscapes are concerned with the planning and design of outdoor space. It is important to consider the landscape as an integral part of your home's sustainable designs.

The scope of design of outdoor space may range from revegetation of a large bush block to the detailed design of small courtyard spaces intimately linked to a sustainable home. The extent and type of vegetation is obviously important but sustainable landscape design can do many things including providing practical solutions to reducing water use through water sensitive design and as part of a wastewater treatment system.

Sustainable landscape design is an approach to designing and constructing the artificial landscapes that surround our buildings. Ideally these landscapes should maintain themselves and survive by being part of the natural cycles of the local environment.

In many cases this means finding out what the original local environment was like. This is often difficult, as in our cities and even in rural areas the landscape was significantly changed after European settlement.

Sustainable landscape means putting back much of what was in place before development. It may also mean introducing things that were not there before.



Edwina Robinson

This garden has been planted with local wetland plants and attracts frogs, dragon flies and local birds.

SITE

Sustainable landscaping is about more than planting Australian natives, it is about designing landscapes to fit the new ecology created when buildings are constructed. It can include food producing gardens irrigated by captured stormwater and landscaping practices like permaculture.

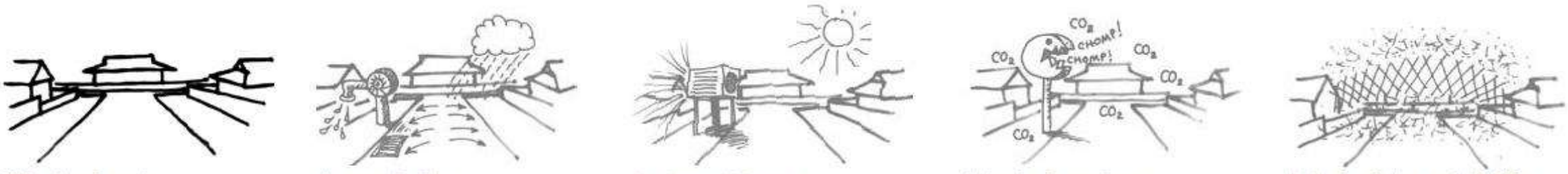
Sustainable landscaping includes such diverse approaches as restoring creeks where development has trammeled or annihilated their previous course, or creating roof gardens to replace the productive capacity of the land taken up by a new building.

Sustainable landscape may be used to control salination, help take up carbon dioxide and contribute to restoring and maintaining biodiversity. The location of vegetation can influence choices about building orientation: a tree may shade part of a site and limit solar access but be an essential part of retaining soil, providing habitat and creating shelter.

When choosing a site, take account of existing vegetation for windbreaks, shading and views.

Design landscaping to be experienced inside and out. Sustainable landscaping can be employed to create shade, or to enhance or frame views. It can be attractive to look at and also provide privacy from surrounding buildings. It can also supply food and help create pleasant areas for recreation. [See: 2.2 Choosing a Site; 2.5 Biodiversity On-site]

In recent years the definition of a sustainable landscape has evolved to include landscape elements that are literally part of a building. Many extensive green roofs are constructed specifically to support native and indigenous vegetation as part of a wider strategy for enhancing or replacing the natural biodiversity of a place or region. Often this kind of roof



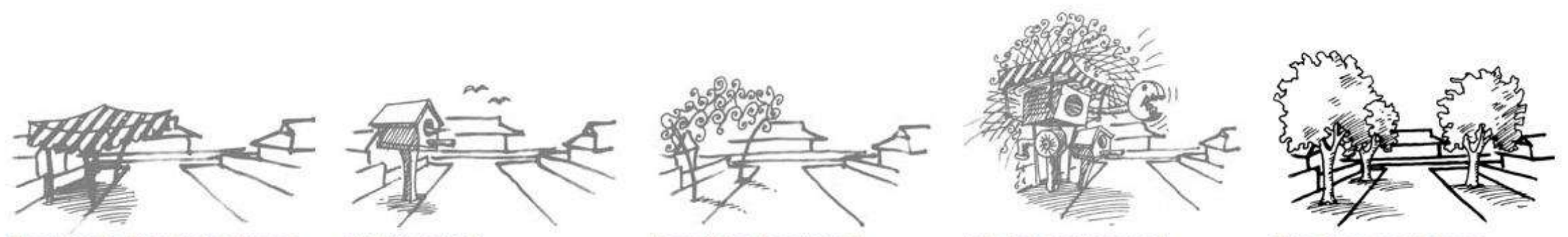
This street needs ...

A pump to take up stormwater

An airconditioner to improve the climate

A device to capture carbon dioxide

A dust catcher and air filter



Shade from ultraviolet radiation

Wildlife habitat

Something decorative?

And low maintenance!

This street needs trees!

greening strategy is also geared towards providing habitat for threatened or endangered species. Depending on their context, function, vegetation types and watering regimes, green walls can be seen as legitimate contributions to the creation of a sustainable landscape and may even be integrated into wastewater treatment systems. [See: 5.13 Green Roofs and Walls]

GROWING PLANTS

Sustainable landscapes use plants which perform well in the local area. Avoid native or exotic plants that are weedy in your region. Suitable plants may include native and indigenous plants, as well as exotics (non-Australian plants) from similar climatic zones. Plants should ideally perform well once established on existing soils and existing rainfall patterns without the need for excessive watering, soil modification and intensive maintenance regimes.

What is the difference between 'native' and 'indigenous'? In general terms, native plants are all plants from Australia. Indigenous plants are those specific to a particular place.

A sustainable garden uses a wide range of plants from different structural categories, such as trees, screening shrubs, medium shrubs, low shrubs, groundcovers, strappy plants and grasses, climbers, perennials and bulbs. Structural diversity will encourage wildlife into the landscape and prickly plants will provide shelter for small birds. Ensure wildlife are not compromised by domestic pets.

Native birds and reptiles can be protected from cats by keeping the cats indoors or in purpose built enclosures.

Growing fruit and vegetables is a way of reducing our ecological footprint. Most vegetables and fruit require fertile soils with good drainage, regular watering and moderate amounts of sunlight depending upon the climatic zone. Vegetable gardens can generally be provided in raised garden beds with the addition of home made compost and well rotted animal manures. Fruit and vegetables generally require regular drip irrigation.

Lawn is a common feature in Australian landscapes but it generally requires high levels of water, fertilisers and energy to maintain its appearance. These impacts can be minimised by:

> Removing lawn and replacing it with a mix of groundcovers and non-woody plants and permeable surfaces such as gravel.

> Reducing the extent of lawn and increasing the area of hardy garden beds.

> Substituting exotic grass species with drought tolerant low maintenance native grasses that retain the appearance of a conventional lawn.

Synthetic grass products are an inappropriate choice for sustainable landscapes. Non-living, synthetic plant substitutes diminish, rather than add to biodiversity. They are products of mining and a great deal of water and energy are used in their manufacture.



Edwina Robinson

A mix of native and exotic hardy plants replace lawn at this Canberra display home.

WATER

A house covers ground that was once productive natural landscape where rain soaked into the soil to support vegetation. Its roof can be used to capture rainwater that can then be used to irrigate new vegetation, perhaps even on a roof garden or balcony. Capturing water this way also reduces the release of stormwater to the street. [See: 5.13 Green Roofs and Walls; 7.3 Rainwater]

Low water-use vegetation or 'xeriscape' can greatly reduce the need for supplementary garden watering. Indigenous species are usually the best for the low rainfall conditions found in much of Australia. [See: 7.6 Outdoor Water Use]

Vegetation can even take up effluent via sub-surface irrigation, especially in outer urban and rural sites. [See: 7.4 Wastewater Re-use]

The use of water bodies like ponds and water features can be integrated into a sustainable landscape solution as part of an overall water management system and as part of the passive climate response strategy for your home.

LANDSCAPE MATERIALS

Landscape materials account for much of the embodied energy in a landscape project. Consider reusing existing site materials such as pavers and excavated rocks. Employ recycled materials wherever possible such as crushed brick/ concrete, recycled timber and products like recycled glass. Where recycled timber is unavailable use sustainably managed plantation timber or timber composite products in preference to imported rainforest timbers. Avoid excessive amounts of paving which can contribute to microclimate heating and reduced site permeability. Following the saying "only pave where you sit, stand and walk!"

AIR

In a healthy house the inside and outside are designed to work together. Sustainable landscaping helps to maintain a healthy internal and external environment. Vegetation can be used to filter air from outside whilst indoor air quality is improved by selection of appropriate plants – some are able to take toxins like formaldehyde out of the air. [See: 3.3 The Healthy Home]

Vegetation can create buffers and filters for wind and dust control.



Paul Downton

Look for a neighbourhood where sustainable landscape approaches are encouraged.

A new science of 'biophilia' (love of nature) is developing from the recognition that vegetation and natural environments have a measurable impact on our psychological health.

ENERGY

Appropriate landscaping can enhance passive heating and cooling. Used as an integral part of passive design strategies, windbreaks can reduce wind chill or the impact of hot winds. Vegetation can cool and filter air as part of a passive cooling strategy. [See: 4.2 Design for Climate; 4.4 Shading; 4.6 Passive Cooling]

Shading needs to be seasonal and is best provided by deciduous plants. Australia has few deciduous native trees (the *Toona australis* or so called Red Cedar is one). Other 'deciduous' natives such as *Brachychiton* lose their leaves in summer and therefore can not moderate solar penetration to suit passive design. It is best to assume that most native vegetation will give permanent or semi-permanent shade. [See: 2.5 Biodiversity On-site; 7.6 Outdoor Water Use]

Captured rainwater or treated wastewater can be used to irrigate deciduous plants that contribute directly to a building's passive solar performance.

RESTORATION ECOLOGY

Particularly challenging sites occur where there is little ecological value or pre-existing ecology has been destroyed. In such cases a substantial contribution to creating a sustainable landscape can be made by restoring as much as possible of the original ecosystem and increasing the ecological value of the site. [See: 2.9 Challenging Sites]

Such strategies are particularly pertinent to urban sites where, very often, all the indigenous vegetation has been removed for development. The movement to replace elements of original living landscapes now extends to the public realm. In choosing a site, consider the wider landscape and neighbourhood environment. [See: 2.2 Choosing a Site]

If you don't have a large garden space or want to contribute to restoring the landscape as part of compensating for off-site impacts, consider participating in native landscape and ecosystem restoration projects run by not-for-profit organisations like Trees For Life in SA and Men of the Trees in WA. Many tree planting and revegetation programs are also intended to compensate for carbon emissions. [See: 1.4 Carbon Neutral; 5.4 Biodiversity Off-site]



Edwina Robinson

This dry creek bed is composed of waste rock excavated from a building site and obtained from a local landscape supplier.

CLIMATE CHANGE

Consider the predicted changes for your region and adapt your landscape accordingly. To cope with increased temperatures increase shade protection to homes using trees, large shrubs to shade walls and climbers. Where space is limited use shade structures with climbers to reduce outdoor and building temperatures. Ensure the landscape has sufficient permeable surfaces to cope with increased rainfall events. Capturing water in rainwater tanks and through greywater recycling will ensure water is available to sustain plants during drought periods. Organic vegetable gardens will provide not only healthy food but reduce your household's ecological footprint.

In dry regions consider creating a small mini-oasis which can provide passive cooling to the house. Locate this area on the cooler side of the building which receives evening breezes. Incorporate moisture loving plants, a water feature, permeable paving and water harvesting methods in this space.

MAINTENANCE

Sustainable landscapes have much smaller energy and water use impacts than traditional landscape designs but they still require management. Native gardens and the use of hardy plants can create environments that consume little water other than that provided by rainfall. Even then, there is no such thing as a maintenance-free landscape. Anything that has been artificially created for human purposes requires on-going maintenance and this should be factored into the overall picture of any home design.

ADDITIONAL READING

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Biodiversity On-site

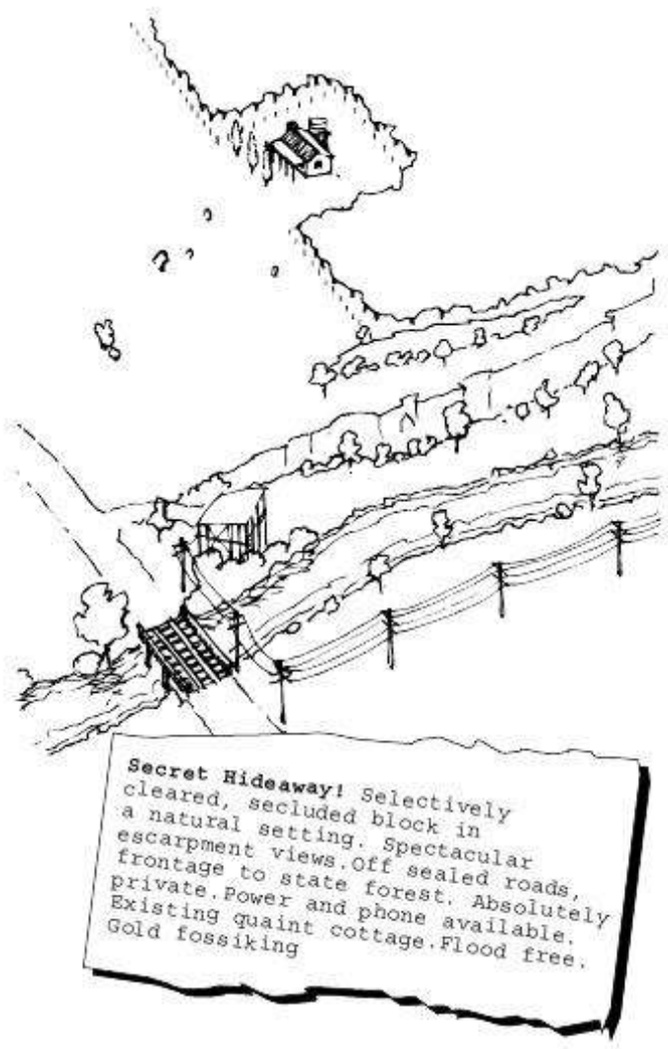
Biodiversity is the variety of all life forms – the different plants, animals and micro-organisms, the genes they contain, and the ecosystems of which they form a part. All development can play a role in protecting and restoring biodiversity and ecological processes.

This fact sheet should be read in conjunction with 5.4 Biodiversity Off-site which covers the lifecycle impact of your design and material choices, and 2.2 Choosing a Site.

THREATS TO BIODIVERSITY

Land clearance can pose a threat to biodiversity. Residential development, especially in growth corridors, city fringes and holiday towns often involves the clearing of native vegetation.

Even so-called sensitive development poses risks to the integrity of remaining natural ecosystems. Habitat degradation occurs with the introduction of pest plants and animals. The construction of buildings and roads alters drainage patterns and soil structure, while altered nutrient levels from run-off and septic tanks can also cause other long term problems.



The smaller the untouched ecosystems and the greater the intensity of development around the edges, the faster these destructive elements can cause a loss of habitat quality.

In some coastal areas the degrading influence of residential development may also extend to nearby foreshore and marine ecosystems.

Some ecosystems, especially grasslands and heathlands, are changed significantly by inappropriate fire regimes. Conflicts between ecological burning requirements and the need to protect residential development within or adjacent to these areas are difficult to resolve.

STRATEGIC APPROACH

Objectives for conservation of biodiversity include:

> Retaining native vegetation and increasing its quality and area wherever possible.

> Recovering threatened communities and species.

> Preventing rare species from becoming threatened.

> Repairing ecological processes.

Replanting cleared sites is definitely no substitute for leaving native vegetation intact. Once land is cleared it is almost impossible to recover the full suite of indigenous species, remove introduced species and restore ecological processes.

DESIGN FOR BIODIVERSITY BENEFIT

Build biodiversity conservation objectives into your planning and design approach from the outset. You may be able to find innovative ways to make a positive contribution.

Design to minimise the use of water, land, non-recycled materials, toxic chemicals and energy. These actions can help reduce impacts on biodiversity. [See: 5.4 Biodiversity off-site]

AVOID SENSITIVE AREAS

Wherever possible, choose a site that has already been permanently cleared.

Growth corridors and the fringes of cities and towns often support native vegetation. Although some of these grassland, woodland, bushland and heathland communities may be degraded, they could contain a wealth of native plants and animals. Waterways may still be in good enough condition to provide habitat for native species.

Some degraded areas may be important because they have been earmarked for habitat restoration.

IDENTIFY SITE VALUES AND THREATS

Identify flora and fauna, potential threats and ways of avoiding or minimising impacts as early as possible in the project. The extent of the development and the sensitivity of the environment will dictate the amount of information needed.

In situations where significant impacts are likely, a flora and fauna survey may be necessary. A nature conservation consultant may be useful at this stage.

ADOPT CONSERVATION POLICIES

Find out if aspects of federal and state legislation apply and if the planning scheme contains policies that affect your site. There may also be biodiversity plans at the state, bioregional or catchment level. The planning department of your local council should be able to advise you.

CASE STUDY: TERMEIL GUESTHOUSE

The guesthouse is located on the NSW South Coast required cabins to be built in a remnant rainforest area. Recognising that any development on the site would have some impact, the designers and the owners set about minimising that impact.

A bridge over an existing creek was required for site access. The bridge site was chosen to avoid the removal of trees and the bridge, designed to clearspan the watercourse, used recycled timbers.

Wildlife corridors between remnant forest and the creek were protected and extended with new plantings grown from seeds from the site.

Roadways were tightly curved to slow traffic for wildlife safety.



The original clearing.

Termeil Guesthouse was restricted to an existing clearing which had overgrown with non-native species.

The development plan for Termeil Guesthouse included:

> Retaining all native trees, although some undergrowth was cleared for bridge construction.

> Restricting clearing to a three metre radius around the building footprint (note fire regulations may limit the potential for maintaining indigenous vegetation on many sites). [See: 3.5 Bushfires]

> Incidental activities (parking cars, piling materials and rubbish and washing equipment were restricted to parking areas and surrounded by well designed sediment control barriers.

> Engaging a builder who was sensitive to the aims and objectives of the project.

> Paying bonuses for best practice by contractors and imposing penalties for breaches.



Completed bridge.

> Reducing footings in number to minimise impact and hand excavating to avoid sedimentation and damage by machinery.

For Termeil Guesthouse, an eight part flora and fauna impact study was carried out by a local consultant to identify important species, existing habitat and wildlife corridors.

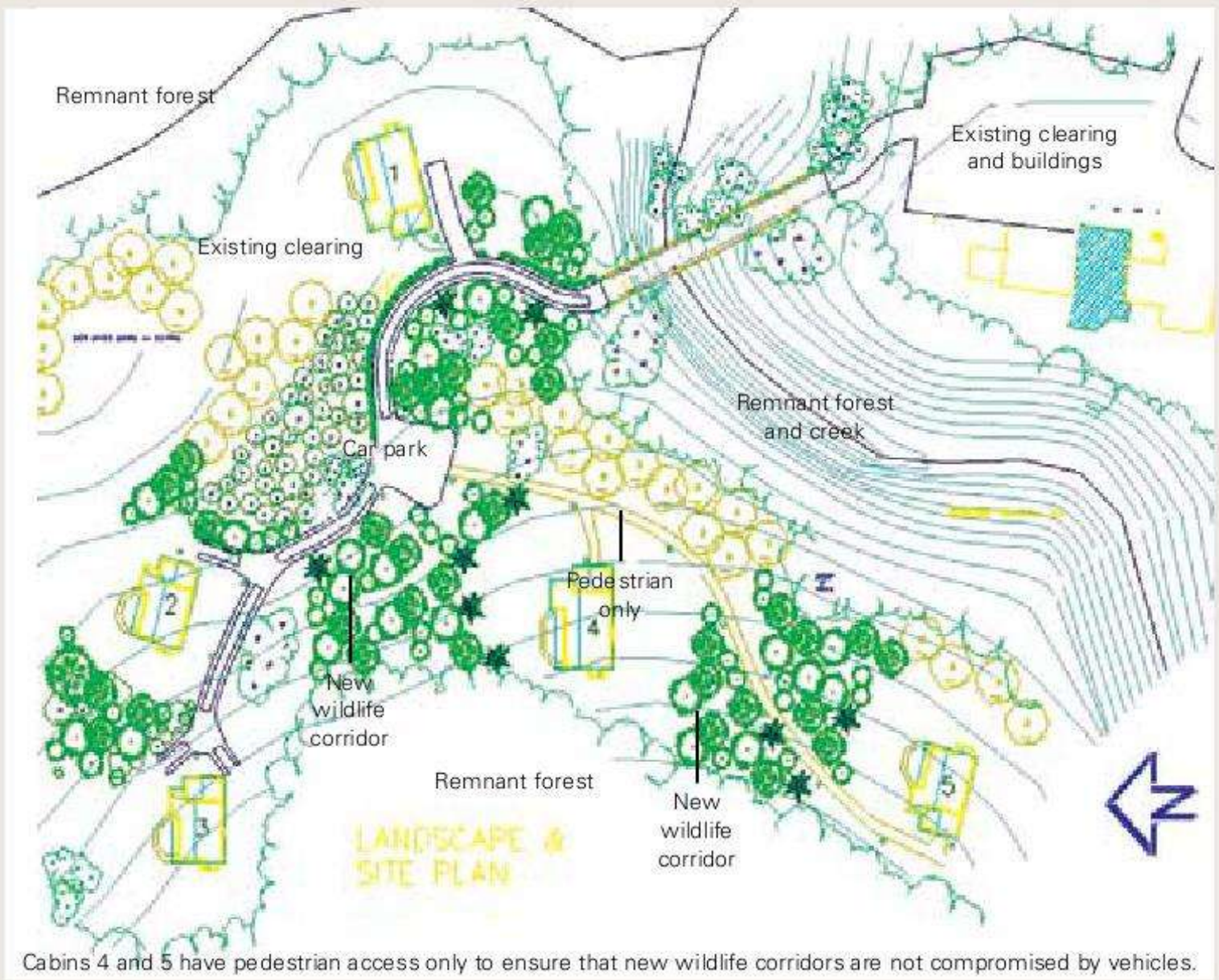
A detailed site survey was conducted to identify all trees, clearings and contours.

A development plan was prepared on the basis of the flora and fauna impact report.

Topsoil was stockpiled at Termeil Guesthouse, and used for landscaping the disturbed areas. Native understorey plants were salvaged.

Weeds and other non-native plants were removed from the cleared area where they had flourished under the broken canopy.

TERMEIL GUESTHOUSE SITE AND LANDSCAPE PLAN



Cabins 4 and 5 have pedestrian access only to ensure that new wildlife corridors are not compromised by vehicles.



Termeil Guesthouse collected seed stock from the best specimens on site and grew seedlings in their nursery during construction, ready for planting on completion.

The three metre building zone was turfed to stabilise soil until fire retardant native (to the site) groundcovers became established.

No other landscaping was required around the building site.

The result was an instant, low water, self maintaining garden and significant savings in landscaping bills.

The cabin was finished one week after the builder left the site.

Source: Suntech Design

MINIMISE DAMAGE ON SITE

> Retain as much native vegetation as possible. View the uncleared areas as a resource to be conserved.

> Avoid unnecessary disturbance to vegetation and soil. Limit clearing outside the building footprint. Vehicle tracks, workers' carparking, rubbish dumps and wash sites should be located away from native vegetation and waterways.

> Retain significant habitat trees including dead trees with hollow limbs or trunks which provide essential shelter and breeding sites for many animals.

> Consider your effects on waterways. Ensure that silt, lime, cement, paint and chemicals do not wash into drains or nearby watercourses.

SYMPATHETIC LANDSCAPING

> Rehabilitate disturbed areas with saved topsoil and salvaged plants.

> Consider using indigenous species in the garden. There are usually nurseries that specialise in native species that belong to the area. It is best to use plants grown from local provenance seed, as they will not mix genes from other areas into the local gene pool of the species. An indigenous garden requires much less watering and provides a link between your home and the ecosystem in which you live.

> Maintain links between adjacent bush and your garden. Many animals, especially birds, invertebrates and small lizards, may be able to use your garden for habitat resources.

> Do not use environmental weeds in the garden. There are many garden plants that spread into native vegetation and contribute to the decline of biodiversity. They are still sold in most nurseries, so you need to check with a reliable source.

COMPENSATING THE ENVIRONMENT

You may like to compensate for impacts on biodiversity by contributing to a recovery program or habitat restoration project. Find out what the biodiversity priorities are from your state or local government, so that your contribution will be as well targeted as possible.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on biodiversity in your local area.
www.gov.au

BEDP *Environment Design Guide*
GEN 3 Biodiversity and the Built Environment.
DES 45 Biodiversity in Landscape Design.

Environmental Weeds, Australian Government
www.anbg.gov.au/weeds/weeds.html

Principal author:
Kathy Preece

Transport

Some of the most important decisions you can make regarding the energy consumed by your household relate to transport. Where will you live? Is there good public transport? Will you have to buy a second car?

You may have an energy efficient home but still be a high energy household if you rely heavily on your car. Transport is a crucial ingredient in the good design of homes, neighbourhoods and cities.

Smart cities throughout the world are designed to have low rates of motor car use and high quality of life. The same can apply to your household.

URBAN VILLAGES

To reduce the environmental, social and economic impact of your transport, think carefully about where you should live. Avoid the sprawling car-dependent suburbs and choose an urban village with good access to public transport.

The main characteristic of an urban village is increased density of development around public transport facilities. Walking, cycling and public transport are used instead of cars. Road space and car parking are restricted and traffic speed and volume are controlled.

In urban villages, street layout should be simple, facilitating the easy movement of pedestrians, cyclists and buses.



Australians produce more motor vehicle pollution per capita than almost any other country. Twice as much as Europeans and many times more than people in Tokyo.



Community ties are strengthened by community interaction at meeting places near the village centre. Local shops and small businesses benefit from community support. Natural areas are protected and quality public spaces created and maintained. This kind of development can promote a sense of community and help reduce car use.

Older parts of cities that developed in the pre-car era exhibit many of the good qualities of urban villages.

PROBLEMS OF CAR DEPENDENCY

Australian homes on average produce around 14 tonnes of greenhouse gases each year and more than a third of this comes from cars.

Promoting urban villages helps us counter car-dependent sprawl and its many negative impacts. Some of these impacts are:

> Greenhouse gas emissions, air and noise pollution.

> Pollution and waste from manufacturing and disposing of cars.

> Communities divided and fragmented by roads.

> Cost burden of car ownership and poor access for non car owners.

> Flooding and water pollution created by run-off from impervious road surfaces.

> Loss of valuable bushland and farmland to roads and car parks.

> Depletion of finite oil reserves.

> High cost of roads and related services.

> Car accident deaths and injuries.

Australian cities require five car parking spaces per vehicle on average. In Los Angeles, 70 per cent of the surface area of the city is dedicated to the motor vehicle.

BENEFITS OF SUSTAINABLE TRANSPORT

By walking, cycling and using public transport you will benefit in many ways:

> You can enjoy meeting and interacting with people while walking or riding a bus or train.

> You will save money on transport.

> Your homes, neighbourhoods and cities will look better.

> A brief walk to the bus or train each day can improve your health and lower stress levels.

> Increasing road capacity attracts more traffic, cancelling the benefits of increased capacity. Building more roads is not the answer to our transport problems!

DECIDING WHERE TO LIVE AND WORK

You can reduce car travel and help create a market demand for urban villages by living in an established area close to public transport and other urban services. In deciding where to live and work, you should consider the following questions:

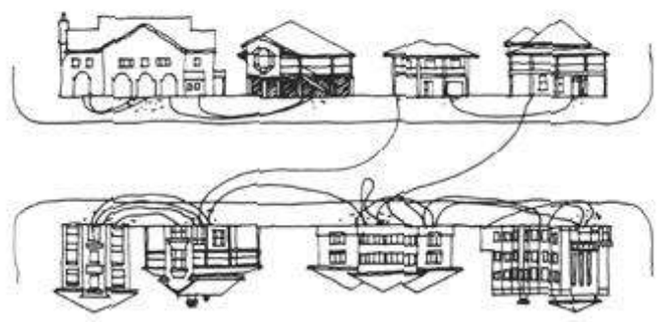
> Are you within walking distance of public transport, shops, schools and other urban services?

> Can you commute to work without a car? For most of us, the work commute is the most significant component of weekly travel.

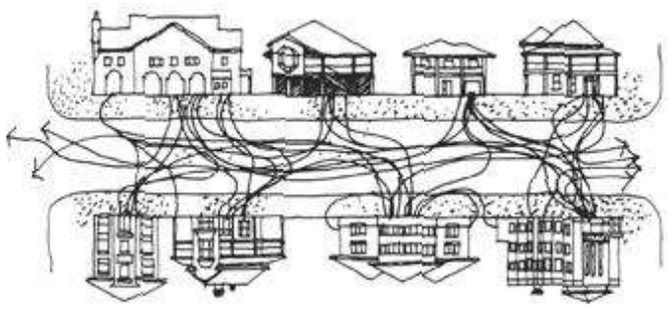
> Are you close to work? If so you will save hours of travel and free up time for activities you enjoy.

> Is your community vibrant? Find opportunities to participate in community activities. These might range from formal meetings on transport issues to local art classes or just chatting to neighbours.

> On a street that has light vehicular traffic, there is generally more social interaction and neighbourhood activity.



High car use low pedestrian street.



Low car use high pedestrian street.



YOUR DAY-TO-DAY TRAVEL BEHAVIOUR

The design of your home, choice of neighbourhood and your day-to-day travel behaviour are important elements of your lifestyle.

In built up areas during peak periods, trains and bicycles can be faster than cars – particularly if time taken to find parking is considered.

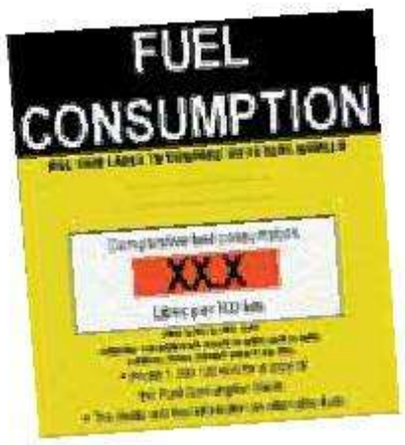
Here are some ideas for improving your lifestyle while reducing the impact of your transport needs:

> Use your car less. Where location demands that you own a car, then limit the number of cars in your household. This will reduce parking impacts and compel members of the household to plan their trips more carefully.

> Share car ownership and car trips. You can share journeys by taking on passengers, riding as a passenger with others or by participating in formal ride sharing schemes.

> Combine multiple car trips into a single trip. With a little planning, this can significantly reduce the extent of your car travel.

> If buying a new car look for the fuel consumption label that will tell you how economical the car is. This label is now mandatory for all new cars, four wheel drives and light commercial vehicles. Choosing the more economical model will save you money and reduce your greenhouse gas emissions. Consider a hybrid petrol/electric car to further reduce your greenhouse gas emissions.



> Work from home. Avoid the commute every now and then by 'telecommuting'. It will reduce your stress levels, add variety to your work routine and allow you to perform some home duties and spend time with your children while working. It is good for your neighbourhood as you can provide surveillance against crime during weekdays.

> Drive smoothly. Minimise acceleration and braking. This will reduce noise, air pollution and accidents. Erratic, aggressive driving creates a stressful and dangerous city.

> Maintain your car regularly. You will reduce noise and air pollution if you ensure that your car's engine and muffler are operating effectively.

> Choose a small car. Driving an unnecessarily large and heavy car such as an off road vehicle in the city wastes fuel and creates unnecessary noise and air pollution. Consider renting a specialised car for the occasions when you need to carry a large load or drive off road.

> Use the most environmentally friendly fuels. Leaded petrol creates more greenhouse gases than LPG and ethanol.

> Shop locally and buy locally made goods. This reduces the extent of your travel and you are helping to create urban villages by reinforcing local social and economic linkages.

Every year, around 1,500 people die on Australia's roads from car related accidents.

WORKING WITH YOUR NEIGHBOURHOOD AND LOCAL COUNCIL

You can work with your local council and neighbours to reduce car use and promote a healthier community. This work could include:



> Traffic calming. Widen footpaths, install speed humps, roundabouts and landscaped strips. Introduce local speed restrictions and road closures. These not only serve to slow traffic, but can transform your traffic-ravaged street into a friendly and attractive space shared by local residents, pedestrians, cyclists and motorists alike.

> Organise or participate in street parties, markets and festivals. They are fun, allow residents to reclaim their streets, strengthen the community, promote pride of place and increase opportunities for social interaction.

> Develop a neighbourhood traffic reduction plan. This involves residents reorganising their travel behaviour to reduce their car use. In order to reduce car travel by others on your street, you must first make an effort to reduce your car travel on others' streets.

> Participate in strategic planning. Local councils have to consider a wide range of issues in the decision making process and a decision that is right for one part of the community could be wrong for another. Councils are continually developing strategic plans and policies that influence transport and your environment. These include pedestrian and cycle-way plans and car parking policies. Your participation can help council in its decision making processes.

> Participate in a local car sharing scheme.

Avoid short car trips – your car generates 40 per cent more greenhouse gases per km when cold. Walk or ride a bicycle instead.

> Comment on development proposals. Your local council is also continually approving new developments that can significantly influence your neighbourhood. You can comment on how (or whether) developments should be approved in the interests of promoting more livable communities.

DESIGNING A HOUSE OR APARTMENT BUILDING

If you are building or renovating a house or apartment, you should consider the following transport-related design elements:

> Avoid a line-up of garage doors along the street.

> Minimise the number of on-site spaces. It is best to eliminate the need for on-site parking altogether. You can do this by not owning a car, or by parking on the street if possible. By minimising on-site parking, you will reduce the extent of paved areas and extend your garden space. You will also reduce the number of driveways crossing footpaths, which is safer for children and pedestrians generally.

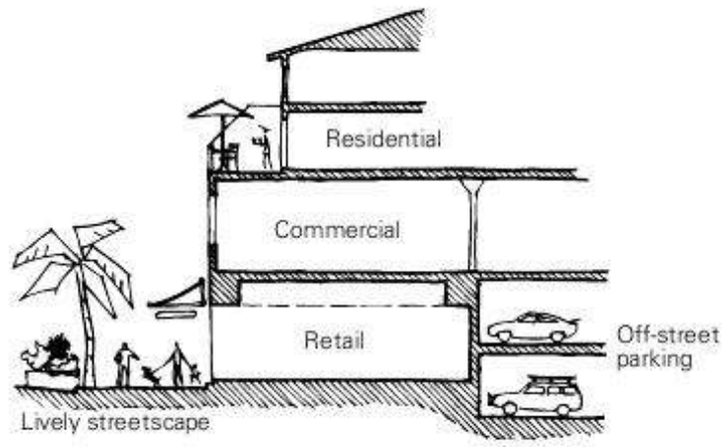
> Minimise the extent of paving. Driveways should be kept as short and narrow as possible and be only partially paved to minimise stormwater run-off.

> Locate on-site spaces appropriately. While parking at the side or rear of a house is recommended to avoid an unsightly line of garages facing the street, this does add to the extent of driveways and paved areas (except if there is rear access). On-site parking for apartments should also be minimised, and while it should be located underground, this adds to the embodied energy of construction.

> Allow space for bicycle storage. This could include a dedicated bicycle storage area or space in the garage. Consider space saving, inexpensive options for storing and securing your bicycle, such as wall mounted bicycle racks.



> Front yards without car parking areas create a more attractive streetscape. [See: 2.3 Streetscape]



> Siting shops and residences instead of car parking at the street level frontage of apartment buildings will retain activity on the street and enhance the streetscape.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on sustainable transport options in your local area.
www.gov.au

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GEN 45 Urban Development Accessibility and Transport in Australia.
GEN 46 Changing the Signs, Making Connections.
DES 16 Transport – Design Strategies, Sustainable Metropolitan.
DES 46 Urban Forms – The Impact of Transports.

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Street Reclaimers
www.lesstraffic.com

Sustainable Transport, Australian Government
www.greenhouse.gov.au/transport

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Noise control

Noise can interfere with sleep, rest and conversation and cause fatigue, irritability, headaches and stress. We all need to contain and reduce noise in order to enjoy a healthy life. Thoughtful design and practice can reduce the impact of noise on our lives and improve the quality of our living environment.

NEIGHBOURHOOD NOISE

Common sources of neighbourhood noise include:

> Road, rail and aircraft traffic.

> Air conditioners, refrigeration units.

> TVs and stereos.

> Burglar and car alarms.

> Household appliances.

> Dogs and other animals.

> Industrial premises and backyard workshops.

> Music from houses, commercial premises and concerts.

> Road and building maintenance and construction.

Sound pressure level is measured in decibels (dB) and some typical values are given below.

SOUND LEVEL (dB)	PERCEPTION EXAMPLE
120	Extreme jet take off at 100m
110	Pop group
100	Loud car horn
90	Very loud heavy traffic
80	Noisy office
70	Loud busy street
60	Average office
50	Noisy normal conversation
40	Moderate quiet office
30	Quiet conversation
20	Quiet room
10	Very faint normal breathing
0	Threshold of hearing

Communities usually agree about what noise volumes are acceptable and what are not but there are several subjective elements that determine our response to noise. Our perception of noise is affected by subjective factors. These include the type of noise, our mood, the time of day, background noise levels and our expectations.

OPTIONS TO REDUCE NOISE

Recognising these subjective factors helps us determine when others are creating noise unfairly and how to respond. If neighbourhood noise is a genuine problem for you there are some actions you can take:

> Choose a quiet neighbourhood.

> Reduce the noise by talking it over with whoever is causing the problem, or by lodging a complaint.

> Block the noise with barriers, sound absorbent materials and appropriate home design.

> Minimise your own contribution to neighbourhood noise.

> Carry out noisy activities during the day.

> Inform your neighbours whenever you need to generate noise, such as a party at home.

> Design your home to minimise noise transfer to your neighbours.

TRAFFIC NOISE

For most Australians road noise is the most important neighbourhood noise issue as it affects a high proportion of the population, and the problem is growing as traffic levels increase. [See: 2.6 Transport]

Minimise the impact of traffic noise on your home – and your contribution to the problem:

> Cycle or walk, rather than drive.

> Buy a quiet car, and drive it less.

> Drive slowly and calmly and maintain your car.

> Shop locally and buy locally made products to reduce freight travel.

> Report noisy vehicles.

Work with your neighbourhood, local council, community organisations and government to create more livable communities with reduced traffic noise. Central to this is the creation of urban villages based on public transport, walking, cycling, traffic calming and other traffic reduction initiatives. [See: 2.6 Transport]

Surveys show that noise is an important environmental concern for most Australians. Many people complain that traffic noise has the greatest direct impact.

NOISE IN BUILDINGS

Non-traffic related noise complaints are rising, particularly in medium and high density housing areas. Many new medium and high density developments are unnecessarily noisy.

It can be very difficult or expensive to do anything about a noise nuisance after a house is built or purchased. Consider potential noise problems before you buy, build or renovate.

Ask for design specifications for noise levels before buying a multi residential unit and ask your solicitor to link them to your contract as a performance measure. This will give you more options if you discover a problem after moving in.

Part 3.8.6 of BCA Volume Two contains sound insulation requirements and technical solutions for separating walls and floors for single dwellings.

The following design sound levels are recommended for an inner suburban house.

Recommended design levels

(dB) ACTIVITY	SATISFACTORY	MAXIMUM
Recreation areas	35	40
Bedrooms	30	35
Work areas	35	40

From Table 1 AS 2107

TYPES OF NOISE

There are two types of building noise to consider:

1. Airborne noise

Airborne noise comes from common sound sources such as voices, TVs and radios. The noise performance of a building system is called the Sound Transmission Class (STC). The higher the STC the better the system is at isolating airborne noise. An STC rating of 45 means that the element reduces the sound passing through it by 45dB.

Rooms with a lot of hard surfaces can be very noisy as they readily reflect sound. Soft furnishings, drapes and rugs can make a significant improvement.

A change of 3 STC (or dB) in the sound level means a doubling or halving of the sound energy. As the human ear does not perceive sound in a linear way, a 3dB change is barely perceptible. The table below shows the subjective perception of sound energy.

REDUCTION IN dB	%	REDUCTION IN SOUND ENERGY SUBJECTIVE PERCEPTION
3	50	Barely perceptible
4-5	70	Significant
6	75	Sound appears to be reduced by about 1/4
7-9	87	Major reduction
10	90	Sound appears to be less than half original

The table below outlines what this means in practice for building elements.

STC	EFFECT ON SPEECH PERCEPTION
25	Normal speech can be heard easily
30	Loud speech can be heard easily
35	Loud speech can be heard but not understood
42	Loud speech heard as murmur
45	Must strain to hear loud speech
48	Loud speech can be barely heard
53	Loud speech cannot be heard

2. Structure-borne noise

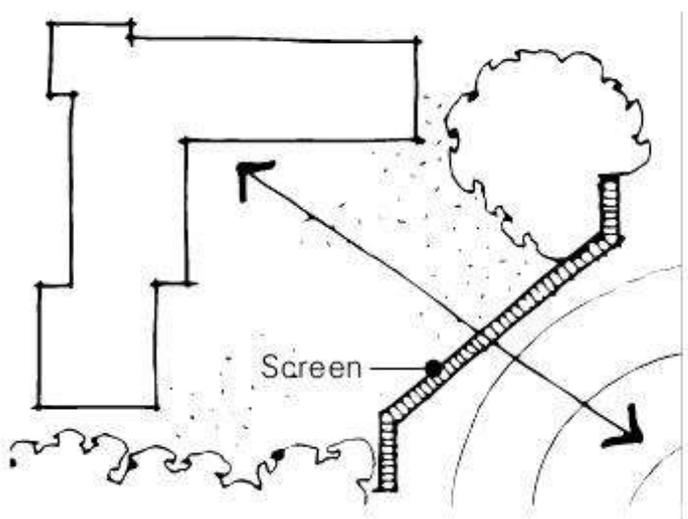
Structure-borne noise, also called impact noise, is produced when part of the building fabric is directly or indirectly impacted. Energy passes through the building structure and creates noise in nearby rooms. Examples are heavy footsteps (particularly on bare timber or tile floors), banging doors, scraping furniture, vibrations from loud music, and plumbing noise. The Impact Insulation Class (IIC) is used to rate the impact noise insulation of floors.

IIC	
45	People walking around are clearly audible
50	People walking around are audible and noticeable
55	People walking around audible but acceptable
62	Walking heard as low frequency thump
70	Heavy walking heard as low frequency thump

NOISE AND GOOD DESIGN

Site planning

Consider noise sources such as shops, hotels, garbage and recycling collection when siting buying or renovating your home.



Place screens such as fences, trees and hedges between the noise source and your home. Place driveways/garages away from bedrooms and living rooms.

Building layout and design

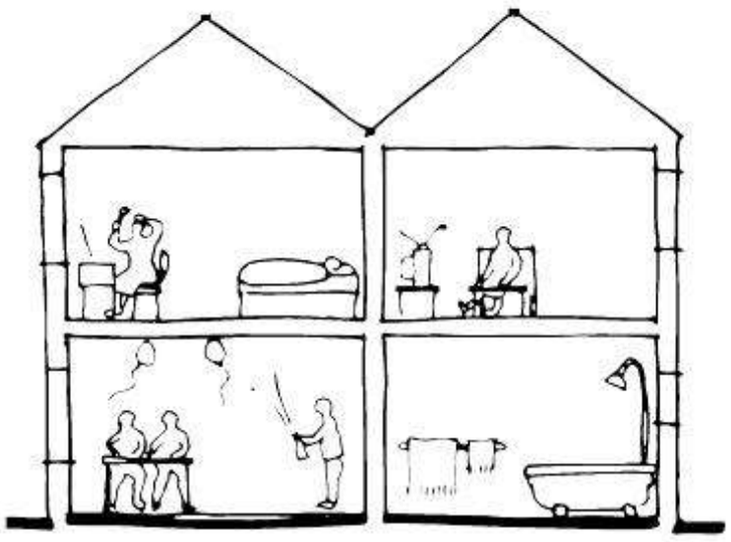
> Locate quiet rooms as far away from noise sources as possible, without compromising passive solar design principles.

> Install windows away from noise sources if possible.

> Locate noisy areas together and away from quiet areas.

> Avoid putting laundries, bathrooms or living rooms next to, above or below bedrooms without adequate sound insulation.

> Accommodate teenagers by providing extra soundproofing for their rooms and locate them away from adult living and sleeping areas, and neighbours.



Noise is a particular problem within medium and high density housing, and special care in design is needed to avoid problems. If people are unable to open windows to keep cool in summer they may need to install mechanical cooling.

> Minimise the need for noisy mechanical cooling.

> Use solid dividing fins between balconies.

> Build units around quiet courtyards and face them away from roads.

> Keep pedestrian and vehicle thoroughfares away from bedrooms and living rooms.

> Avoid placing windows and doors of neighbouring units opposite or adjacent to one another.

Construction

The BCA Building Code of Australia (BCA) specifies the minimum STC wall and floor requirements between adjoining dwellings. The BCA uses a sound reduction index (Rw) which is directly equivalent to STC.

The BCA specifies the minimum required Rw (airborne) + Ctr (impact) sound values for separating wall construction in new single dwellings (Class 1 building). For further information please refer to Part 3.8.6 of the Volume Two of the BCA.

Exceeding the minimum specifications is highly recommended, particularly given the trend towards higher density living.

The BCA does not specify IIC, but certain construction types are 'deemed to comply'.

Rw levels in the BCA only consider individual building elements as measured in a laboratory. Sound transmission properties of the structure as a whole or on-site construction practices are not taken into account. These can reduce the effective value by up to 5 Rw due to flanking sound transmission paths.

Good design detail and construction practice is critical to the performance of both heavy and light construction.

Pay attention to elements like floor and ceiling plates and installation of services such as plumbing and power outlets to ensure the desired performance is achieved.

BCA Rw requirements for walls between adjoining dwellings are:

	MINIMUM R_w
Floors above dwellings	50
Walls between a bathroom, laundry or kitchen and a habitable room in adjoining dwelling*	50
Other walls	45

*These walls must also have a satisfactory level of impact insulation as outlined in the code

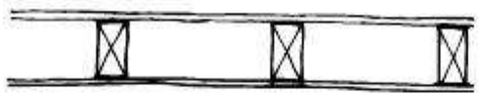
For the BCA minimum requirements for Rw (airborne) + Ctr (impact) sound values for separating wall construction in new single dwellings (Class 1 building) please refer to Table 3.8.6.1 Required Rw airborne and impact sound levels for separating walls.

Although the BCA specifies no sound insulation requirements within dwellings it is important to consider sound transmission in homes now that multiple TVs, stereos and bathrooms are common.

The Rw ratings of some typical wall and floor construction methods are outlined here.

Heavy dense materials, such as concrete, are generally better for sound insulation but a range of lightweight solutions are also available.

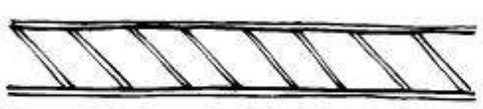
Walls



Rw32. Using 10mm plasterboard on 100 x 50mm timber studs at 450mm centres provides very little sound insulation and is not recommended for occupied rooms.



Rw42. 100mm low density AAC block with 10mm adhered plasterboard both sides.



Rw45. 90mm calcium silicate brick with adhered 10mm plasterboard both sides. This complies with the BCA minimum for adjoining dwellings.

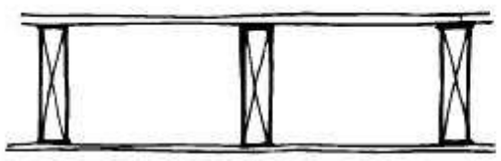


Rw50. 90mm solid concrete block with adhered 10mm plasterboard both sides.

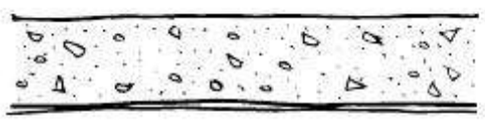


Rw50. 16mm fire protective plasterboard on staggered timber 70 x 45mm studs at 600mm centres both sides with 120 x 35mm timber plates and 50mm glass fibre batts.

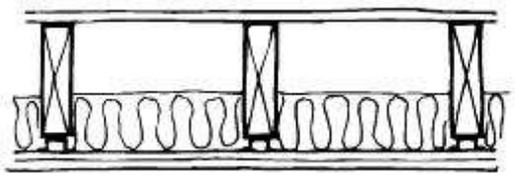
Floors



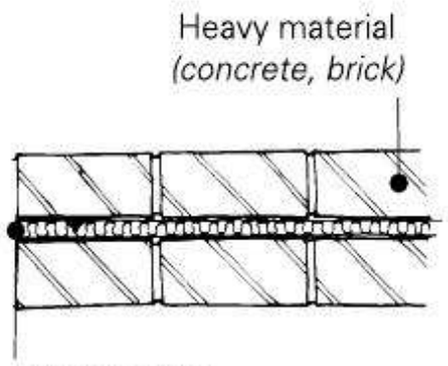
Rw35. Bare 20mm floorboards on 200 x 50mm joists at 450mm centres, with one layer of 13mm plasterboard. This provides very little sound or impact insulation and is not recommended.

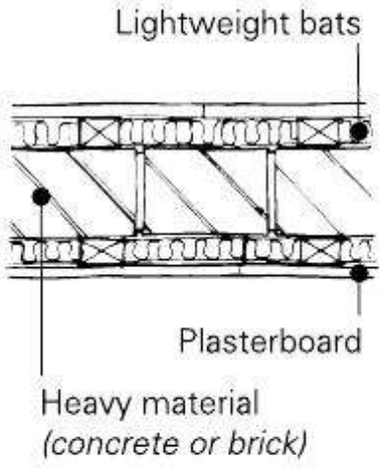


Rw48. 150mm concrete slab (365kg/m²) with 10mm of plaster.



Rw50. IIC 50. Bare 20mm floorboards on 200 x 50mm joists at 450mm centres, with two layers of 16mm fire protective plasterboard on furring channels and resilient mounts, and 100mm batts. Using carpet and underlay will increase the IIC to 70.

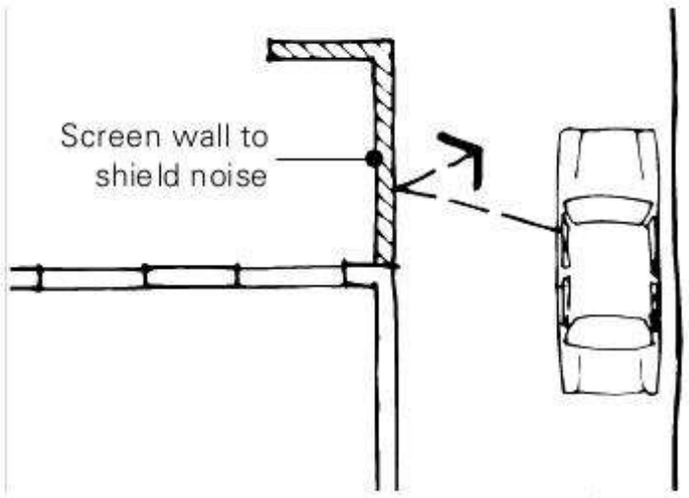


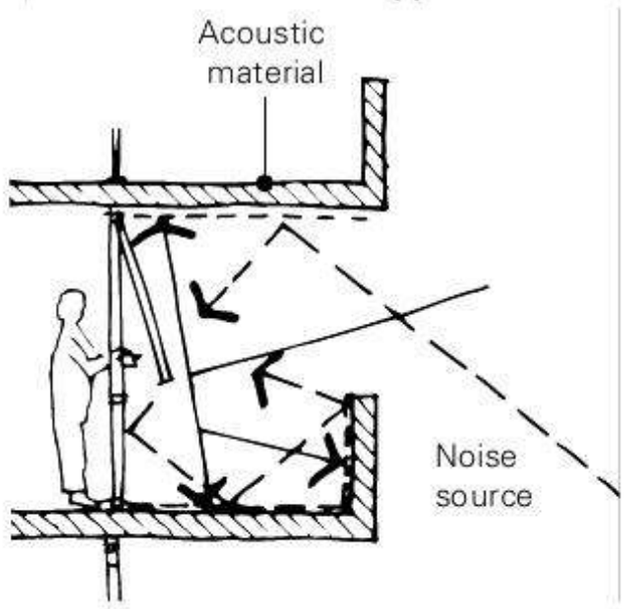


Dense materials will, however, readily transmit impact noise.

Composite construction using combinations of light and heavy mass materials are best to reduce noise transmission.

Airborne noise is easily reflected. Provide screen walls to shield noise and use acoustic materials to reduce noise reflection.





Glass and noise

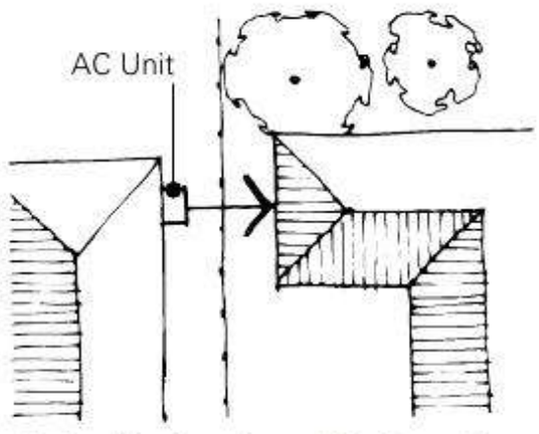
A 3mm single glazed window has a very low STC, and windows can let in a lot of noise, open or closed. The potential sound reduction from a highly insulating wall can be substantially reduced by poor window design.

Double glazing and laminated glass are both effective at reducing noise.

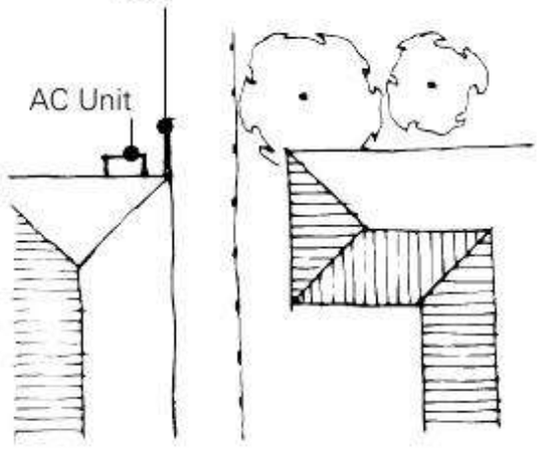
The table below shows the percentage noise reduction compared to 3mm glass. Note that these percentage reductions are not the same as STC values.

VOICE NOISE REDUCTION	%	TRAFFIC NOISE REDUCTION	%
Glazing type (Single)		Glazing type (Single)	
6.38mm laminated	13	6.38mm laminated	24
10mm glass	24	10mm glass	38
10.38mm laminated	29	10.38mm laminated	43
Glazing type (Double)		Glazing type (Double)	
4mm /12mm space /4mm	19	10mm /12mm space/6.38mm laminated	46
10mm /12mm space/6mm	34	6mm /100mm space/4mm	57
6.38mm laminated/8mm space/4mm	46		

Source Pilkingtons Note: Thicker glass generally does not improve thermal insulation.
For a combination of sound and thermal insulation use double glazing. **[See: 4.10 Glazing]**

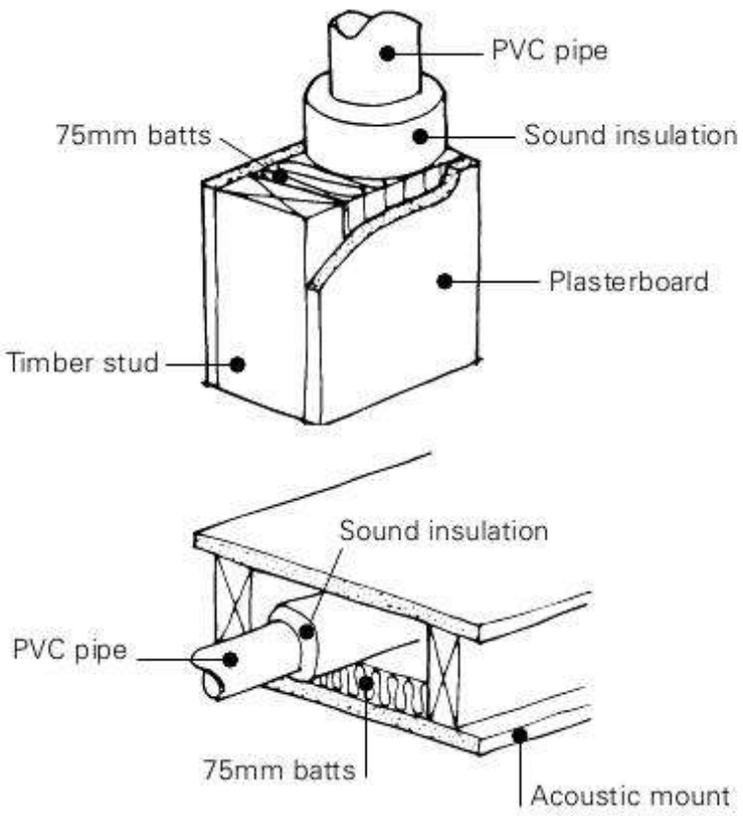


Unsuitable location for air conditioning unit.



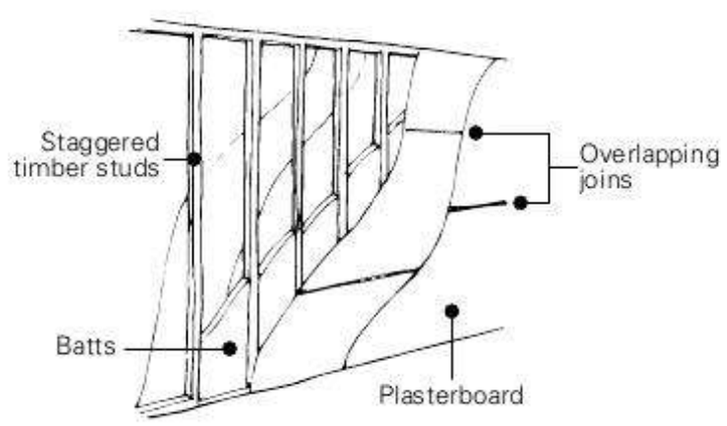
Suitable location for air conditioning unit.

Other noise abatement tips



> Plumbing and waste pipes should not pass close to quiet rooms or should be adequately soundproofed. A range of sound insulation products exist for plumbing and waste pipes in walls and floors.





> Pay special attention to details that might affect the integrity of sound insulation such as power points and plasterboard joints. Power outlets should be offset and placed in different sections of the wall cavity. When using double layers of plasterboard ensure the joints overlap and offset joints on opposite sides of the wall.

> Provide extra sound insulation for noisy rooms such as laundries. Use acoustic mounts or pads for clothes washers and dryers.

> Avoid hard floor surfaces that are above ceilings without good sound insulation. Use cork, carpet or impact absorbing finishes instead of bare timber or tiles.

> Low density coverings such as carpet will have little effect on STC but will greatly reduce both impact noise (increasing the IIC by about 20 points) and internal sound reflection.

> Proprietary noise reduction underlays can be used to increase both STC and IIC ratings of floors. They are ideal for reducing sound transmission on existing floors within a home.

> Use built-in robes as sound buffers between bedrooms.

> Solid core doors are more effective sound insulators than hollow core. Use door closers or foam/plastic strips on door frames to stop doors banging.

> Reduce sound reflection transmission through gaps with draught sealing strips.

OUTDOOR NOISE SOURCES

> Site noisy areas like swimming pools and outdoor living areas away from neighbour's windows.

> Hard exterior surfaces such as concrete paving reflect sound rather than absorb it. Softer surfaces are more desirable, particularly in higher density housing, as they absorb sound. Permeable surfaces also reduce stormwater run-off. **[See: 7.5 Stormwater]**

> Make sure outdoor noise sources (AC units, pool pumps) are not going to be a nuisance for neighbours. If pumps can't be placed far enough away, build a noise reduction enclosure.

> There are laws governing noisy air conditioners that may annoy neighbours. The best solution is to buy the quietest air conditioner suited to your needs. Install it as far as possible from your neighbour or in a well shielded location. Most air conditioners in Australia have a label that specifies the amount of noise they make. The smaller the number of dBA on the label the quieter the air conditioner. Get specialist advice from the supplier or installer.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on noise control in residential areas.
www.gov.au

Australian Building Codes Board (2007), *Building Codes of Australia Volume 1 and 2*, AGPS Canberra.
www.abcb.gov.au

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Sediment Control

Sediment control practices are used on building sites to prevent sand, soil, cement and other building materials from reaching waterways. Even a small amount of pollution from a site can cause significant environmental damage by killing aquatic life, silting up streams and blocking stormwater pipes.

Sediment control usually requires little effort and results in:

> Cleaner waterways and healthier aquatic life.

> Reduced clean-up costs to the community.

> Improved site conditions.

> Improved wet weather working conditions.

> Reduced wet weather construction delays.

> Reduced losses from material stockpiles.

> Fewer mud and dust problems.

> Fewer public complaints and less chance of fines.

COUNCIL REGULATIONS

Most local councils have guidelines on sediment control. Ask them for information.

A sediment control management plan may need to be submitted to council for approval prior to work commencing. This should address the location, design, scheduling and maintenance of sediment control measures and details of site rehabilitation.

The need for sediment control is influenced by:

Soil type. Clay soils are more likely to cause environmental harm, while sandy soils are more likely to cause traffic hazards and drainage problems. Exposed subsoils generally cause more problems than exposed topsoils.

Slope. The steeper and longer the slope, the greater the potential for erosion and sedimentation.

Extent, nature and duration of the soil disturbance. The greater the disturbance, the greater the risk of erosion and sedimentation.

Climate and season. Rainfall (intensity and duration) and high winds will influence erosion and sedimentation.

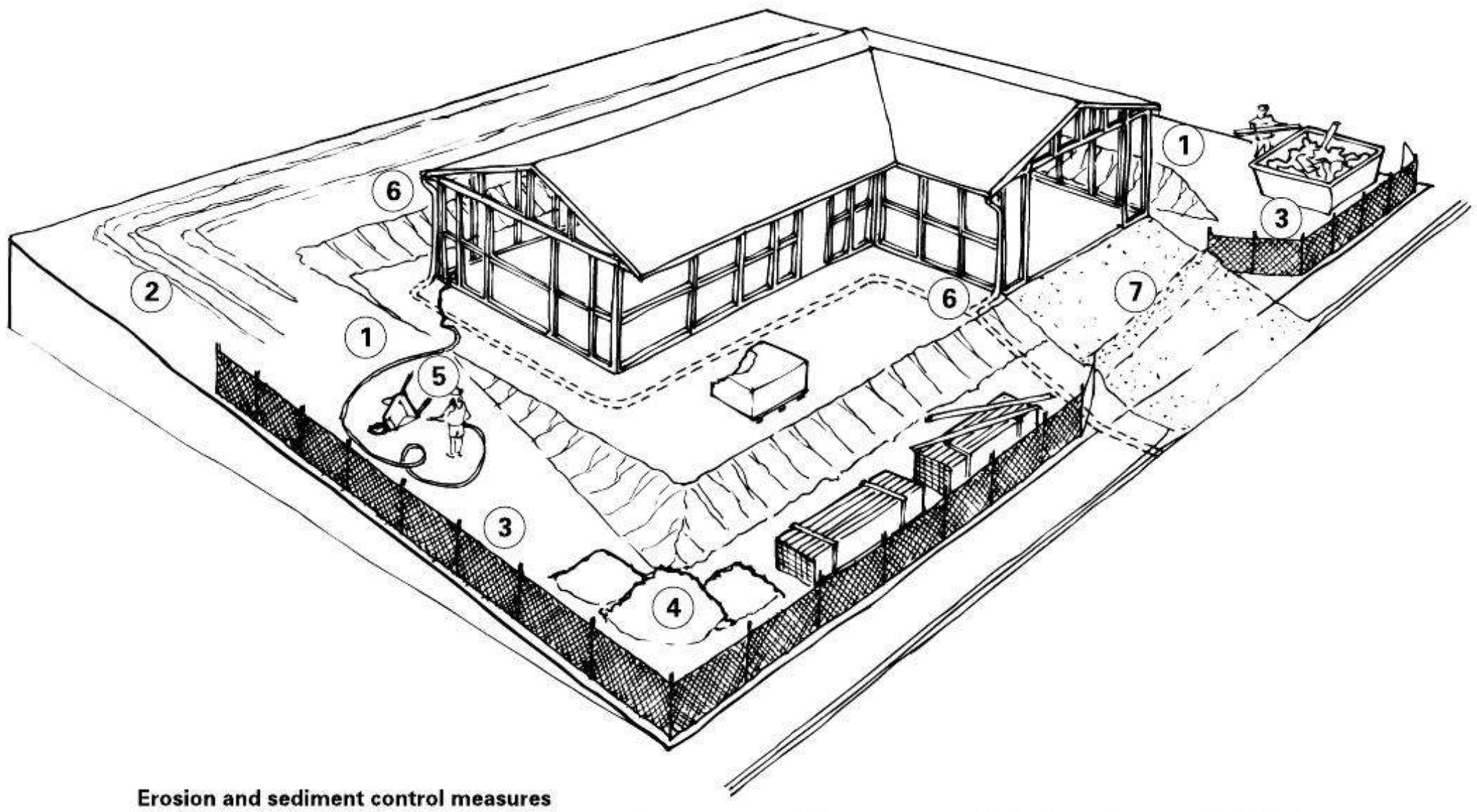
Size and location of the site. Sediment control on small sites is often harder to implement, especially if the slope is towards the street. Consult your local council. Large vegetated rural sites may not always require specific controls.

The objectives of sediment control are:

> To divert uncontaminated water away from the site.

> To minimise erosion by minimising site disturbance, stabilising disturbed surfaces and securing material stockpiles.

> To prevent sediment contaminated water leaving the site.



Erosion and sediment control measures

(1) Minimise disturbance (2) Diversion devices (3) Sediment barriers (4) Secure stockpiles (5) Other containments (6) Early stormwater connection (7) Controlled access point

MINIMISING SITE DISTURBANCE

Prevention is better than cure. Careful design and an efficient construction sequence will minimise disturbance to the site. This will save money and reduce environmental impact.



Design to avoid excessive cut and fill, unnecessary clearing of vegetation and to preserve existing site drainage patterns. Clear only those areas necessary for building work to occur. [See: 2.2 Choosing a Site]

Preserve grassed areas and vegetation where possible. This helps filter sediment from stormwater run off before it reaches the drainage system and stops rain turning exposed soil into mud.

Delay removing vegetation or commencing earthworks until just before building activities start. Avoid building activities that involve soil disturbance during periods of expected heavy or lengthy rainfall.

HOW TO IMPLEMENT SEDIMENT CONTROL

Install sediment control measures before commencing any excavation or earth moving. Regularly maintain them until construction is complete and the site is stabilised.

Three important steps to take are:

1. Divert uncontaminated stormwater away from the work area

Avoid contamination of stormwater with sediment. Use diversion devices to reduce the volume of stormwater reaching the disturbed area.

On compact urban sites avoid overland flow through the work area by installing the final stormwater drainage system as early as possible in the construction process. Before installation of the final stormwater system, install an up-slope perimeter bank and catch drain connected to a temporary drop pipe, to take uncontaminated stormwater directly to the stormwater system. On steep sites, line catch drains with turf or geotextile fabric.

On larger sites a diversion channel may be used to divert uncontaminated stormwater around the disturbed area. Construct the channel uphill of the disturbed area with a bank on the lower side. Regularly remove sediment from the channel.

Line the channel with erosion control mats or turf to prevent soil erosion or use check dams constructed from sand or gravel filled bags.

Uncontaminated stormwater from the channel should discharge to the stormwater system. In some cases discharge onto non-erodable areas of land is permissible. Check with your local council. Do not allow discharge into neighbouring properties.

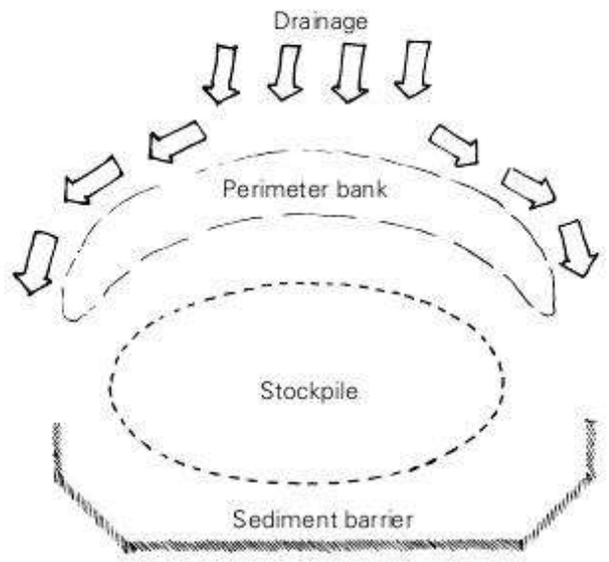
Roof drainage must discharge to the stormwater system, unless rainwater is being harvested. Complete the final stormwater drainage system before the roof is installed. Connect using either temporary or permanent downpipes. [See: 7.3 Rainwater]

2. Minimise the potential for erosion

Construct a single vehicle entry/exit pad to minimise tracking of sediment onto roadways. Use a 150mm (minimum) layer of 40mm recycled aggregate or crushed rock. A raised hump across the entry/exit pad can be used to direct stormwater run-off into a sediment trap to the side of the pad.

Protect materials that may erode, particularly sand and soil stockpiles, with waterproof coverings. Contain waste in covered bins or traps made from geotextile fabric.

Locate stockpiles of building materials away from drainage paths and uphill of sediment barriers. Divert run-off around stockpiles unavoidably located in drainage paths using a perimeter bank uphill.



Use biodegradable erosion control mats to protect exposed earth. These are particularly useful on high risk soils and steep sites where there is a delay in building or site rehabilitation.

3. Prevent sediment-contaminated water leaving the site

Use barriers to trap coarse sediment at all points where stormwater leaves the site, before it can wash into gutters, drains and waterways. Install sediment fences down slope of the disturbed area, usually along the lowest site boundary with the ends returning uphill. Inspect barriers after storms and remove sediment. Stockpile extra sediment fence on site for emergency repairs. See Sediment Control Devices.

Regularly sweep adjacent streets and gutters clean – do not hose them. Relocate sediment on site or dispose of it suitably. Remove accidental spills of soil or other material immediately.

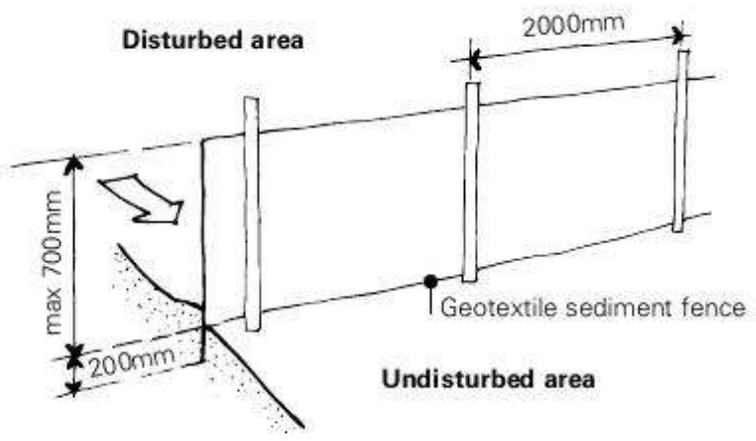
Maintain kerbside vegetation in a healthy state as it can function as an additional filter for sediment. Do not use nature strips or footpaths for parking or stockpiling unless unavoidable. Council permission is required.

Cut brick, tile or masonry on a pervious surface such as grass or loosened soil within the property boundary. The same applies when cleaning equipment. Waste concrete, paint and other solutions used on site should be properly disposed of so they do not contaminate stormwater. [See: 7.5 Stormwater]

SEDIMENT CONTROL DEVICES

Geotextile fabric sediment fences

These are generally the most efficient barrier for building sites.



Constructed from geotextile fabric attached to posts, these fences trap sediment but allow water through. On small frontage sites with limited access, use steel posts and wire tied fences that can be readily unhooked for unloading of materials.

Vegetated filter strips

These are useful as a secondary measure, generally not as a substitute for sediment barriers. Strips of turf or vegetation are used to trap sediment, acting as a buffer zone between the site and the gutter. The nature strip is often used for this purpose.

Stormwater inlet traps

Stormwater inlets are not usually found in residential building lots but may occur on larger development sites. Construct a temporary filter fence around on-site stormwater inlet grates. Wrap geotextile fabric around posts fitted at each corner of the drainage grate. The base of the fabric should be embedded in soil.

Off-site sediment traps

For safety and efficiency, sediment barriers should not be located outside property boundaries, particularly on roads. Anything placed on a road requires the permission of the road owner, whether it is the local council or the developer.

Sediment barriers in front of roadside stormwater inlets are rarely effective and usually just result in the sediment being washed down the street into the nearest gully inlet.

As a last resort use off-site sediment traps, made from sand or gravel bags of geotextile fabric. Ensure they do not fully block the gully inlet. Check daily and remove accumulated sediment.

POST-CONSTRUCTION AND EROSION CONTROL

Stabilise the site as soon as possible after construction, or while the last trades are finishing, to minimise the potential for ongoing soil erosion.

Turf lawns are commonly used to stabilise soil but their high water consumption can be an environmental burden. Native ground cover plants do the same thing with considerably lower water use. Avoid replacing native vegetation with turf.



Mulch (straw or other material) can be used on open garden beds to protect soil and support plant growth. Mulch spread to a depth of 75-100mm minimises soil and water loss and controls weed growth. Mulch may be less suitable on steep sites and in high wind areas.

Temporary, quick germinating grasses such as rye and oats can be used to stabilise soil until slower growing plants can be established. This method is only effective after the grass seeds have germinated and established a root structure.

Semi permeable paving can be used to stabilise areas of the site. Avoid excessive use of hard surfaces that prevent stormwater being absorbed. [See: 7.5 Stormwater]

Biodegradable erosion control mats are useful when revegetating steep slopes.

Integrate landscaping strategy with sediment control. For example, diversion channels and trenches that filter sediment can be used with rubble in the base to create a deep root planting opportunity.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on sediment control. www.gov.au

BEDP *Environment Design Guide*
DES 52 Erosion and Sediment Control

Housing Industry Association, *Site Management Guide For Residential Builders.*
www.hia.com.au/hia/channel/Builder/region/National/classification/Greensmart/Resources.aspx

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Challenging Sites

A challenging site sets particularly stringent constraints on the design of your home. The conditions that provide those constraints may include both physical and social factors. This fact sheet outlines a number of strategies and techniques available to address the design challenges of constrained sites.

It may be preferable not to build on a challenging site because of the environmental impacts that result from site constraints. On the other hand, such sites often provide exciting opportunities for creating a sustainable home and are worth investigating.

The design and construction of a home for a challenging site raises three questions:

1. What are the characteristics of this type of site?
2. What difficulties does this type of site create for the homeowner, builder or designer?
3. What principles can assist in addressing these difficulties in order to reduce environmental impacts?

Delivering sustainable outcomes

This is about examining ways to deal with difficult constraints whilst minimising environmental impacts.

The following constraints provide a useful starting point:

> **Structural** – topography, natural and artificial structures.

> **Environmental** – climatic, health, visual and acoustic parameters.

> **Spatial** – size, shape and volume.

> **Location** – remoteness, proximity, servicing.

> **Ecology** – ecological value, landscaping.

STRUCTURAL

Structural constraints apply to the physical factors of the site that include topography, natural and artificial structures.

Topographic conditions relate to geological conditions that have been created over time. Three key factors are:

> Site slope (fall).

> Ground conditions.

> Storm water run-off.

Site slope

A steep site generally has a gradient in excess of 30°. The slope of a site has an impact on the type of home that can be built, ie flat land house types (slab on ground) are good for flat sites whilst hillside houses (such as pole framed houses) match steep sloping sites. This typology aims to minimise the amount of cut and fill needed to accommodate the slope. The slope may also be non-uniform with some parts steeper than others, sometimes with a cross fall with the slope running diagonally across the site. Steep sites require careful consideration of the contours for an appropriate design response.

Three environmental strategies often used on steep sites are to:

> Balance cut and fill.

> Avoid retaining wall being higher than one metre.

> Build along contours.

Ground conditions

Ground conditions influence the type of foundations and disturbances to the site. Different soil conditions present different constraints dependent on the design requirements for rock, sand, clay or wetlands.

The most challenging and difficult ground conditions are clay and wetlands due to the instability associated with the conditions found where sites contain this type of material. Rock on the other hand presents the most stable ground condition but large environmental penalties occur with building basement structures in these conditions.

Storm water run-off

Steeply sloping sites increase storm water run-off both above and below the surface. This can create a major constraint on building and consideration needs to be given to both the site slope and ground conditions in relation to the hydrology.

Strategies for environmentally responsive design include:

> Directing storm water run-off to appropriate destinations.

> Collecting and utilising run-off for landscaping.

> Minimising interference with sub-surface hydrology.

Early identification of artificial and existing environmental effects is crucial.

Artificial structures on or below the site ground level are best identified early in the site selection and site analysis phase. The consequences of artificial structures can be as important as for pre-existing natural structures. In particular this includes environmental issues such as waste, pollution and services whether subsurface or overhead. Costs of mitigating existing environmental conditions can create an unintended design challenge; early identification is critical for effective site planning and later construction work.



Hillside housing offers its own challenges.

ENVIRONMENTAL

Environmental constraints result from the variability of a site's biophysical conditions and include climatic, health, visual and acoustic parameters.

Four main environmental strategies apply:

> Undertake and integrate climatic analysis in site selections and site planning.

> Look for positive local effects of the 'mesoclimate' – eg. nearby hillsides to the west providing shade from the late afternoon sun.

> Set priorities for key environmental factors such as solar access and air flow that can generate solutions.

> Address environmental problems at source where possible rather than on the site.

Exposure to extreme climatic elements occurs where the site is directly affected by the full force of wind, water and sun (macro climate conditions) without moderation from the structural constraints described above (ie local topographical or artificial structures). Opportunities exist to address the constraint by careful examination of the meso and microclimate of the site, and by studying the local history of extreme weather conditions.

Vulnerability of the site to extreme conditions can create a significant impact on site planning and building location. Life threatening events such as flooding, storm damage (adjacent trees) and fire create measurable risks. Minimising risks involves careful site planning and ongoing maintenance. Sites that are exposed to 100 year flood levels as well as storm and fire paths, should be identified and planning measures adopted.

The mesoclimate is the resultant modification of the regional climate by topography and other local conditions. There are five main mesoclimates:

> Coastal – sea breeze/land breeze effect, which moderate regional extremes; storm exposure is an important consideration.

> Flat open country – subject to accelerated wind speeds, minor changes in topography can have significant effects.

> Woodlands and forests – differential solar access and airflow, higher humidity.

> Valleys – differential solar access and temperatures dependent on location and elevation.

> Cities – elevated ambient temperatures, differential solar access and airflow, increased turbidity.

Challenging sites occur where the topography and other factors negatively impact on the climate – eg. reducing the effects of natural heating or cooling. Where two mesoclimates overlap, for example cities in coastal areas, the benefits of one can be negated by the other.

Microclimate conditions are the effects of local and adjacent structural conditions on the mesoclimate conditions of temperature, humidity and airflow. Challenging sites occur where these microclimate conditions negate climatic effects used in passive design. For example when adjacent buildings overshadow the site and limit solar access in winter.

Other environmental parameters (health, visual, acoustic).

These include identification of excessive noise, pollution and smells. Identification of these parameters can be difficult as the phenomena may be intermittent, for example noise from an air conditioner may only occur during hot nights, air pollution may only occur with a particular wind direction.

SPATIAL

Spatial challenges occur when there is not a proper fit between the size, shape or volume of the block, the building program and environmental factors. Strategies to address spacial challenges include:

> Keeping the building footprint to 50 per cent of the site area.

> Make every metre count for greater planning flexibility.

> Consider the building as a 'volume' on a tight site.

> Consolidate blocks rather than undertaking subdivision.

Shape of block

The subdivision of land for building in Australia usually results in rectangular blocks of land. Non-rectangular geometries of small area are often constraining. These often result from subdivision of an existing block into two blocks.

'Setbacks' are the clearances between the site boundary and the building walls required by planning rules – creating non-orthogonal geometries on a block and preventing construction in those areas. 'Setbacks' constrain the height and location of walls above the ground and have a profound influence on the building volume and spatial configuration.

A 'tight site' is where there is little flexibility in the fit. The shape of the block and the building program determines building responses and environmental factors. This can lead to the need for specific design solutions to overcome issues of poor orientation, circulation and access (See Howard Street case study at the end of this fact sheet).

Options to be considered for mitigating the effects of a tight site include:

> Reducing the physical building footprint.

> Increasing the number of building levels.

> Consolidating blocks.

A way of increasing plan flexibility with tight sites is to reduce the ratio of the building's ground floor area to site area (building footprint). Effective planning that eliminates waste space helps to optimise a building's footprint. Increasing the number of storeys reduces the building footprint on the ground and releases site area allowing optimisation of orientation, circulation and access. Where these measures fail, it is often better to consolidate blocks to make a larger spatial context.

LOCATION

Location challenges occur when remoteness, proximity and servicing become design constraints. Remote sites may have limited access to building services (gas, water, electricity and waste disposal) and to other networks such as road, rail, bus and pedestrian mobility. A significant constraint on the design of a sustainable home may result from it being located in a protected area.

Remote sites are those located at a distance from main population centres which creates challenges for the supply of materials and services. Increased energy is required for transportation of construction materials, and the availability of skilled tradespeople is often limited.

Services accessibility

The lack of access to services leads to greater reliance on building autonomy and the need to provide services on site. Additional technologies for water, energy and waste disposal are needed on site. Ironically this can lead to a better environmental solution.

Pedestrian and vehicular access

Challenging sites may prevent easy access of vehicles and pedestrians. On sloping sites this can involve steep access roads or large amounts of cut and fill to gain access. Access for disabled pedestrians requires a slope of no more than one in one so steep sites may need excessively long ramps for access. Provision of a lift may be a cost-effective option in these situations.

ECOLOGY

Site ecology constraints include issues of ecological value and landscaping and arise from the challenges of dealing with the interrelation of living organisms on a site where humans are one of the resident species. Flora and fauna studies are needed when sites may have high ecological value and endangered or unique species are part of the habitat of the site. How to restore ecological value can become the primary challenge.

Environmental strategies for changing sites with high ecological values include:

> Establishing a habitat conservation area.

> Monitoring ongoing impacts of construction.

> Monitoring activities that may disturb the habitat.

Habitat conservation

Maintaining existing habitats is a central issue on sites with high ecological value. This involves establishing an inventory of existing species and examining impacts of site planning on the species distribution and viability of habits. Establishing areas for habitat conservation becomes a central strategy, in which case it becomes crucial to reduce the noise and light pollution impacts of the home on these areas.

[See: 2.5 Biodiversity On-site]

Restoring ecological value

The process of subdivision often results in the removal of existing flora and fauna. Inner-city sites rarely contain even remnant vegetation. Measures to restore ecological value are then needed. Reintroducing the local gene pool of the soil is an imperative. If the soil from the site's clearance has been stored it can be reintroduced across the site. Consideration of subsurface and surface hydrology is needed to re-establish catchments and enhance catchments of water flow across the site. Depending on the site, the creation of wildlife pathways can allow animal movement across blocks and provide flora food sources for both humans and native animals.

Challenging sites occur where there is little ecological value or pre-existing ecology has been destroyed. Increasing the ecological value of the site as part of the landscaping plan is an obvious strategy. Such a strategy is particularly applicable to inner-urban sites. Strategies that increase biodiversity range from restoration of indigenous species to the establishment of permaculture gardens. [See: 2.4 Sustainable Landscapes]

ADDITIONAL READING

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Hyde, R (2000), *Climate Responsive Design*, Spon Press, UK.

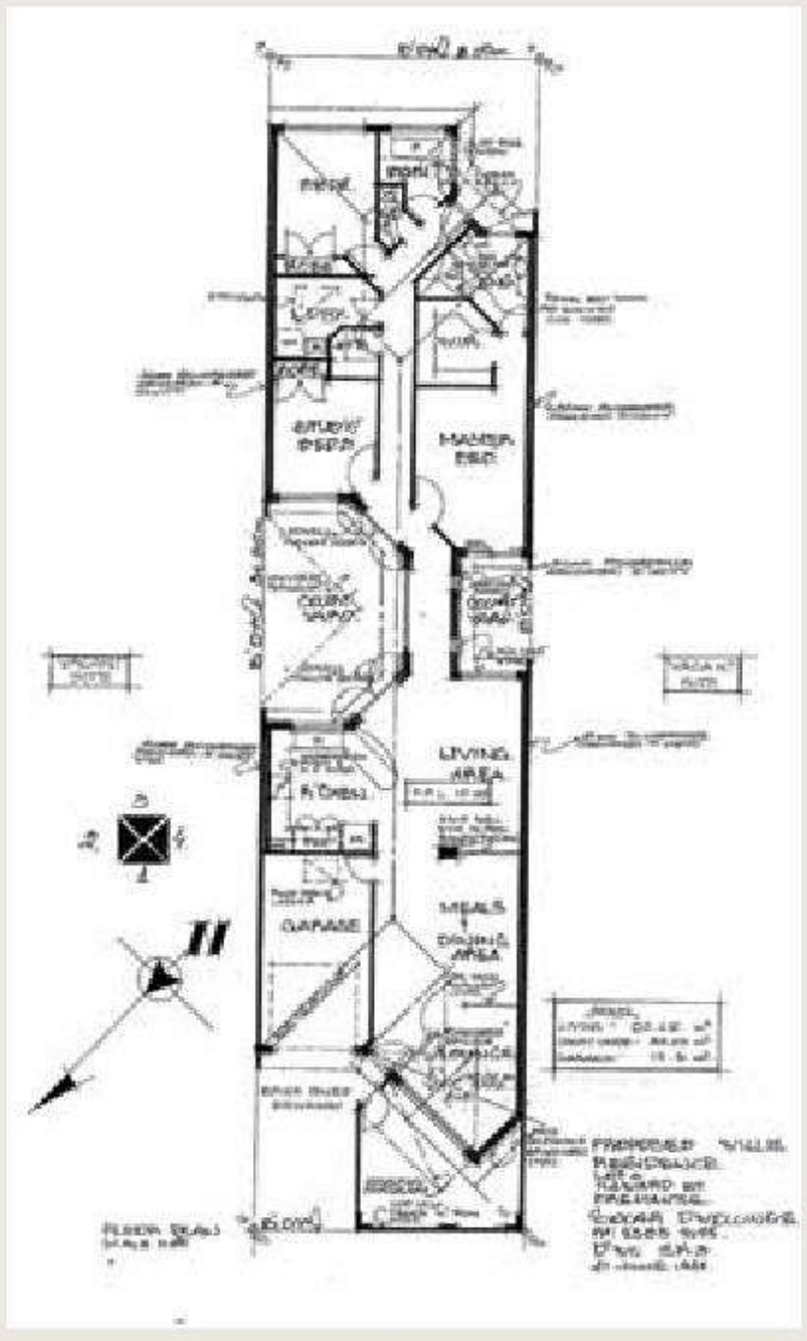
Hyde R, Watson S, Cheshire W and Thompson M (eds) (2007), 'Green Globe Design and Construct Standard' in *The Environmental Brief*, Routledge, UK.

Principal author:
Richard Hyde
Catherine Watts

Case Study: Howard St Fremantle, WA

The brief was to design a passive solar, energy efficient home on a tight, urban infill block. The long narrow block with an 8m frontage, was orientated 45° to north, with the northern façade facing the street and garage access only possible to the front. Solar access was compromised due to an existing two story neighbouring building and the block was bordered high parapet walls on both sides. The brief posed quite a challenge for the designer.





To overcome the obstacles the front living room wall of the home was angled to face directly North and a saunders ceiling with tapered ranking gable windows was incorporated to increase solar access. Air volume was minimised and thermal mass introduced on the floor and vertical internal walls. This ceiling and window configuration effectively almost doubled solar heat gain, which is then able to be stored in the vertical thermal mass.

Two internal courtyards were introduced to allow further solar gain. Combined with carefully selected shading for summer protection the courtyards also assist with airflow in summer to naturally cool the home.

Source: Solar Dwellings – Energy Efficient Homes

Design for Life

Sustainability does not only relate to the environment, it is also about the community, future generations and the quality of life for individuals. Design for Life involves designing or renovating your home for the present but also ensuring it is adaptable to opportunities and challenges that may arise in the future. Considerations such as safety, security, changing lifestyle choices and responses to natural disasters are all important for the long term viability of your home.

This section contains detailed information about:

> The Adaptable House.

> The Healthy Home.

> Safety and Security.

> Bushfires.

3.2 THE ADAPTABLE HOUSE

An Adaptable House is one which is able to respond effectively to changing household needs without requiring costly and energy intensive alterations. The average household is becoming both smaller and older and an increasing number of people are living independently in their later years.

The balance between home and work also places altering demands on our houses as many people choose to work from the office. A single space may act at different times as a nursery, home office, teenage retreat, study or bedroom for an elderly relative.

Designing an Adaptable House would consider the following:

> Easy entry and access from both street and car parking in all weather and light conditions including appropriate layout for garbage cans, garden beds and letterboxes.

> The interior of the house would allow for easy movement between spaces, for example, through slight widening of internal doors and passageways.

> The kitchen should not limit a person's independence for example, lower workspaces to accommodate wheel chair users or non-slip floor finishes.

> At least one bedroom should be accessible to family members who may experience physical limitations.

> In multi-level housing, accessible living spaces should be provided on the ground floor.

3.3 THE HEALTHY HOME

This fact sheet discusses the likely sources of indoor air pollutants and possible associated conditions. It also provides guidance when considering a new build or renovation.

Common sources of indoor air pollutants include:

> Building operation and construction material (eg lead, aesbestos, combustion systems).

> Household products (eg sprays, polishes, air freshners).

> Human indoor behaviour (eg passive smoking, interaction with pets).

There are many ways to manage indoor air quality issues in the home. This fact sheet provides further guidance.

3.4 SAFETY AND SECURITY

Many domestic accidents can be prevented with better building design. Most domestic accidents occur in the bathroom and kitchen. There are many actions that you can take to improve home safety through design, fittings and behaviour. The actions contained in the fact sheet particularly seek to protect children, the elderly and the disabled.

Safety tips include:

> Round bench edges and corners.

> Eliminate cross-traffic routes through the work triangle (area between stove, sink and refrigerator).

> Use slip resistant flooring and avoid steps in bathrooms.

> Install fail-safe mixing valves on both the bath and the shower.

> Ensure that privacy locks on bathroom doors can be opened from the outside in the case of an emergency.

> Provide energy efficient outdoor lighting along paths.

Security measures such as those promoted by 'Crime Prevention Through Environmental Design' can be followed to ensure peace of mind when at home or when away. Security can be improved through maintaining the integrity of doors, windows, sky lights and roofing; through landscaping that avoids dark corners and hidden recesses and provides an open interface with the street and through community surveillance.

3.5 BUSHFIRES

The potential for bushfires is an integral part of Australia's bushland. The functioning of our natural environment requires and accommodates fire. Therefore, buildings sited in this environment similarly need to cope with fire.

Consider the following when designing for a bushfire resistant property:

> Preventing fire ignition sources.

> Avoiding fuel load that could contribute to spread or intensification.

> Creating fire barriers that permit safe movement for people and reduce fire advancement and propagation.

> Creating site surroundings and using construction elements to reduce fire load on buildings.

Meeting the specifications for bushfire resistance can be at odds with some sustainability goals. Environmental design emphasises the use of local materials with low embodied energy and toxicity and high recycled content. Meeting bushfire needs can call on different priorities. For example, recycled timber often does not meet non-combustion rating requirements, fire resistant paint embodies toxins, steel and other non-combustible components have high embodied energy. This fact sheet provides further guidance on design decisions for bush-fire prone areas.

Principal author:
Ramola Yardi

The Adaptable House

A HOME FOR CHANGING NEEDS

An Adaptable House is one which is able to respond effectively to changing household needs without requiring costly and energy intensive alterations.

When building a new house many people anticipate spending a number of years, if not decades, living in their home. Others may conceive of a shorter stay. Whatever the intention, any new home is likely to have to accommodate changing needs over its lifetime.

Australian demographics are changing rapidly with average households becoming both smaller and older, with an increasing number of people living independently in their later years. The balance between home and work life also places altering demands on our houses as many people choose to work from home offices. A single space may act at different times as a home office, a teenage retreat, a family study or a bedroom for an elderly relative.

An Adaptable House accommodates lifestyle changes without the need to demolish or substantially modify the existing structure and services.

Similarly, an adaptable dwelling might be designed to easily enable a reduction in size over time through the division of a large family home into two smaller housing units, offering residents the opportunity to continue living within a familiar environment.

Household needs vary over time in relation to physical capabilities. Everyone can expect to experience temporary or permanent variations in their physical capabilities in their lifetime due to injury, illness or age. The Australian Bureau of Statistics reports that the percentage of individuals with a disability increases significantly with age, rising to more than half for people aged over 60. Due to longer life spans and higher proportions of older people in our society, it is more likely that every home will be required to respond to the needs of a person with a physical limitation whether they are a primary resident or visitor.

For those with limited mobility, reduced vision or other disability, the ability to perform common tasks such as carrying shopping into the home, cooking a meal, using the bathroom or accessing items from high shelves may be unnecessarily limited by the physical design of a home. As the needs of individuals are specific to their personal circumstances there is no single solution to designing for an aging or disabled occupant but a number of design approaches exist:

1. The 'Universal House' which is usable by as many people as possible without the need for specialisation.
2. The 'Accessible House' which meets the Australian Standard AS1428.1-2001 Design for Access and Mobility and is able to accommodate wheelchair users in all areas of the dwelling.
3. The 'Adaptable House' which adopts the idea of a 'Universal House' and in addition is able to be easily adapted to become an 'Accessible House' when required.

THE UNIVERSAL HOUSE

Universal design has been defined as the design of products and environments so that they are usable by all people, to the greatest extent possible, without the need for adaptation or specialized design. The intention being to simplify life for everyone by making more housing usable by more people at minimal extra cost.

A Universal House uses building features, fittings and products in combination to increase usability, benefiting people of all ages and abilities. For example, a doorway or passageway is more easily navigated by users of mobility devices such as walking frames, wheelchairs or even a children's pram if it is slightly wider than typical.

With regard to fittings, people with limited hand function find screw-type sink taps more difficult to use than lever-type taps which can be used by everyone. A similar benefit is found in using lever-type door handles and rocker electrical switches; incorporating the most usable fittings at the time of construction reduces the need for later retrofitting. A Universal House will ensure rooms and services within the home are of a size and type which is usable by as many people as possible.

When homes are retrofitted with ramps, handrails, and other devices to provide enhanced usability an institutionalised appearance can result. Universal design does not propose special features for the aged or disabled but instead promotes normalised solutions to access and usability for the majority of people through the use of standard building products and practices. For example, designing an entry without the need for steps removes the need for the later addition of a ramp and handrails for wheelchair users, while improving current access for children's prams.

THE ADAPTABLE HOUSE

In addition to being designed to be usable by most people, the Adaptable House has provision for additional modifications should they be required to meet the specific needs of an occupant. This may include the modification of kitchen joinery to meet changing physical needs, alterations to the laundry and bathroom to increase access and usability, the increase of lighting levels in response to sensory disability or the introduction of support devices such as grab rails and/or additional security measures.

Australian Standards provide guidance for designing houses to accommodate varying degree of physical ability over time.



A typical house plan (above) often requires the expensive relocation of wet areas such as bathrooms and kitchen if the house is to be extended.



Another floor plan (above) provides larger wet areas for improved accessibility, and these wet areas are located to allow for future extensions with only minor changes to the existing dwelling.

Starting with the requirement that all houses are accessible to visitors using wheelchairs these standards then require the house to be able to adapt, becoming accessible to an occupant using a wheelchair. Although the need to accommodate a wheelchair user is unlikely to be experienced in every home, space requirements are set for wheelchair use as they represent the most difficult scenario for circulation and access. By providing enough space for wheelchairs, people with walking frames, children's prams, trolleys and other equipment can be better accommodated.

AS4299 recommends that adaptable features designed into a dwelling be documented with 'before' and 'after' drawings clearly demonstrating the features which have been included. This avoids the reliance upon recollection and enables the information to be readily passed on to contractors or subsequent owners. Compliance with this standard enables a design to be certified as an Adaptable House, clearly identifying and recognising its adaptable features. Whether or not a designer is seeking certification, this document provides useful information.

BENEFITS TO THE OWNER

The Universal House and the Adaptable House remain appropriate to occupant needs over a greater period of time. This reduces the need to relocate to alternative housing which can lead to dislocation from existing community ties. They are also attractive housing options for the greatest number of people and therefore provide a sound investment for resale and rental.

Design for adaptability enables rapid response to changing life needs which can be quick and unexpected. It also increases the building's serviceable life span prior to remodelling, with associated financial, energy and material savings.

DEVELOPING A DESIGN

In the early stages of designing a new house or renovation consider what type of use may be desirable and discuss your choices with your architect, designer or builder. Consider:

> Is it likely that the house will be extended in the future?

> How might the use of space change over time?

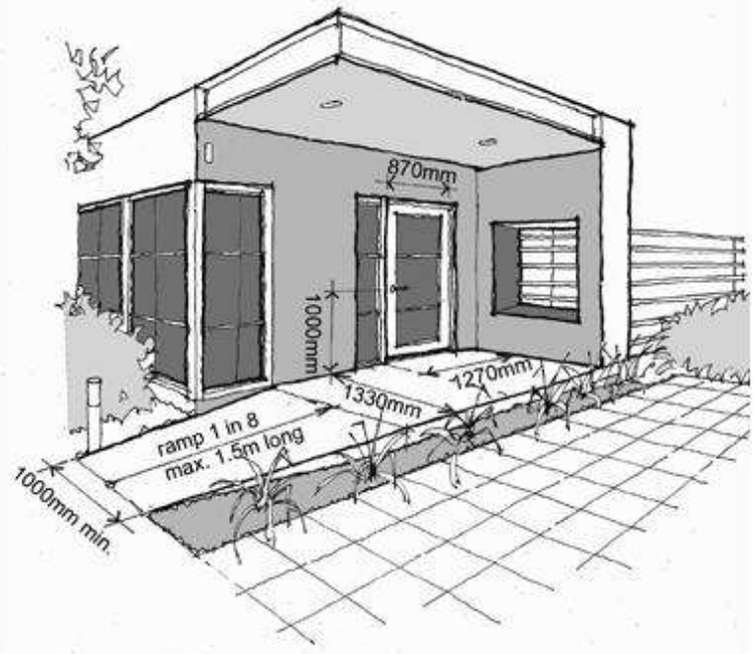
> Is it desirable for the house to be visitable by elderly or disabled friends and relatives? (if yes, then ask your designer to adopt the Australian Standard for Adaptable Housing)

> Is it desirable to make provisions for the future accommodation of an ageing or occupant or one with a disability? (if yes, then ask your designer to adopt the Australian Standard for Adaptable Housing)

Adaptable housing solutions can also be considered in smaller projects.

Minor alterations to bathroom or kitchen plans can integrate many desirable adaptable housing features with minimal additional cost, making significant savings when adaptations are required in the future.

The following section provides initial advice as to how spaces within and around a home may begin to accommodate both universal and adaptable housing principles. Essential features prescribed by the Australian Standard for Adaptable Housing (AS:4299) and required dimensions set by the Australian Standard Design for Access and Mobility (AS:1428) may vary over time as these documents are periodically revised.



ACCESS AND ENTRY

An Adaptable House should:

> Provide easy access from both the street and car parking spaces in all weather and light conditions.

> Avoid stairs and use ramps only where essential.

> Dimension both ramps and stairs in compliance with AS:1428.

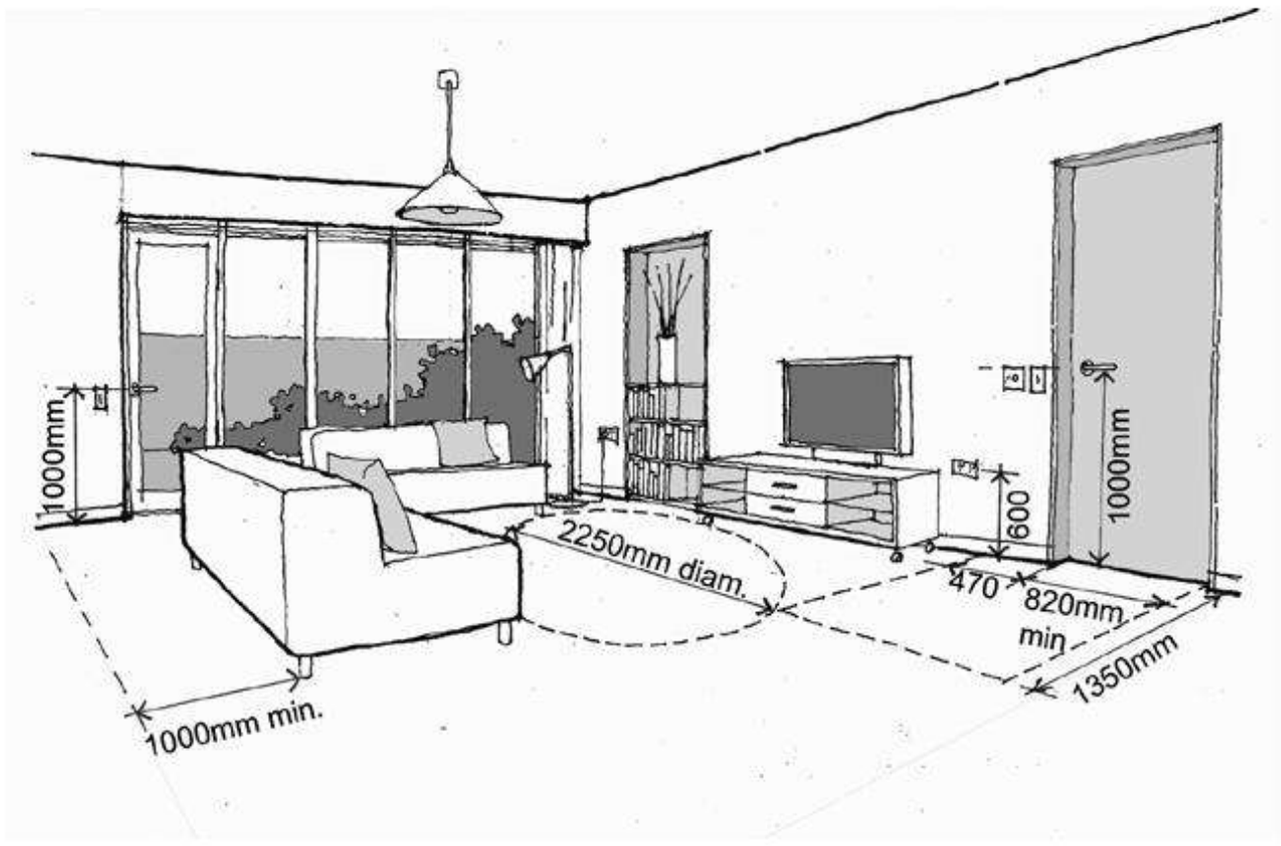
> Construct access paths from well drained, solid, non-slip surfaces that provide a high colour contrast to surrounding garden areas.

> Light pathways with low level lighting directed at the path surface, not the user.

> Protect paths and entries from weather.

> Avoid overhanging branches and plants which may drop leaves causing potential hazards.

For security, the house entrance needs to be visible from the entry point to the site or the car parking space. The entry itself should provide a level, sheltered landing dimensioned for wheelchair manoeuvrability and be adequately lit for visibility from inside the home. Entry door locks and lever handles should be fitted at appropriate heights and be able to be used with one hand. Avoid any obstructions or level changes which limit access by a wheelchair user or provide a tripping hazard to others.



INTERIOR – GENERAL

The interior of a house should allow easy movement between spaces. Often, this simply involves a slight widening of internal doors and passageways. Ideally, easy access should be provided throughout the entire home but it may be considered necessary only in some portions of the home such as between living spaces, kitchen, bathroom and one bedroom.

Internal doors with a minimum unobstructed width of 820mm and passageways with a minimum width of 1000mm are appropriate but any additional width is beneficial. Doorway width is measured from the face of the open door to the opposite frame. Circulation space around doors to allow wheelchair access is required, with special attention given to providing enough space to reach and operate the door lever. As door types and room configurations vary, reference should be made to AS:1428 for dimensions.

Electrical outlets are best located at a minimum of 600mm above the floor. For light switches and other controls the ideal height range is 900-1100mm. The use of two way light switches at each end of corridors and where spaces have more than one entry is desirable. Lighting design needs to respond to the specific uses of different spaces with an even distribution of light to avoid shadows and light fittings located over work surfaces where specific tasks are undertaken. It is advisable to ensure that lighting can be adapted to provide higher lighting levels when required due to visual limitations.

Window sills should be low enough to allow unobstructed views to the exterior from standing, sitting and lying positions where appropriate. Where different floor surfaces meet these need to be level and fitted with appropriate cover strips to avoid tripping.

LIVING SPACES

Living spaces should be comfortable and accessible to all residents and visitors. To accommodate a range of activities and tasks it is advisable to install thermal conditioning and services to suit a variety of furniture layouts. Australian Standards recommend:

> A minimum of four double electrical outlets.

> A telephone outlet adjacent to an electrical outlet.

> Two TV antennae outlets, all located at appropriate heights.

> Clear circulation space within the room of at least 2250mm diameter for wheelchair manoeuvrability.

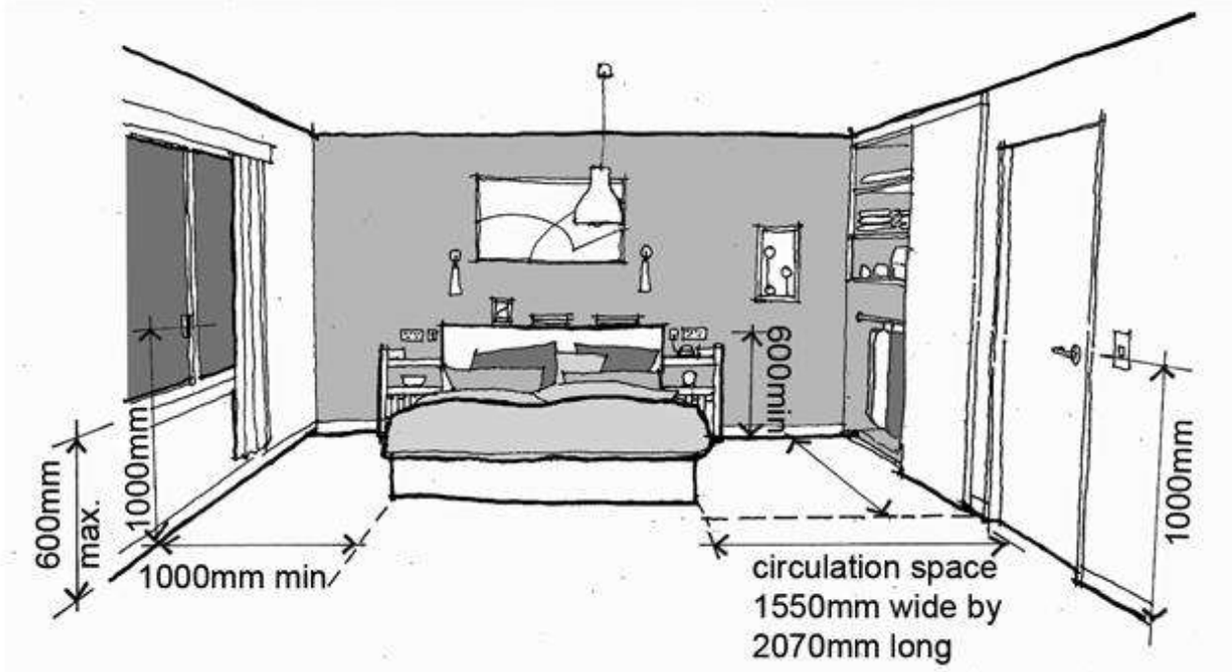
In homes accommodating an elderly or disabled resident it is advisable to provide an additional living area separate to the bedroom and main family areas which provides an opportunity for personal space. This may be located inside or outside the home in an area protected from weather.

COOKING SPACES

As a person's physical abilities change over time the kitchen is one of the main rooms in the house where the impact of physical limitations is felt. Detailed documentation for designing kitchens and joinery for wheelchair users is widely available, however even among wheelchair users people's maximum reach and strength vary greatly, as do kitchens designed specifically for individual disabled users. The design of a kitchen should not limit a person's independence and ought to be adaptable to accommodate specific individual's needs.

To accommodate a wheelchair user or other seated occupant, portions of the work surfaces should be constructed at a lower level than those for standing users with leg room provided under work benches. To enable such changes to occur easily kitchen joinery can be installed using modular components which allow for easy removal or modification of individual components rather than the reconstruction of the entire joinery layout. Such components should be installed after the non-slip floor finish is completed to avoid replacement at a later stage.





Depending upon the user either top or front loading laundry appliances may be preferred. In either case, provide:

> A minimum circulation space 1550mm deep in front or beside appliances.

> Taps located to the side, not the back, of any laundry tub.

> Sufficient storage shelves at a maximum height of 1200mm.

Access to external drying areas should consider mobility issues and the need to use clothes baskets and trolleys.

The kitchen should also be designed with safety considerations in mind including:

> Location of appropriately sized work spaces to the side of all appliances such as the cooktop, oven, microwave and refrigerator.

> The relationship between the cooktop and the sink to allow easy transfer of pots for draining.

> Contrasting colours between bench tops and cupboard fronts to assist the visually impaired.

SLEEPING SPACES

At least one bedroom in the house should be accessible to a person using a wheelchair and be sized to enable manoeuvring within the space. The location of an accessible bedroom should take into account who is likely to use it, be it a family member with a temporary physical limitation, visitors of various abilities or an ageing resident. Additional services such as two way light switches, telephone outlet, additional electrical outlets and TV outlet are recommended to ensure maximum usability and security.

WET AREAS

In the design of all wet areas such as toilets, bathrooms and laundry, ensure:

> Adequate sizing for access and circulation.

> Location of storage for easy and safe use.

> Installation of non-slip surfaces to minimise accidents.

At the time of construction either an accessible or visitable toilet should be included for use by visitors. If possible, include a bathroom that provides full accessibility for a wheelchair user, ensuring the bathroom and toilet are able to be used by residents with limited mobility or with the assistance of a carer.

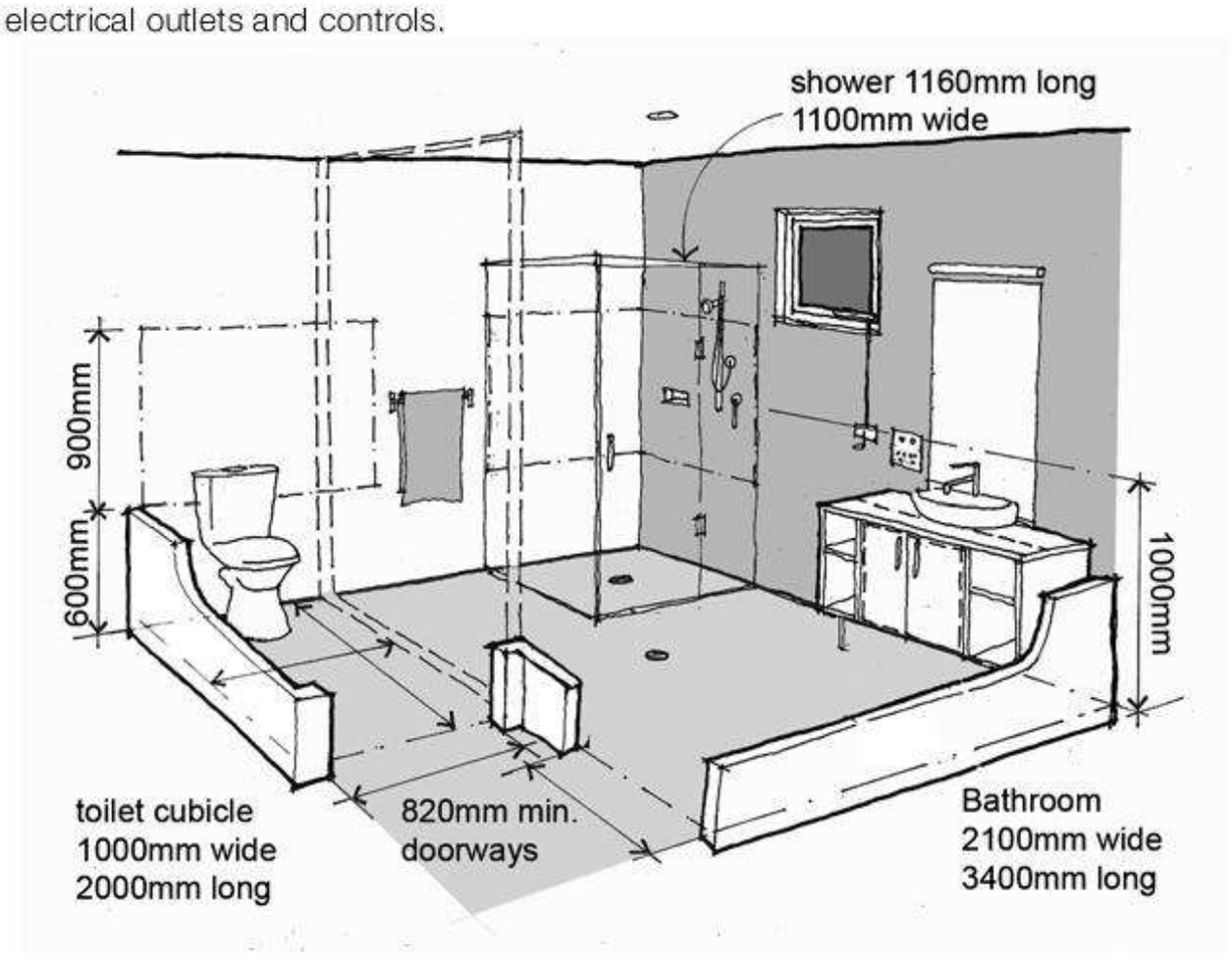
If separate bathroom and toilet facilities are preferred at the time of construction an adaptable approach might be taken to achieve the same outcome, such as the use of a removable wall between the toilet cubicle and bathroom. To reduce the amount of work required at adaptation such a wall should be installed as a non-load bearing partition after the floor and wall finishes are completed. Similarly, any items such as vanity cupboards, toilet bowls, or shower screens which may require relocation or modification should not be constructed integral with the initial construction but installed as removable fixtures after all surrounding surfaces are completed.

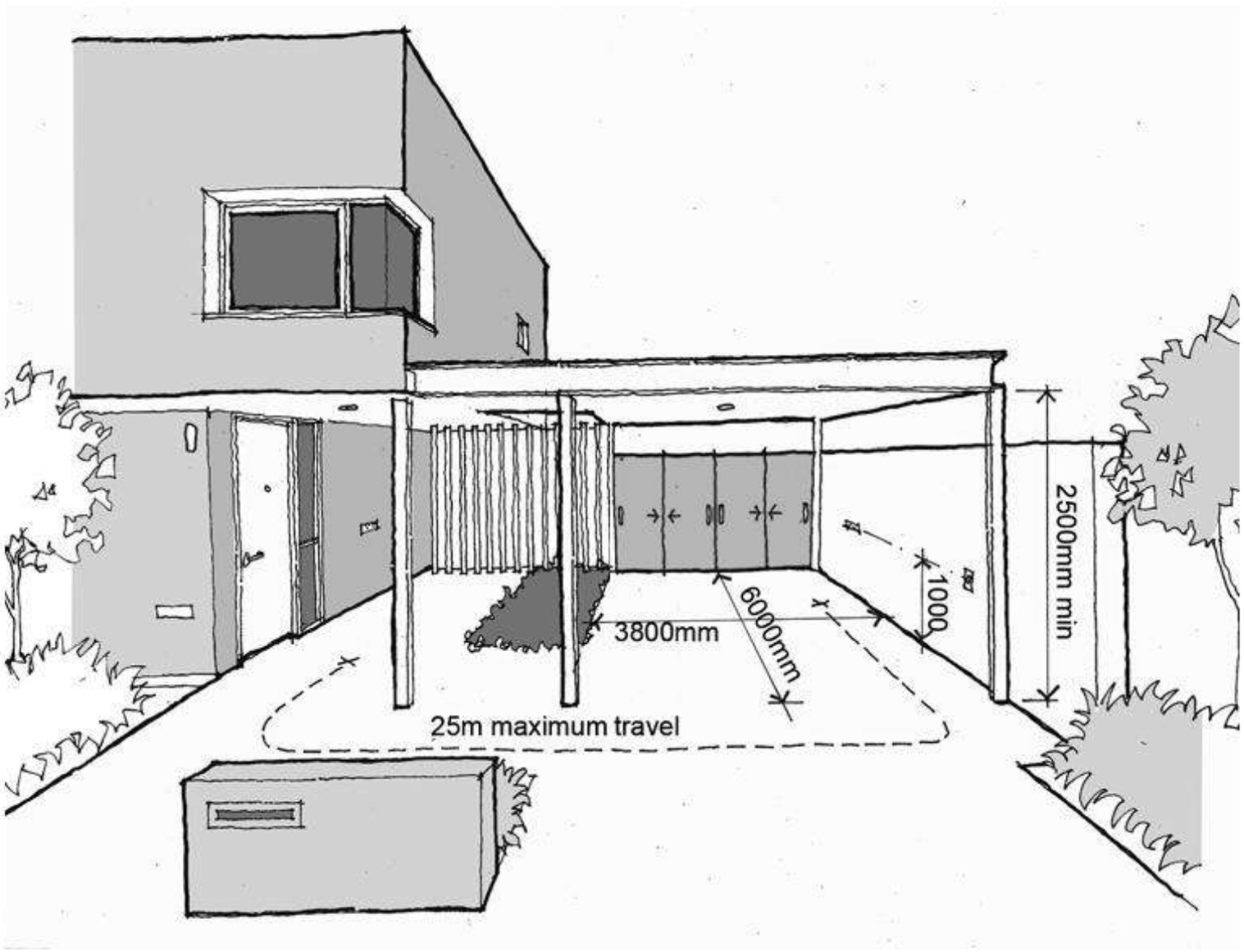
One of the most common adaptations employed in residential bathrooms is the installation of grab rails to provide support and stability. So that these can be installed without the need to demolish sections of wall to insert support points it is recommended that 12mm structural plywood be fixed to any stud wall framing behind the finished wall materials. When designing a bathroom remember it may be used by people either standing or seated, as this will inform leg space around hand basins and the location of items such as mirrors, electrical outlets and controls.

MULTI-LEVEL HOUSING

Although single level homes seem an obvious choice for accessible housing, two or more storey houses and apartments can also be suitable for adaptation. The ground floor of a multi-level house can be accessible to visitors with a disability or even accommodate an occupant with a temporary disability. In addition to providing access between living, kitchen and bathroom spaces, the inclusion of an accessible bathroom and a space appropriate for use as a bedroom on the ground floor ensures maximum flexibility.







To facilitate multi-level access, floor plans should allow for the future installation of vertical lifts or staircase lifts. A future vertical lift requires space for a hole through each floor adjacent to circulation space on all levels – initially the hole in the upper floor can be filled in or the space can be utilised for storage until adaptation is required. A stair lift requires ample space on top and bottom stair landings.

SITE

Activities such as mail collection, rubbish storage, car parking and enjoyment of outdoor spaces must also be considered in designing for full accessibility:

> Make rubbish bins and recycling storage, letter boxes, clotheslines and garden tool storage accessible via paths, as described under 'Access and Entry'.

> Provide access and circulation space to external occupied areas such as patios and terraces as described in 'Living Spaces'.

> Provide private, sheltered areas with access to northern sun in winter that is visible from inside the home.

> Allow for raised garden beds for elderly or disabled gardeners in the initial garden layout.

> Locate car parking close to the entry with at least one covered parking space sized to enable wheelchair access.

> Make garage doors electronically operated.

> Allow future secure space for storage and recharging of a wheelchair or other mobility device such as a scooter.

> Ensure that garden and fence layouts do not compromise security by limiting visibility through the site.

> Ensure that house or unit numbers are clearly visible from the street.

> Use movement activated sensor lights.

ADDITIONAL READING

Australian Standards
AS4299-1995 Adaptable House.
AS1428.1-2001 Design for Access and Mobility.

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Principal authors:
Jasmine Palmer
Stephen Ward

The Healthy Home

Most of us spend more than 90 per cent of our lives indoors. It is worth thinking more closely about air quality in our homes. This fact sheet discusses the likely sources of indoor air pollutants and the possible associated health conditions. It provides advice and actions that you can take to protect the health of people living in your home. This fact sheet will also help you make better-informed decisions about health and indoor air quality issues when discussing a new build or renovation with your architect, designer, builder or building material supplier.

An ounce of prevention is worth a pound of cure.



INDOOR AIR QUALITY AND HEALTH

Poor indoor air quality may cause a range of health effects from mild and generally non-specific symptoms such as headaches, tiredness or lethargy to more severe effects such as aggravation of asthma and allergic responses. Most of these conditions can also arise from a number of different causes other than the quality of the air in your home.

Consult your doctor if you are concerned about any of these health conditions.

Whether a source of air pollutants causes an indoor air quality problem or not depends on:

> The type of air pollutant.

> The amount and rate at which it is released from its source.

> The degree of ventilation available in the home to remove it from indoors.

Common sources of indoor air pollutants include:

> Building operations and construction materials.

> Household products.

> Various human indoor activities.

> External factors (from outdoors).

A person is most commonly exposed to air pollutants when they breathe in an air pollutant or allergen. Exposure to an air pollutant by swallowing or through the skin may occur in some circumstances. The body has a range of defences against airborne substances (eg skin, liver, immune system). Some defences keep substances out of the body; others overcome substances once they enter the body.

What you do in the home can make the single biggest difference to the health of the indoor environment. eg. avoid smoking indoors, don't let dust build up, don't leave the car running in the garage and be wary of all fumes – if it smells bad it probably is!

Generally, the greater the amount of pollutant (exposure), the greater the health response. The duration of exposure is also important. If low-level exposure occurs over a long period of time (perhaps many years), the total dose may be large.



Some groups of people in the community are more vulnerable to pollutants than others. These include:

> The very young.

> The very old.

> Those with pre-existing respiratory or cardiovascular disease.

> Those who are sensitised to a substance.

> Some of these groups are also more likely to spend more time indoors than the general population.

Before jumping to conclusions about whether or not your home is making you ill, look for clues and patterns, such as:

> Do you notice any change in your health before and after a particular change in the home environment?

> Is there any change in your health after particular activities, like dusting or cleaning?

> Do your health problems occur at the same time each year?

> Do your health problems get better if you and your family are away from home for any extended periods, such as holidays?

POTENTIALLY HAZARDOUS AIR SUBSTANCES

There are many different types of airborne substances. Exposure to most substances indoors is generally low and of little or no health consequence. This section summarises some important types of pollutants and allergens that might be found in Australian homes.

POLLUTANT	MAJOR SOURCE(S)	HEALTH EFFECTS
Nitrogen dioxide	gas combustion	chronic respiratory disease
Carbon monoxide	kerosene, gas and solid fuel combustion, cars idling in enclosed garage, cigarette smoke	aggravation of cardiovascular disease, poor foetal development
Formaldehyde	pressed wood products, consumer products, hobby, crafts	eye, nose and throat irritation
Volatile Organic Compounds (VOCs)	new building products, cleaning products, office equipment, consumer products	eye, nose and throat irritation, headache, lethargy
Passive smoke	tobacco smoking	eye, nose and throat irritation, aggravation of asthma, chronic respiratory disease, lung cancer
House dust mite allergens	dust mites in bedding, carpets, furniture	aggravation of asthma, nasal inflammation, eczema
Mould spores	bathrooms, damp rooms, window sills, indoor plants, poorly ventilated areas	aggravation of asthma, nasal irritation and inflammation
Lead in indoor dust	pre-1970s paint, hobbies and renovation	poor childhood intellectual development
Pet dander	cats and dogs	aggravation of asthma and hay fever

Lead

Lead is a concern when small particles or fumes are swallowed or inhaled. Many older building and household products contain lead but newer products no longer do. Items such as old paint, flashing, old plastic pipe and, fittings, electrical cabling and glazed pottery can contain variable amounts of lead.

Contact with lead can arise from home renovation activities, particularly when stripping old paint, through some hobbies (eg lead-lighting, making fish sinkers or pottery glazing) or coming into contact with contaminated soil.

Care should be taken when renovating. Avoid sanding, abrasive blasting or burning paint containing lead. Do not burn old painted wood in fireplaces or in barbeques.

Asbestos

Asbestos was used widely in the construction, car and textile industries because of its strength and ability to resist heat and acid. It is no longer allowed to be used in building products for the home.

Asbestos-containing products were rarely labelled. Products like cement sheet, roofing sheet, some textured paints, vinyl floor tiles, pipe lagging and fire-resistant boards and blankets bought for the home before the mid 1980s may contain asbestos.

Generally, home building products containing asbestos are not a health risk but if asbestos is disturbed to produce fibres or dust, asbestos fibres may be released into the air and inhaled.

Always seek professional advice about managing asbestos in your home. Accurate identification can be difficult, and immediate removal is often not the best option.

Combustion products

Combustion products include smoke (small soot particles), ash and gases that can get inside your home from fireplaces and heaters burning wood, coal, gas or kerosene, gas cooking appliances, tobacco smoking, outdoor air, exhaust from cars in garages, and hobbies, such as welding and soldering.

Combustion particles are so small they behave almost like a gas — they can enter or leave a home very easily. When you breathe them in they travel into the deepest part of the lungs. Under certain circumstances these particles and gases may cause ill-health or, in extreme cases, even death.

To maintain good air quality when you have combustion sources:

> Vent products to the outdoors (via a flue, chimney, exhaust fan or rangehood) where possible.

> Keep flues and chimneys clean, and make sure any permanent ventilation openings are not blocked.

> Service heating or cooking appliances regularly to ensure they are working properly and are not leaking gases into your home.

> Ensure plenty of fresh outdoor air is coming into the room(s).

> Make sure insulation has not obstructed a heater flue or ventilators in the wall or roof space.

> Always follow the appliance manufacturer's instructions — seek advice from the manufacturer, supplier or your gasfitter/ plumber if you have any concerns.

> Ensure doors connecting garages to the house are tightly sealed.

> Minimise running time for vehicle engines in garages.

> Never use an appliance if it is damaged or not working properly.

> Do not use a gas oven or gas cooker to heat a room.

> Do not use barbeques or camp stoves indoors.

Volatile organic compounds

Volatile organic compounds (VOCs) are chemicals containing carbon that evaporate into the atmosphere at room temperature. They often have an odour and are present in a wide range of household products, construction materials and new furnishings. Household products that contain VOCs include paints, varnishes, adhesives, synthetic fabrics, cleaning agents, scents and sprays. VOCs can also occur as a result of personal activities, such a smoking.

When used in building products or other indoor items VOCs slowly make their way to the surface and 'offgas', into the surrounding air. Most offgassing occurs when products are new and/or freshly installed, after which it lessens dramatically over time.

Only a few specific VOCs have been studied in detail and little is known about the health hazards when VOCs mix with each other and other pollutants. The level of VOCs in the home can vary greatly, not only over time but also from room to room, especially if new VOC-containing products are frequently introduced.

Strategies to reduce VOC exposure in the home take two forms:

> Stop or reduce the use of products that contain VOCs.

> If the product is necessary, ensure adequate ventilation when using it.

> Open doors and windows whenever possible and practicable.

Air fresheners, cleaning sprays, polishes, spray deodorants and other toiletries are major sources of VOCs and should not be used excessively in non-ventilated areas. Building products are another source of VOCs. When selecting such products you should:

> Look for building products that are pre-dried in the factory or are 'quick-drying'.

> Use surface coating products that are water based or classed as containing zero or low levels of VOCs.

> Seek advice from the supplier or manufacturer, particularly if the information displayed on the container is not clear — ask for the product's Material Safety Data Sheet (MSDS).

> Ensure rooms are fully ventilated when adding new furnishings or resurfacing walls and floors, until the odour reduces considerably or disappears.

Four steps to better air quality

1. **Eliminate** – Identify the source of air problems and wherever possible eliminate through better product selection and design.
2. **Ventilate** – If too little fresh air enters a home, pollutants can accumulate to levels that can pose health and comfort problems.
3. **Separate** – Separate problem materials from occupants by using air barriers or sealers such as coatings.
4. **Absorb** – Indoor plants can be used to the quality of the indoor environment, as well as for their beauty.

QUESTIONS FOR A HEALTHY HOME

Planning

What was the home site previously used for?

The land on which you intend to build (or have built) may have chemical residues from previous industrial or agricultural processes. Talk to local long-term residents about the land's former use. Visit the planning section of your local government. Get advice about legal searches that might show how the land was used.

What about current and future industrial or agricultural development?

Check how emissions from existing or future industries might affect your home. The closeness of a main road, bus depot, airport, orchard or industrial plant can affect the amount of airborne pollutants entering your home. Check with your local council about likely future land use in your area.

Does the home's location make best use of the local climate?

Local topography, proximity of trees, and nearness to water all influence air temperatures and wind patterns around your home. A home on top of an exposed hill will be affected differently to the same home in a deep valley, or on an urban block with houses nearby. Design to enhance natural ventilation and shelter in a way that takes account of your home's specific location. [See: 2.2 Choosing a Site; 4.2 Design for Climate]

If buying or moving to an established home, will major renovations be needed?

The materials used in some old homes, as well as the activities associated with renovation, can increase the health risks for renovators and anyone else in the home during the work. Assess the risks and manage them through safe work practices and clean-up.

Will the main types of plants in the area to which you intend moving make your hay fever worse?

Ask a local plant specialist about the main local vegetation types within 1 kilometre of your new home. Moving to the new home without investigating its surroundings might lead to future health problems.

Design

How effectively does the home's design use natural ventilation?

Good design and orientation can encourage breezes and convection currents to draw stale air out and fresher air in. If windows are closed for security or noise reasons, install fixed wall vents to ensure adequate ventilation. Strike a balance between the need to introduce fresh air, maintaining comfortable room temperatures, and acceptable energy conservation. [See: 4.3 Orientation; 4.6 Passive Cooling]

Does the home's design keep moisture to a minimum?

In brick homes, if a damp-proof course has not been fitted or has been broken, moisture may migrate from the ground into the wall. High and prolonged periods of humidity can increase in moisture within the building. Avoid mould growth by lessening moisture levels in your home.

Will building security compromise health outcomes?

Closing doors and windows may improve security but it reduces air exchange. Install security products that allow you to feel secure, but also allow you to regulate the air flow between indoors and out.

Is mechanical ventilation a good idea?

Most Australian homes rely on openable windows and doors (and in older homes fixed wall vents) to provide ventilation. Ducted air systems may heat or cool recirculated indoor air, but don't introduce fresh air from outdoors or remove pollutants. Seek advice from a specialist engineer about mechanical ventilation systems. Evaporative cooling systems increase indoor humidity and may increase levels of mould or dust mites. Make sure all units are regularly maintained. [See: 6.2 Heating and Cooling]

Does your home 'design out' termites?

Termites are part of Australia's ecology. In the past, environmentally persistent organochlorines were used to kill them but these are now banned due to health and environmental concerns. The replacement – organophosphates pose less of an ecological hazard and have less potential for long-term health risks. Specially designed physical barriers, like mesh or crushed rock, reduce the need for extensive and repeated chemical treatment.

Can the dust be easily removed from the rooms?

The visible and invisible dusts in your home are made up of many substances. While most of the dust will be benign, there may be a small proportion that, if inhaled or swallowed, could trigger a health response. Design and furnish your home with easy to clean and washable surfaces and/or fabrics.

Carpeted floors?

If new carpets are fixed with adhesives, these may contain VOCs. Underlay can also be a source. Ask to see carpets promoted by manufacturers as 'low emission' products. Make sure your supplier unrolls the carpet in a well-ventilated area and lets it air for several days before it is delivered and installed.

Trapped dust and microbiological pollutants can be a problem if they are released from the carpet into the air, or may be a direct problem for crawling babies and young children playing on carpets.

What about tiled, vinyl, linoleum or polished floors?

Smooth floor surfaces, like ceramic tiles, vinyl linoleum or polished wood, can be easier to clean. Before specifying such products, check whether there are likely to be any VOCs present, either in the product itself or in other products used to lay it (like adhesives) or to seal the floor covering (like varnishes and paints) and for maintenance products, such as cleaning fluids and polishes.

Is a wood-burning heater your best option?

Poorly installed or badly maintained wood-burning heaters and stoves can be a major source of fine combustion particles and gases from leaks and from opening of the door for refuelling. Before installing a wood-burning heater or stove check that your local government allows them. Compare safety and efficiency claims of competing manufacturers. Ensure the flue or vent is properly designed and installed and is regularly maintained. Only burn well-seasoned wood. [See: 6.2 Heating and Cooling]

Are gas appliances vented to the outside?

Buy appliances that vent their combustion products to the outside (gas cookers should be vented to the outside by an exhaust fan or a range hood).

Unvented mobile gas heaters are considered by some researchers to pose a health risk and have been associated with more frequent respiratory symptoms. If use of unvented heaters is unavoidable, buy only low-NOx (nitrous oxide) appliances, and don't operate them in confined spaces for long periods of time. Ventilate the heated area with fixed wall vents (compulsory in some States). Ensure regular maintenance and servicing by a licensed gasfitter. Older heaters (pre-1990) are more likely to produce higher NOx values than new heaters. Consider replacing your old model with a new, flued (vented) model.

Is there a sealable door between the garage and the rest of your home?

The exhaust from conventional petrol and diesel engines contains many pollutants, including millions of very fine particles and a variety of toxic gases. Such engines should not be run in confined spaces (like a garage) for more than a few seconds, unless there is very good ventilation. Do not allow contaminated air from the garage to circulate through your home. Choose a garage that stands apart from your home. If it is attached, make sure the linking door is well fitted and able to be securely sealed against leaks.

In-use/maintenance

Do the kitchen, laundry or bathroom windows remain damp for more than fifteen minutes after cooking or washing?

Depending on your home's original design or the impact of recent renovations there may not be enough 'air changes' to quickly remove cooking odours or moisture. The kitchen, laundry and bathrooms should have exhaust fans to vent moist air to the outside. Ask your fan supplier about energy efficient models. In the absence of exhaust fans, and where it is safe to do so, open kitchen and/or bathroom windows to 'flush' the air after cooking, washing clothes and bathing.

When was the kitchen exhaust fan or range hood last cleaned?

A well-sited kitchen exhaust fan and/or range hood that vents to the outside may remove many of the particles and gases that arise when cooking on gas stoves, but fat droplets settle within the vent. These deposits build up over time and can become both a fire hazard and a home for fungi and bacteria. Wash exhaust fans and range hoods regularly.

Is the floor properly cleaned?

Poorly cleaned carpets become reservoirs for dust and microbiological pollutants. Clean carpets regularly to minimise health risks. Invest in a vacuum cleaner with high filter efficiency (HEPA filters) and mechanical pile agitation. Carpets should be professionally cleaned every 18 months. Seek professional advice about the best way to clean your carpet — methods will vary depending on the type of carpet, its 'backing' and any underlay present, and the level of traffic and type of use. Smooth flooring should be cleared of dust before wet mopping so that the water does not simply spread the dust. Avoid cleaners that use fragranced products as they include VOCs.

How well does your vacuum cleaner capture fine particles?

Most modern mobile vacuum cleaners are good at picking up and retaining visible dusts. However, many struggle to remove all the particles trapped in carpets, and most machines let very fine particles pass through the filter/bag, back into the room's air.

If your health or that of your family seems to suffer after floors have been vacuumed, consider a central vacuum system which expels air outdoors. Alternatively, purchase a high filter efficiency (HEPA) vacuum cleaner, preferably with mechanical pile agitation (they cost more). If you are particularly sensitive to allergens, wear a face mask during vacuuming and for a short period afterwards.

Are doormats located at all entrance points?

Carried on footwear, pollutants including lead particles from vehicle exhausts or contaminated soil, can enter your home and become part of the breathable dust load. Doormats can reduce the amount of material brought into your home.


Paul Downton

How good a fit is the 'fitted kitchen'?

Cockroaches seek tight spaces to squeeze into. With food, water and a snug place like the little cracks and crevices common in poorly fitted kitchens — cockroaches couldn't be happier. Plug all gaps between kitchen units, walls and floor. Ask your local hardware supplier about the types of non-toxic gap sealants available.

The wood you intend to burn: has it been chemically treated?

Do not burn chemically treated wood, indoors or out. Do not burn wood with varnish, paint or other visible chemical treatment, like creosote. Avoid burning 'CCA (chromated copper arsenate)-treated' wood. If in doubt, don't burn. Well-seasoned, clean wood is best for burning in heaters and stoves.

Thinking of buying new fixtures made of pressed wood products?

Most modern furniture is made wholly or partly from plywood, particleboard or medium-density fibreboard (MDF). The resins in these products can off-gas formaldehyde for many years. Australian manufacturers produce low-emission products and are marked low formaldehyde emission LFE (E1) or LFE (E0) and their emissions are certified through product quality assurance programs. Some imported products may have high emission levels. Check the origin and emission class with your retailer or contact the Australian Wood Panel Association.

Do the new soft furnishings have low gas emissions?

Many soft furnishings contain foams or other synthetic. These can release various unhealthy gases over time. Some manufacturers are working to reduce off-gassing. Ask suppliers for details about the chemicals used in the product, particularly VOCs, and their advice on possible health effects. Try to find products with low-emission labels.

Is that fragrant product such a good idea?

Most liquid cleaning agents, many personal hygiene products, air fresheners and perfumed toiletries contain VOCs. Some people's health rapidly deteriorates after smelling or coming into contact with one or more of these types of product, even for just a few seconds.

Are you looking after your compost heap properly?

Compost heaps need regular maintenance and should be located well away from living areas. Unless the heap is managed correctly, not only will it attract unwanted vermin, such as rats, mice and cockroaches, but it may also increase the numbers of fungal spores in the air close to your home. Most gardening books and nurseries provide good information on how best to look after your compost heap.

Has the potting mix been stored in a cool place?

Sealed bags of soil potting mix have been known to contain high levels of the bacteria responsible for legionnaires' disease. Store unopened bags in a cool, dark place. When opening a bag for the first time, do so in a well-ventilated area and avoid breathing the dust. Wear a face mask.


Paul Downton

Renovation

Does the paint you intend to remove contain lead?

Lead paint is most likely to be found in homes built before 1970. Paints containing up to 50 per cent lead were commonly used on the inside and outside of houses built before 1950. Up to the late 1960s paint with more than 1 per cent lead was still being used. Regulations have reduced the levels of lead in paint to 0.1 per cent.

Commercial home test kits are available from some hardware stores. For more reliable results, use the services of an analytical laboratory. If you do find lead in or around your home, phone your state or territory public health unit for advice.

What precautions are you or your painting contractor taking when sanding back existing paint?

Rubbing existing paint with an abrasive, such as sandpaper, creates a lot of fine particles. This is a potential health risk, both when the particles are in the air (where they can be inhaled) and when they settle on a surface (where children or pets may swallow them). The risk increases if the paint contains more than very small amounts of lead or other metals. Contractors know how to capture the dust before it travels any distance through or into your home and should take care in cleaning up residues. Without appropriate equipment, vacuuming of lead paint dust is not recommended.

ADDITIONAL READING

Asthma Australia
www.asthmaaustralia.org.au

Australian Environmental Labelling Association
www.aela.org.au

BEDP *Environment Design Guide*
PRO 4 Chemical Risks in the Built Environment – An Introduction

D'Alessio, V. (2002) *Allergy Free Home A Practical Guide to Creating a Healthy Environment*, New Holland, Sydney.

Material Safety Data Sheets
www.msds.com.au

Spengler, J, McCarthy, J and Samet J (eds) (2000), *Indoor Air Quality Handbook*, McGraw-Hill, New York.

The Australasian Society of Clinical Immunology and Allergy
www.allergy.org.au

Total Environment Centre
www.safersolutions.org.au

Principal author:
This fact sheet has been adapted from *Healthy Homes: A guide to indoor air quality in the home for buyers, builders and renovators*; Department of Health and Ageing, 2003.

Safety and Security

Good building design can help achieve a safer and secure living environment. These design features can be incorporated upfront in the design and contruction phase or through ongoing modification and maintenance. This fact sheet should be read in conjuction with 3.2 The Adaptable House, 3.3 The Healthy Home and 3.5 Bushfires.

SAFETY

Most accidents occur in the home. The design of a house, construction methods, materials, finishes, applicances and maintenance all influence home safety. This section provides an overview of safety issues relating to:

> Kitchens.

> Bathrooms.

> Fittings (doors, windows and hot water systems).

> Outdoor areas.

> Fire risk prevention.

Kitchen safety

The majority of domestic accidents occur in the kitchen and bathroom.

Apply the following general design tips to reduce the likelihood of accidents:

> Design for unobstructed access to the work triangle (the area containing the stove, sink and refrigerator).

> Eliminate or reduce cross traffic through the work triangle.

> Protect hot plates with a guardrail or deep setback and use fire resistant finishes adjacent to and above the cook top.

> Round-off bench edges and corners.

> Design heatproof benchtops or inserts either side of oven and grill for rapid set down of hot dishes and trays.

> Locate microwave ovens above the eye level of children or at back of a bench to prevent them gazing into it. Have the microwave checked regularly for microwave leakage.

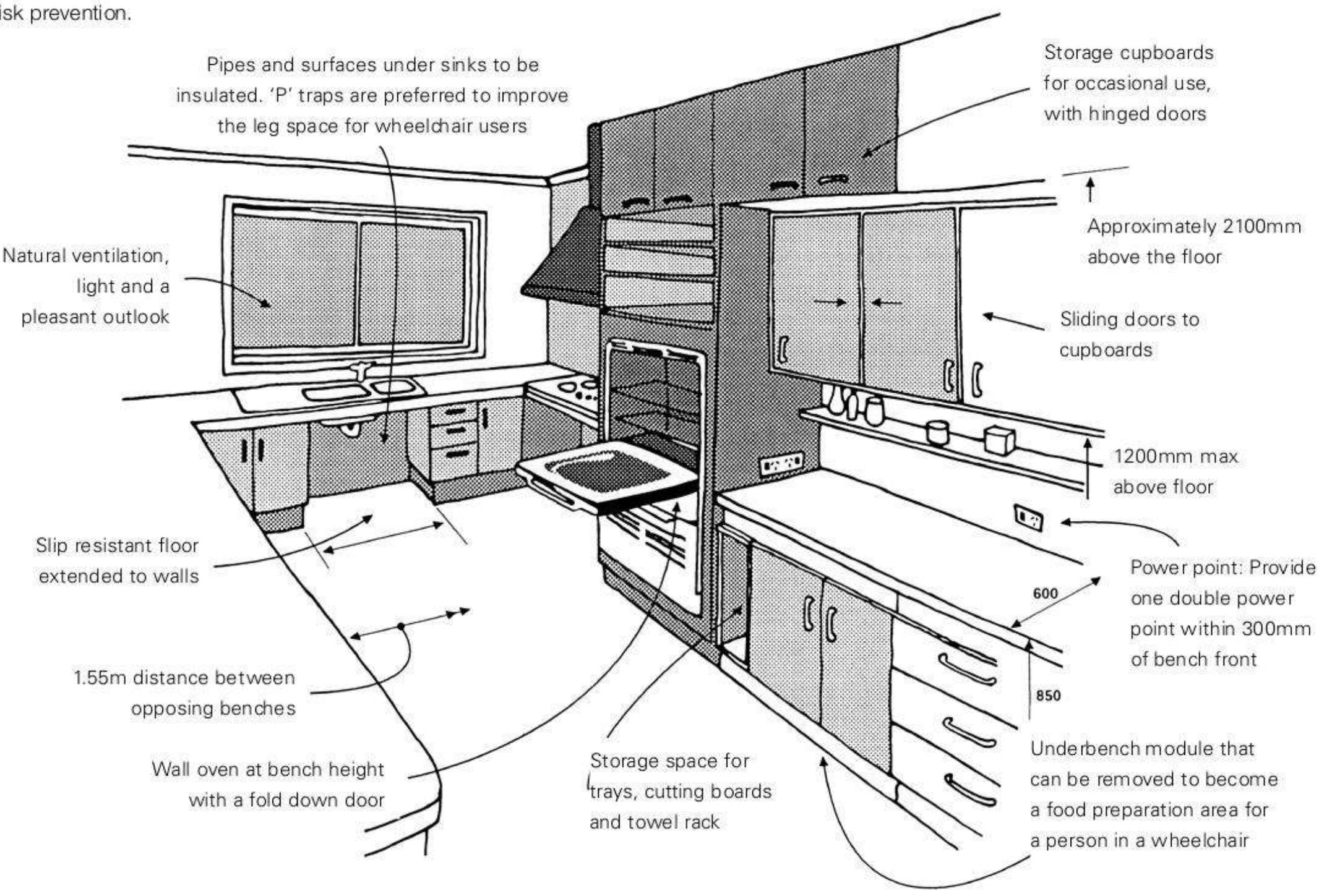
Bathroom safety

> Use slip resistant flooring and avoid steps.

> Provide handles and bars near baths, in showers and adjacent to toilets for elderly and disabled users.

> Design and install child resistant cabinets for medicines and hazardous substances.

> Comply with Australian Standards that specify minimum distances between water sources (baths, basins, tubs) and power points.



Courtesy Robert Moore , 'Housing for life'

> Comply with the BCA requirements for outward opening of sanitary WC doors or install sliding doors or use hinges that permit doors to be removed from the outside. Many heart attacks occur in WCs with the victim blocking inward opening doors.

> Ensure that privacy locks on bathroom doors can be opened from the outside in the case of an emergency.

> Provide a night light or movement sensitive light switch in the passage for safe access to the toilet at night.

Fittings

Hot water

> Instantaneous hot water systems should have their thermostats set at 50°C or less to help prevent scalding.

> Hot water storage systems should be set to at 60°C to inhibit growth of harmful bacteria such as legionella. Incorporate a fail-safe mixing valve on both the bath and shower to avoid scalding. [See: 6.5 Hot Water Service]

> Install a tempering valve or an outlet shut-off valve in your existing system to reduce the flow of water to a trickle if it's too hot. When cold water is added and the temperature becomes safe, the valve opens and the flow returns to normal. This can prevent accidents if you have small children or elderly people in your home.

Doors

> Install self-closing (but not self-locking) screen doors at external entrances.

> Internal door handles should be one metre from the floor so young children cannot open them.

> Consider latch rather than knob type handles for ease of use by weak or disabled people.

Floors, stairs and ramps

> Use ramps instead of stairs where possible.

> Observe optimum rise to run ratios for stairs as shown in the figure below.

> Ensure that stair rails and balustrades comply with BCA minimum standards. Balustrades with maximum 125mm gap between balusters must be provided where finished floor level is higher than one metre above the ground level.

> Avoid changes of level within the house and between the house and the outside. Where changes of level are necessary, ensure that they are clearly visible with colour change in floor covering.

Use non-slip, impact absorbing floor surfaces where possible, especially on stairs or ramps and in wet areas.

Windows

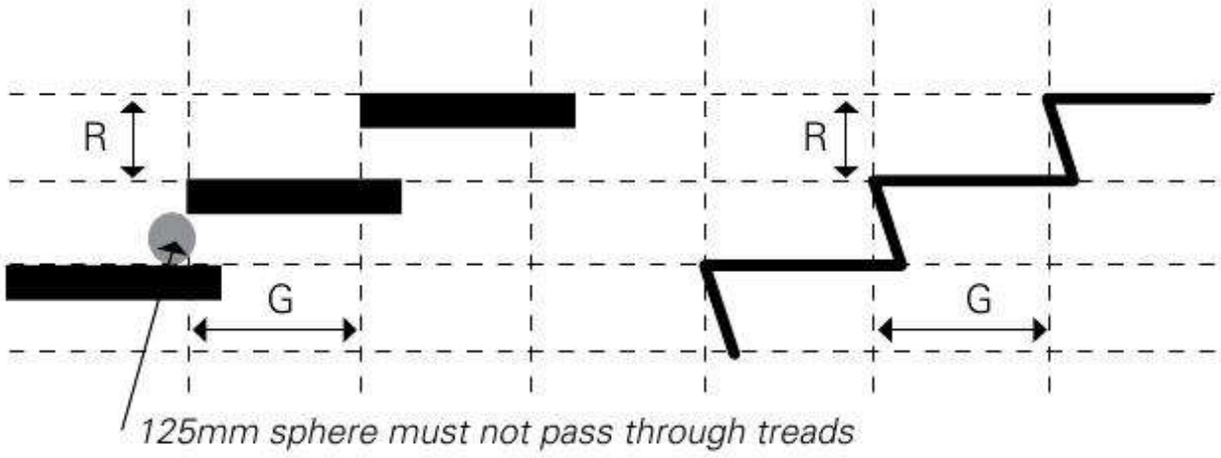
> Design windows with easy access for opening, closing and cleaning. Windows should comply with requirements of the Australian Standard 1926.1-1993 in situations where the window provides access from a building to a swimming pool area.

> In areas of a building that have a high potential for human impact grade A safety glazing should be used. Glazing in high human impact areas should be marked to make it readily visible according with section 3.6.4.6 of the BCA..

> Ensure that all new glazing complies with relevant Australian standards and bears a manufacturer's stamp certifying compliance.

STAIR RISER AND GOING DIMENSIONS (mm)

Stair type	Riser (R) (see figure below)		Going (G) (see figure below)		Slope relationship (2R+G)	
	MAX	MIN	MAX	MIN	MAX	MIN
Stairs (other than spiral)	190	115	355	240	700	550
Spiral	220	140	370	210	680	590



Source: Building Code of Australia

Wiring and electrical

> Carefully plan the provision of power outlets. Insist on an electrical layout plan. It will save you later inconvenience and may save your life.

> Install earth leakage devices and circuit breakers to all power outlets.

> Provide adequate power points and circuits. This eliminates the need for power boards, which can overload circuitry. It also reduces the need for cords to trail across walkways, where they can trip or electrocute.

> Ensure that the switchboard can be easily accessed at night. Safety switches should be used on indoor and outdoor circuits.

Heaters

> Ensure fan heaters have a safety switch to cut power off if the fan stops or heater overheats.

> Never leave a heater unattended.

> Position the heater to avoid intake blockage or material falling on it.

> Pets may lie close to heaters and accidentally knock bedding, mats and other materials onto the heater.

Ceiling fans

Position ceiling fans at least 2.4m above floor level to reduce risk of injury.

Outdoor safety

> Plant light coloured plants along the edges of paths to make them clearer at night.

> Provide solar powered or movement sensitive outdoor lighting along paths, especially near steps or bends. Use energy efficient lighting. [See: 6.3 Lighting]

> Provide safety fencing around pools and ponds in accordance with BCA and state regulations to prevent access by unsupervised children.

Fire risk and prevention

> Use fire resistant materials, linings and finishes, particularly in kitchens.

> Install smoke alarms and regularly ensure that batteries are fitted correctly and still charged.

> Equip the home with fire extinguishers.

> Consider installing a domestic sprinkler system.

House fires can often be prevented through careful design and maintenance.

> Favour furnishings and floor coverings with fire retardant properties. Ratings are available for many items and include flammability indexes, spread of flame indexes and smoke generated indexes. Various construction systems have fire ratings that determine how long they will withstand a fire and retain structural integrity. Ask your local council for full details.

SECURITY

The view that crime prevention and security is only a matter for law enforcement agencies is no longer true. Individuals, neighbourhoods, local authorities and planners can all play a role in reducing the incidence and fear of crime.

Appropriate design of individual dwellings and their relationship to one another and to the surrounding neighbourhood can all play a part in preventing crime. This approach is often referred to as 'crime prevention through environmental design' and there is a lot of evidence based research to show that it works.

Many burglaries are opportunist crimes. A burglar only needs to spot an open window or an unlocked door or gate to make their move.

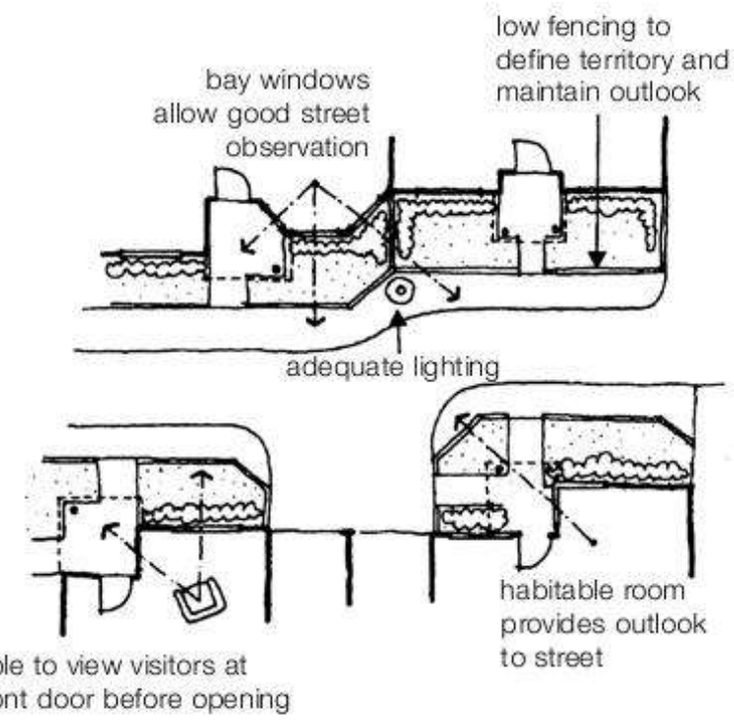
The principles for crime prevention through design for individuals and neighbourhoods include the following:

Territoriality

Outdoor spaces should be designed to foster a stronger sense of ownership and communality. In apartments, for example, residents need to feel that public spaces such as halls and elevators belong to them.

Natural surveillance

Surveillance should be a part of the normal and routine activities of individuals and neighbourhoods. It can be enhanced by positioning windows for clear sightlines so streets, footpaths and play areas can be watched.



Target hardening

Improve building security standards. Locks and security screens should be installed to deter thieves. Doors, windows and halls should be made more secure, and the quality of exterior doors, door frames, hinges and locks must be high. Exterior lighting and alarm systems can add to security.

Access control

Use real or perceived barriers to discourage intruders. Real barriers include a picket fence, a brick wall or a hedge. Perceived barriers can be created by a flower garden or a change in level or design between the public space of a footpath and private front yard.

(The above has been adapted from Geason and Wilson, 1989).

See also the quick tips below:

> Install an intruder alarm system according to the Australian Standard (AS 2201.1, Intruder alarm systems Part 1: Systems installed in client's premises).

> Display security system notices prominently.

> Select a security system with low standby power consumption. Many systems use excessive electrical energy over a year. [See: 6.1 Energy Use Introduction]

> Design or modify your home to eliminate dark corners, narrow pedestrian walkways and hidden recesses.

> Design balconies and windows to maximise natural observation of vehicle and pedestrian movement.

> Ensure that perimeter doors and windows are of solid construction and fitted with quality deadlocking devices.

> Glass should be reinforced with shatter resistant material to prevent entry.

> Ensure that skylights and roofing tiles can not be easily removed from the outside.

> Fit the main entry doors with viewing ports to allow identification of visitors.

> Direct infrared activated security lights toward likely access/egress areas to illuminate potential offenders.

> Avoid or modify trees, carports and lattices that can act as 'ladders' to upper storeys.

> Ensure that external storage areas, laundries, letterboxes and communal areas are well lit and observable from inside.

> Clearly delineate property boundaries using gardens, distinctive paving, lawn strips, ramps and fences.

> Fences and walls should be low and/or open to improve observation and maximise sunlight. Vegetation should not obscure building entrances, windows and other vulnerable areas.

> Ensure that entrances are clearly private and well illuminated.

> Install sensor lighting or timed lighting that can be controlled from within the dwelling.

> Join or establish Community Safe House programs in your area.

> Provide pleasant, well-defined pedestrian routes overlooked by neighbouring houses and employ traffic calming measures to slow cars and encourage pedestrian activity where possible. [See: 2.3 Streetscape; 2.6 Transport]

> Set buildings back from the verge to create a perception of semi-private space.

> Encourage casual use of public and semi-private open spaces during evening hours so they can be 'animated' with legitimate activities.

ADDITIONAL READING

Geason, S. and Wilson, P., (1989), *Designing Out Crime: Crime Prevention Through Environmental Design*, Australian Institute of Criminology, Canberra.

SA Department of Justice, Crime Prevention through Environmental Design
www.cpu.sa.gov.au/cpted.html

UK Association of Police Offices – Crime Prevention Initiative, Secured by Design
www.securedbydesign.com

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Bushfires

This fact sheet outlines essential design issues for buildings in bushfire prone locations. The potential for bushfires is an integral part of Australia's bushland. The functioning of that natural environment requires and accommodates fire. Buildings sited in this environment thus similarly need to cope with fire.



Bushfire is a fact of life in much of Australia.

Long hot summers dry out the vegetation. The vegetation holds oils and flammable fibre which, along with the fallen leaf and bark debris, create a substantial fuel load.

High temperatures, strong winds, airborne dust, and ignition sources from natural and human factors combined can then trigger and propagate fire.

Building sustainably emphasises certain preferred outcomes including the use of local materials with low embodied energy and with recycling and low toxicity attributes.

Meeting bushfire needs can call on different priorities: recycled timber often does not meet non-combustion rating requirements, fire resistant paint embodies toxins, steel and other non-combustible components have high embodied energy. Meeting the specifications for bushfire resistance can be at odds with some sustainability goals.

For intense bushfire prone places, bushfire resistance comes first in building construction decisions. In other locations, sustainable and bushfire resistant construction choices can mix.

MECHANISMS OF FIRE SPREAD

The Australian landscape has features that instigate and propagate wildfire.

Indigenous vegetation contains oils in timber and leaf that at higher temperatures form flammable vapour and feed flame. Vegetation debris such as bark, leaf and fallen limbs form base fuel loads which aid the spread of fire. Flammability arises also from detailed features such as leaf size and form.

Climatic factors that contribute to ignition and propagation of fire by drying out vegetation include:

> Long dry summers.

> Low rainfall.

> High temperature.

> Windy days.

Bushfire develops in stages from ignition through fire spread, growth, travel and changes in intensity. Bushfire resistance aims to:

> Prevent ignition.

> Minimise fire spread.

> Combat flame growth and intensity change.

The goal is to minimise destructive effects. The attention throughout is on minimisation of adverse impact on people and property.

Ignition

Ignition can be from natural and manmade causes.

> Natural ignition sources include lightning from summer storms striking ground features.

> Human instigated fire can begin from solar heat concentration onto manmade debris such as glass shards or bottles concentrating heat to ignition.

> Direct human ignition of vegetation is an on-going concern.

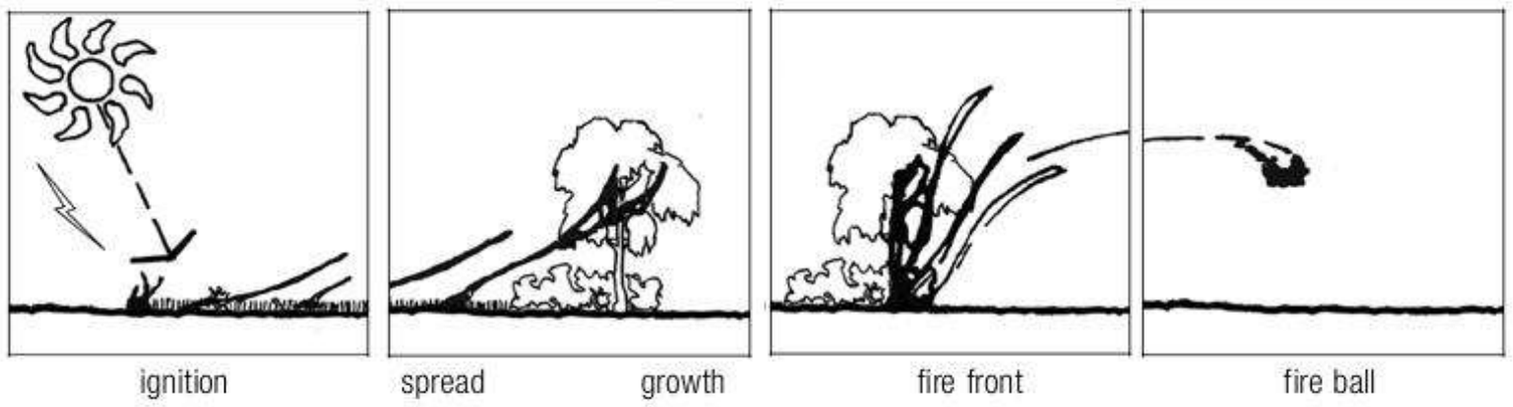
Fire progression

After ignition, the small initial fire travels through direct fuel load, principally ground debris.

> Ground slope and wind assist the spread of fire.

> Density of fuel load permits increasing fire intensity.

Fire Progression



As the fire enlarges, this permits flame spread through debris and vegetation, both in the understorey and canopy, giving the fire additional height and moving it toward intensification.

Fire grows by:

> Burning debris dispersal.

> Direct fire front heat radiation.

> Direct flame onto further vegetation.

Growth

Increasing fire intensity and growth then permits fire propagation through living vegetation from burning debris and direct flame, with the increased fuel load including vegetation oils boiled off and vegetation dried ahead of the fire front by direct radiation.

Development of intense fire front includes creation of individual fireballs of oils and embers propelled ahead of the main fire line advance. These fireballs permit spot fires separate from the fire front, causing either independent fires or accelerating the fire front advance.

Fire propagation

The speed of fire front advance is contributed to by the ambient weather, notably dry high temperatures and wind. See illustration below.

Ground level fire propagation is increased by changing ground slope and vegetation. Wind behind the firefront and upslope can accelerate fire spread, as can wind swirl around landform obstacles together with downslope and dry ground conditions.

The vertical spread of vegetation across the layers from grass to understorey and canopy enables fire to change in flame form and height, with independent fire travel at each level of this vegetation mix.

Design priorities

To deal with the fire behaviour outlined above, a design approach to bushfire resistance within the property focuses on:

> Preventing fire ignition sources.

> Avoiding fuel load that could contribute to spread or intensification.

> Creating fire barriers that permit safe movement for people and reduce fire advancement and propagation.

> Creating site surroundings and using construction elements that reduce fire load on buildings.

These are each expanded on in text and diagrams.

Site issues

The intensity of fire impact on buildings can be reduced by the features in the surrounding land area.

Reducing fire approach and intensity is contributed to by site development, its on-going maintenance, and fire fighting tasks on the day:

> Selection of high water bearing and fire resistant plant species.

> Long term wetting of ground, mulch, ground cover and plants with wastewater or garden water sources.

> Active fire fighting in the garden as well as on the building.

At time of fire approach, water delivery and spray to the garden similarly reduces fire intensity, in particular via airborne burning embers.

Water spray is delivered on ground and vegetation to retain a wetted condition, with reciprocating stand sprinklers creating a water droplet curtain to reduce fire approach intensity.

On-going maintenance is integral to such site development issues with on-going debris reduction, and ensuring serviceability of water delivery including stand pipes and sprinklers which need to be effective at time of fire. See illustration below.

Development for passive bushfire resistance can include creating changes in landform in the direction of potential fire approach. That type of mound can provide both shielding from direct radiant heat in the fire front, and deflect the core fire front flame or fire ball above the building form.

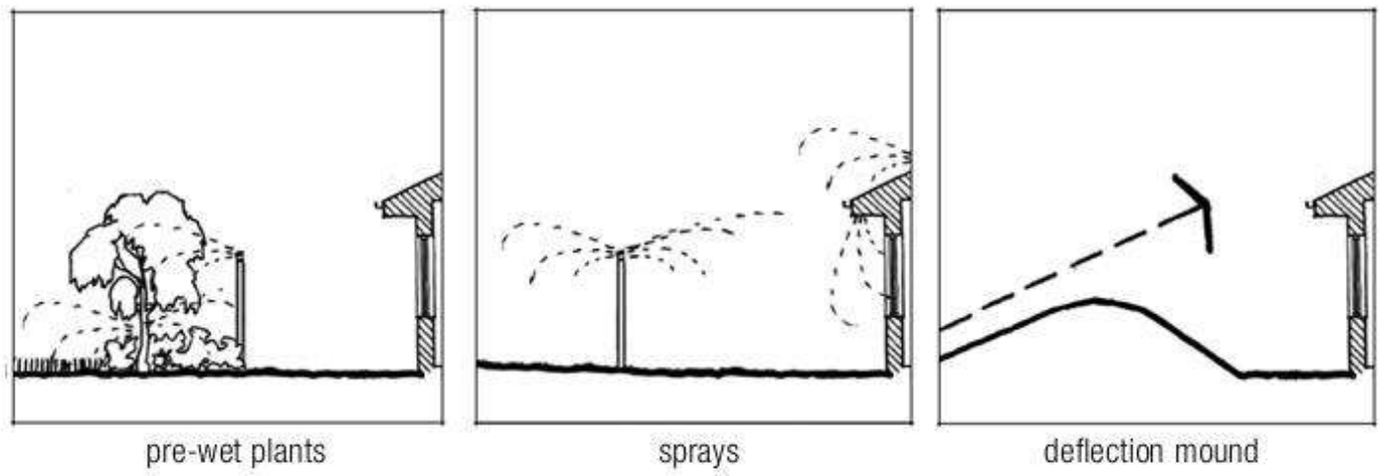
In the same way, the fundamental siting of the building in relation to natural landform and stands of vegetation determines the likely fire intensity at the building face.

Positioning below the crest of rising ground can reduce fire heat intensity on the building face compared with siting on the hill top. Siting behind existing dense vegetation can be a position where fire approach slows and fire front radiance is reduced. The positioning of wind break vegetation and out-building clusters can also contribute in this role.

Fire Propagation



Fire protect site



Landscape

While vegetation is often considered as contributing to fuel ignition source and fire spread fuel, in selected circumstances it can be part of fire barrier design.

Vegetation can form part of a fire barrier if it:

> Holds moisture throughout summer.

> Creates a continuous screen from understorey to canopy.

Water delivery and its capacity to be retained on surfaces can also contribute.

Plant criteria which reduce fire potential include:

> Leaves with moisture and mineral content, and low oil levels.

> Leaves with fine form and dispersed foliage density.

> Dispersed foliage clumps or clumps clear of the ground.

> Limited foliage volume.

> Low dead foliage content.

> Bark which is tight fitting and continuous rather than presenting recesses in which embers can lodgement.

> Plants that create debris with fine form and make a compact litter.

Approach paths to buildings

Occupants wanting to evacuate the property during bushfire need fire safe paths on the property. These are also essential for access into the property for fire fighting and to provide defensible spaces during fire fighting.

Attributes of paths and defensible spaces include:

> Pathway width, slope and surfaces able to be negotiated when conditions are bad and visibility is affected by smoke and flame.

> Paths that avoid going toward high fire intensity areas.

> Widths and turnarounds that accommodate the needs of fire fighting vehicles.

> Avoidance of adjacent and overhanging vegetation that might be a fire source or create barriers by collapsing across pathways.

Legislation

Development legislation includes minimum requirements for bushfire resistance of building construction. The Building Code of Australia (2.) sets performance goals (Part F2.3.4) and defines accepted standard construction (Part 3.7.4).

Requirements vary according to the location's assessed fire risk (medium, high, extreme). An individual building site is assessed according to Australian Standard 3959 (3.) that sets out assessment methods and bushfire resistant building elements.

Advice and formal assessment is performed by the approriate regional Country Fire Services or Country Fire Authority. For some locations, the state government provides mapping for the general bushfire prone category of various regions.

The following summarises thinking about fire resistance in building construction drawn from the sources above.

Building envelope

Beyond reducing fire intensity as described above, the building itself is built to be fire resistant. Detail construction to the building exterior seeks to avoid ember entry and combustion commencement through construction with non-combustible materials, surfaces and sealed construction junctions.

Complicated roof shapes generally offer more places for embers to lodge and make it more difficult to seal the roof. Keep roof forms simple.

Adjacent open structures (pergolas and decks) may contain combustible elements or ember traps. These building elements should be structurally separate from the building and not penetrate the building exterior.

In the building itself, common construction junctions need to be sealed against ember entry and flame access to the structure.

The junctions are:

> Roof ridge and flashings.

> End flutes of roof sheet at the gutter line.

> Eaves junctions to fascia and wall.

> Openings to cavities in walls and under suspended floor voids.

Openings are potential fire entry sources. Embers can enter through gaps in openable portions, and flame can enter through glass broken by fire radiant heat.

Construction to resist this includes:

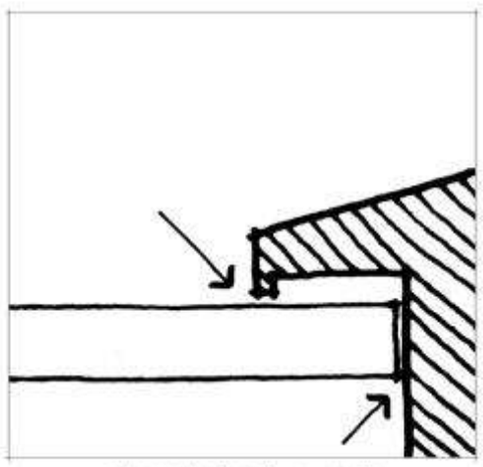
> Seals placed in junctions between frames and exterior claddings.

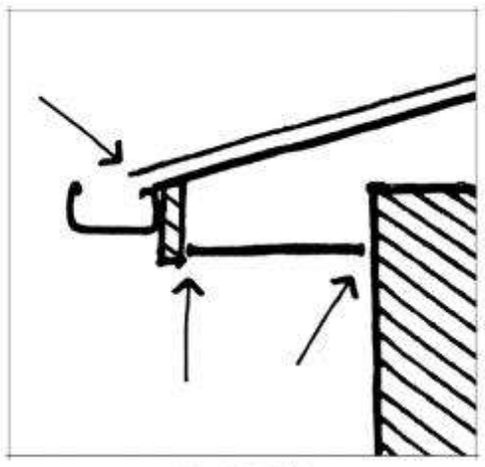
> Seals around frames in openable sashes.

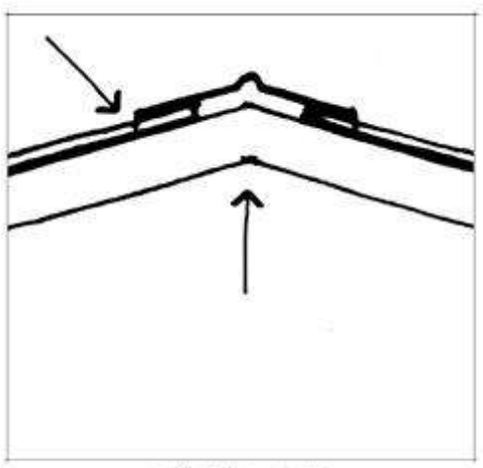
> Bronze mesh flyscreens covering openable sections of doors and windows.

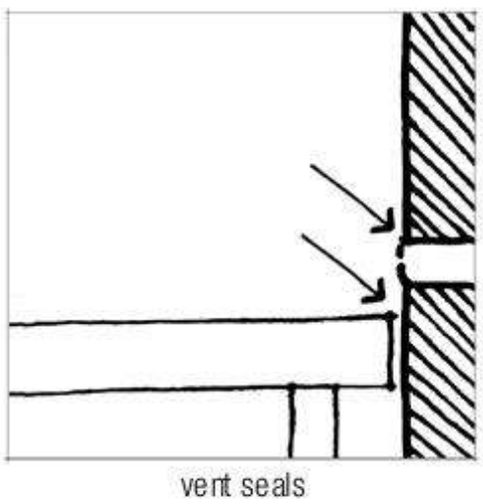
> Flyscreens covering open drainage and perps (open vertical joints for ventilation required by other legislation seeking to avoid damp and vermin in buildings) in walls.

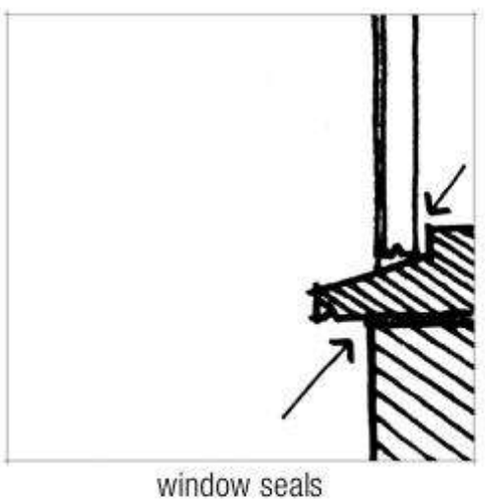
Non-combustible materials include sheet and masonry materials (steel, fibre cement, brick and stone). Manufacturers continue to evolve treatments to provide fire resistance to timbers but some paint coating options may contain

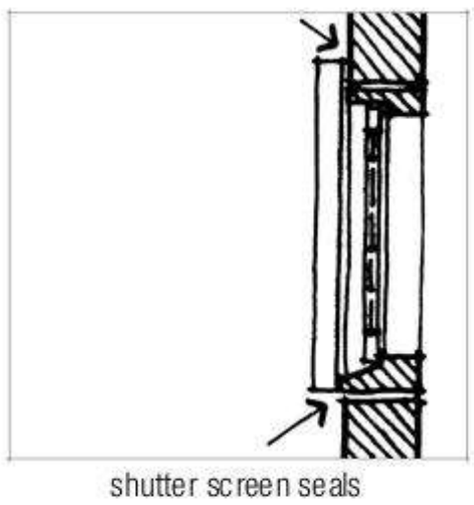

external structure seals


eave seals


roof ridge seals


vent seals


window seals


shutter screen seals

chemicals and combustion toxins. In some jurisdictions (South Australia) some dense timber species (turpentine, blackbutt) are accepted as adequate for use in some bushfire risk categories.

Improving fire resistance to glazing can include using toughened glass that is less prone to heat load breakage as it requires 450°C surface temperature to physically fail.

Further fire resistance can be achieved beyond minimum requirements with fixtures including shutters over openings either of non-combustible or fire rated construction.

Some fire entry points may be unexpected. Services ducts, conduits and pipes need to be non-combustible both where externally exposed and 300mm down into the ground.

Maintenance

Ageing and decay of materials, construction and finishes can reduce building resistance to fire.

Burning embers can lodge in the resulting cracks in surface and material depth of those external surfaces, giving a foothold for fire damage to the building exterior.

Movement of non-combustible linings away from structure and services can expose previously protected material that may then be prone to damage by fire, providing a fire path to the building interior.

Routine maintenance beyond debris removal includes repair to building surfaces and openings to maintain bushfire resistant performance:

> Fill cracks and gaps as these develop.

> Maintain exterior surface finishes intact.

> Remove ember lodgement and entry places.

> Maintain seals (ridge, eaves, flashings).

> Maintain flyscreens.

ADDITIONAL READING

Australian Building Codes Board (2007), *Building Code of Australia, Vol 2*, Part 3.7.4 Bushire Areas, AGPS, Canberra.

CSIRO
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Ramsay G and Rudolph L (2003), *Landscape and building design for bushfire areas*, CSIRO, Melbourne.

Schauble J (2004), *Australian Bushfire Safety Guide*, Harper Collins, Pymble, NSW.

Timber Development Association
www.timber.net.au/bushfire

Yates A et al (2002), 'Special conditions – gardening in fire-prone areas' in *Yates Garden Guide*, Angus and Robertson, Pymble, NSW.

Principal author:
Emilis Prelgauskas

Passive Design

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

Incorporating the principles of passive design in your home:

> Significantly improves comfort.

> Reduces or eliminates heating and cooling bills.

> Reduces greenhouse gas emissions from heating, cooling, mechanical ventilation and lighting.

Building envelope is a term used to describe the roof, walls, windows, floors and internal walls of a home. The envelope controls heat gain in summer and heat loss in winter.

Its performance in modifying or filtering climatic extremes is greatly improved by passive design.

Well designed envelopes maximise cooling air movement and exclude sun in summer. In winter, they trap and store heat from the sun and minimise heat loss to the external environment.

The fundamental principles of passive design, explained above are relatively simple and can be applied to the various climate zones, house types and construction systems in Australia.

To explain all of these combinations in sufficient detail, information has been divided into separate fact sheets as follows:

4.2 Design for Climate

This fact sheet provides an introductory guide to the main climate zones in Australia as well as the key passive design responses for each climate. It also explains the conditions required for human thermal comfort and how passive design assists our bodies in achieving comfort.

4.3 Orientation

A home that is well positioned on its site delivers significant lifestyle and environmental benefits. Correct orientation assists passive heating and cooling, resulting in improved comfort and decreased energy bills.

The information is presented in three parts:

> Principles of good orientation.

> Orientation for passive solar heating.

> Orientation for passive cooling.

4.4 Shading

Shading of glass is a critical consideration in passive design. Unprotected glass is the single greatest source of heat gain in a well insulated home.

Shading requirements vary according to climate and house orientation.

In climates where winter heating is required, shading devices should exclude summer sun but allow full winter sun to penetrate.

This is most simply achieved on north facing walls. East and west facing windows require different shading solutions to north facing windows.

In climates where no heating is required, shading of the whole home and outdoor spaces will improve comfort and save energy.

This fact sheet explains how to choose or design climate and orientation specific shading solutions for all types of Australian housing.

4.5 Passive solar Heating

Passive solar heating is about keeping the summer sun out and letting the winter sun in. It is the least expensive way to heat your home.

The fact sheet explains how the following key elements of passive solar heating are applied.

> Northerly orientation of window areas.

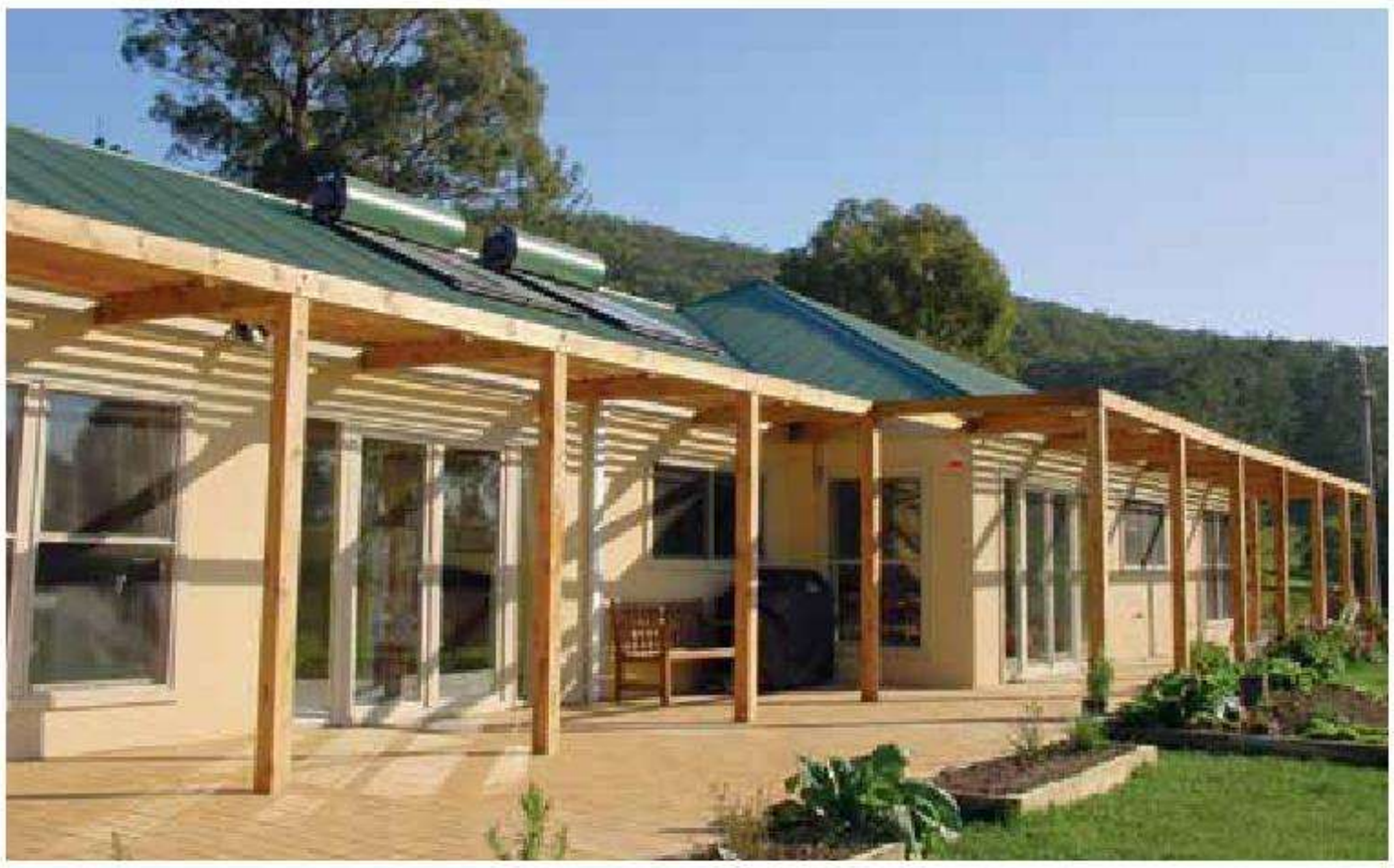
> Passive shading of glass.

> Thermal mass for storing heat.

> Minimising heat loss with insulation, draught sealing and advanced glazing.

> Using floor plan zoning to get heating to where it is most needed and keeping it there.

Passive solar houses can look like any other home but they are more comfortable to live in and cost less to run.





4.6 Passive Cooling

Passive cooling is the least expensive means of cooling your home. It is appropriate for all Australian climates.

This fact sheet explains how to design and modify homes to achieve summer comfort and minimise or eliminate energy use for cooling.

Four key approaches are examined:

> Envelope design for passive cooling.

> Natural cooling sources.

> Hybrid cooling systems.

> Adapting lifestyle.

4.7 Insulation

Insulation is an essential component of passive design. It improves building envelope performance by minimising heat loss and heat gain through walls, roof and floors.

Topics covered include:

> Insulation types and their applications.

> Recommended insulation levels for different climates.

> Strategies for cost effective insulation solutions.

4.8 Insulation installation

This fact sheet explains where and how to install insulation, providing detailed examples of a range of insulation solutions for various construction types.

4.9 Thermal Mass

Externally insulated, dense materials like concrete, bricks and other masonry are used in passive design to absorb, store and re-release thermal energy. This moderates internal temperatures by averaging day/night (diurnal) extremes, therefore increasing comfort and reducing energy costs.

Topics covered include:

> Where and how to use thermal mass.

> Thermal mass solutions for different climates and construction types.

> How much thermal mass to use.

4.10 Glazing

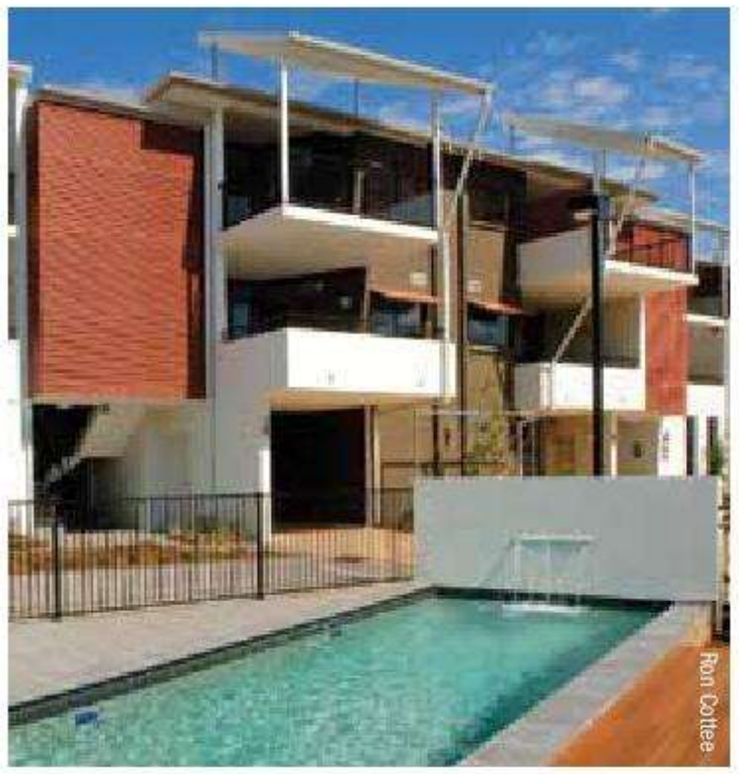
Windows and glazing are a very important component of passive design because heat loss and gain in a well insulated home occurs mostly through the windows.

With good passive design, this is used to advantage by trapping winter heat whilst excluding summer sun. Cooling breezes and air movement are encouraged in summer and cold winter winds are excluded.

4.11 Skylights

Well positioned and high quality skylights can improve the energy performance of your home and bring welcome natural light to otherwise dark areas.

This fact sheet explains how to position skylights to gain the maximum benefit.



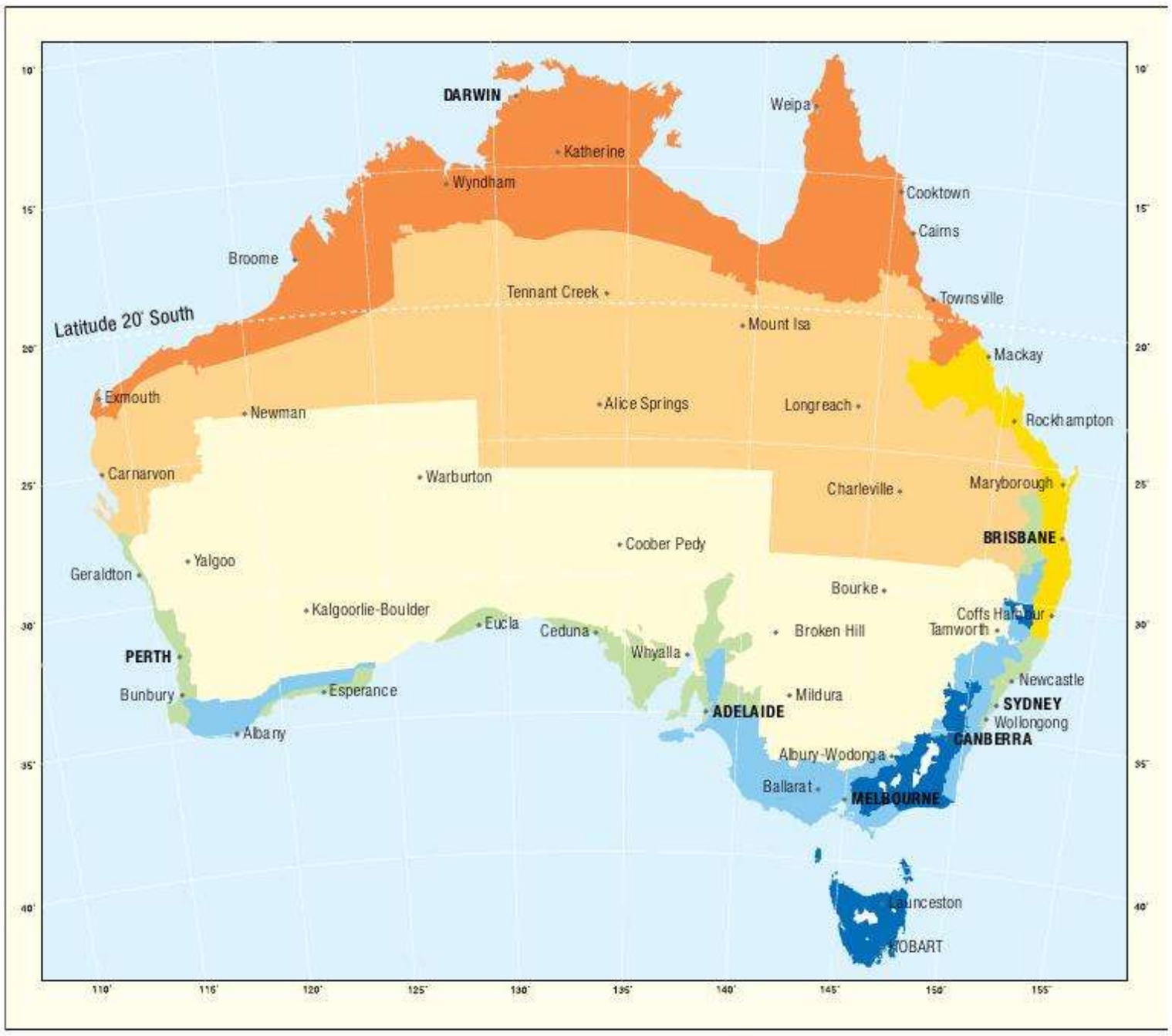
4.12 Apartments and Multi-unit Housing

Apartments and multi-unit dwellings offer additional challenges and opportunities for passive and sustainable design compared to individual dwellings.

This fact sheet examines the multiple design opportunities available.

Principal Author:
Chris Reardon

Design for Climate



ZONE	DESCRIPTION
1	High humid summer, warm winter
2	Warm humid summer, mild winter
3	Hot dry summer, warm winter
4	Hot dry summer, cool winter
5	Warm temperate
6	Mild temperate
7	Cool temperate
8	Alpine

This fact sheet provides an introductory guide to key passive design responses for each main climate zone in Australia. This is a simplified overview only and should be used in conjunction with more detailed information presented in subsequent fact sheets.

An explanation of the conditions required for human thermal comfort and how our bodies achieve it is included at the end of this fact sheet.

This fact sheet will guide you in choosing the passive design features most appropriate for your needs, site and climate.

AUSTRALIAN CLIMATE ZONES

Australia's broad range of climatic conditions have been grouped into eight zones, for simplicity. The main characteristics affecting envelope design for human comfort have been listed for each zone along with key responses.

Choose the climate zone for your site from the map and refer to the appropriate section for an overview of the climate and how to respond to it in passive design terms.

The BCA defines eight climate zones for thermal design within Australia. The designer or builder should be aware that the design and construction requirements of single dwellings differ for each climate zone.

There are many definitions of Australian climate zones. The zones used in this guide are defined by the Building Code of Australia.

Use this overview, and the highlighted references to other fact sheets to access more detailed information as you proceed through the various stages of designing, purchasing or altering your home.

ZONE 1

High humid summer, warm winter



Main characteristics:

Highly humid with a degree of 'dry season'.

High temperatures year round.

Minimum seasonal temperature variation.

Lowest diurnal (day/night) temperature range.

Key design responses:

Employ lightweight (low mass) construction.

Maximise external wall areas (plans with one room depth are ideal) to encourage movement of breezes through the building (cross ventilation). [See: 4.6 Passive Cooling]

Ceiling fans should be used where required.

Site for exposure to breezes and shading all year. [See: 4.3 Orientation]

Shade whole building summer and winter (consider using a fly roof). [See: 4.4 Shading]

Use reflective insulation and vapour barriers. [See: 4.7 Insulation]

Ventilate roof spaces.

Use bulk insulation if mechanically cooling. [See: 4.6 Passive Cooling]

Choose light coloured roof and wall materials.

Elevate building to permit airflow beneath floors.

Consider high or raked ceilings.

Provide screened, shaded outdoor living areas.

Consider creating sleepout spaces.

Design and build for cyclonic conditions.

ZONE 2

Warm humid summer, mild winter



Main characteristics:

High humidity with a definite ‘dry season’.

Hot to very hot summers with mild winters.

Distinct summer/winter seasons.

Moderate to low diurnal (day/night) temperature range. This can vary significantly between regions eg inland to coastal.

Key design responses:

Use lightweight construction where diurnal (day/night) temperature range is low and include thermal mass where diurnal range is significant. [See: 4.9 Thermal Mass]

Maximise external wall areas (plans ideally one room deep) to encourage movement of breezes through the building (cross ventilation). [See: 4.6 Passive Cooling]

Site for exposure to breezes. [See: 4.3 Orientation]

Evaporative cooling or ceiling fans should be used if required.

Shade whole building where possible in summer. [See: 4.4 Shading]

Allow passive solar access in winter months only.

Shade all east and west walls and glass year round.

Avoid auxiliary heating as it is unnecessary with good design.

Use reflective and bulk insulation (especially if the house is air-conditioned) and vapour barriers. [See: 4.7 Insulation]

Use elevated construction with enclosed floor space, where exposed to breezes.

Choose light coloured roof and wall materials

Provide screened and shaded outdoor living.

ZONE 3

Hot dry summer, warm winter



Main characteristics:

Distinct wet and dry seasons.

Low rainfall and low humidity.

No extreme cold but can be cool in winter.

Hot to very hot summers common.

Significant diurnal (day/night) range.

Key design responses:

Use passive solar design with insulated thermal mass. [See: 4.9 Thermal Mass]

Maximise cross ventilation. [See: 4.6 Passive Cooling]

Evaporative cooling or ceiling fans should be used if required.

Consider convective (stack) ventilation, which vents rising hot air while drawing in cooler air.

Site home for solar access and exposure to cooling breezes. [See: 4.3 Orientation]

Shade all east and west glass in summer. [See: 4.4 Shading]

Install reflective insulation to keep out heat in summer. [See: 4.7 Insulation]

Use bulk insulation in ceilings and walls.

Build screened, shaded summer outdoor living areas that allow winter sun penetration.

Use garden ponds and water features to provide evaporative cooling.

ZONE 4

Hot dry summer, cool winter



Main characteristics:

Distinct seasons with low humidity all year round.

High diurnal (day/night) temperature range.

Low rainfall.

Very hot summers common with hot, dry winds.

Cool winters with cold dry winds.

Key design responses:

Use passive solar principles with well insulated thermal mass. [See: 4.5 Passive Solar Heating; 4.9 Thermal Mass]

Maximise night time cooling in summer. [See: 4.6 Passive Cooling]

Consider convective (stack) ventilation, which vents rising hot air while drawing in cooler air.

Build more compact shaped buildings with good cross ventilation for summer.

Maximise solar access, exposure to cooling breezes and cool air drainage. Protect from strong, cold winter and dusty summer winds. [See: 4.3 Orientation]

Shade all east and west glass in summer. [See: 4.4 Shading]

Provide shaded outdoor living areas.

Consider adjustable shading to control solar access.

Auxiliary heating may be required. [See: 6.6 Renewable Energy]

Use evaporative cooling if required.

Avoid air-conditioning. [See: 6.2 Heating and Cooling]

Use reflective insulation to keep out summer heat. [See: 4.7 Insulation]

Use bulk insulation for ceilings, walls and exposed floors.

Consider double glazing.

Use ponds and water in shaded courtyards to provide evaporative cooling.

Draught seal thoroughly. Use airlocks to entries.

ZONE 5

Warm temperate



Main characteristics:

Low diurnal (day/night) temperature range near coast to high diurnal range inland.

Four distinct seasons. Summer and winter can exceed human comfort range. Spring and autumn are ideal for human comfort.

Mild winters with low humidity.

Hot to very hot summers with moderate humidity.

Key design responses:

Use passive solar principles. [See: 4.5 Passive Solar Heating; 4.6 Passive Cooling]

Use insulated thermal mass. [See: 4.9 Thermal Mass]

Use high insulation levels. [See; 4.7 Insulation]

Maximise solar access in winter. [See: 4.5 Passive Solar Heating]

Minimise all east and west glazing. Use adjustable shading. [See: 4.4 Shading]

Use double glazing to insulate windows. [See: 4.10 Glazing]

Minimise east and west wall areas.

Use cross ventilation and passive cooling in summer. [See: 4.6 Passive Cooling]

Use convective ventilation and circulation.

Site homes for solar access and exposure to cooling breezes.

Draught seal and use airlock entries.

No auxiliary heating or cooling is required in these climates with good design.

Use reflective insulation for summer heat.

Use bulk insulation to walls, ceilings and exposed floors.

ZONE 6

Mild temperate



Main characteristics:

Low diurnal (day/night) temperature range near coast to high diurnal range inland.

Four distinct seasons. Summer and winter can exceed human comfort range. Spring and autumn are ideal for human comfort.

Mild to cool winters with low humidity.

Hot to very hot summers, moderate humidity.

Key design responses:

Use passive solar principles. [See: 4.5 Passive Solar Heating; 4.6 Passive Cooling]

High thermal mass solutions are recommended. [See: 4.9 Thermal Mass]

Use high insulation levels, especially to thermal mass. [See: 4.7 Insulation]

Maximise north facing walls and glazing, especially in living areas with passive solar access. [See: 4.3 Orientation]

Minimise all east and west glazing.

Use adjustable shading. [See: 4.4 Shading]

Use double glazing and heavy drapes with sealed pelmets to insulate windows.

Minimise external wall areas (especially east and west).

Use cross ventilation and passive cooling in summer. [See: 4.6 Passive Cooling]

Use convective ventilation and heat circulation.

Site new homes for solar access, exposure to cooling breezes and protection from cold winds.

Draught seal thoroughly and use entry airlocks.

No auxiliary heating or cooling is required in these climates with good design.

Use reflective insulation to keep out summer heat.

Use bulk insulation to walls, ceilings and exposed floors.

ZONE 7

Cool Temperate



Main characteristics:

Low humidity, high diurnal range.

Four distinct seasons. Summer and winter exceed human comfort range, variable spring and autumn conditions.

Cold to very cold winters with majority of rainfall.

Hot dry summers.

Key design responses:

Use passive solar principles. [See: 4.5 Passive Solar Heating]

High thermal mass is strongly recommended. [See: 4.9 Thermal Mass]

Insulate thermal mass including slab edges. [See: 4.7 Insulation]

Maximise north facing walls and glazing, especially in living areas with passive solar access.

Minimise east, west and south facing glazing.

Use adjustable shading. [See: 4.4 Shading]

Use double glazing, insulating frames and/or heavy drapes with sealed pelmets to insulate glass in winter.

Minimise external wall areas (especially east and west).

Use cross ventilation and night time cooling in summer. [See: 4.6 Passive Cooling]

Site new homes for solar access, exposure to cooling breezes and protection from cold winds. [See: 4.3 Orientation]

Draught seal thoroughly and provide airlocks to entries.

Install auxiliary heating in extreme climates. Use renewable energy sources. [See: 6.2 Heating and Cooling; 6.6 Renewable Energy]

Use reflective insulation to keep out heat in summer.

Use bulk insulation to keep heat in during winter. Bulk insulate walls, ceilings and exposed floors.

ZONE 8

Alpine



Main characteristics:

Low humidity, high diurnal range.

Four distinct seasons. Winter can exceed human comfort range.

Cold to very cold winters with majority of rainfall. Some snowfall.

Warm to hot, dry summers, variable spring and autumn conditions.

Key design responses:

Use passive solar principles. [See: 4.5 Passive Solar Heating]

High thermal mass is recommended but must be well insulated. [See: 4.9 Thermal Mass]

Use high levels of insulation. [See: 4.7 Insulation]

Insulate thermal mass including slab edges.

Maximise north facing walls and glazing, especially in living areas with passive solar access.

Minimise east, west and south facing glazing.

Use adjustable shading. [See: 4.4 Shading]

Use double glazing and insulating frames. Augment with heavy drapes and pelmets.

Minimise external wall areas.

Use night time cooling in summer. [See: 4.6 Passive Cooling]

Use convective ventilation and circulation.

Site homes for solar access and protection from cold winds. [See: 4.3 Orientation]

Draught seal thoroughly and airlock entries.

Auxiliary heating may be required. [See: 6.2 Heating and Cooling]

Use reflective insulation to keep out summer heat. [See: 4.7 Insulation]

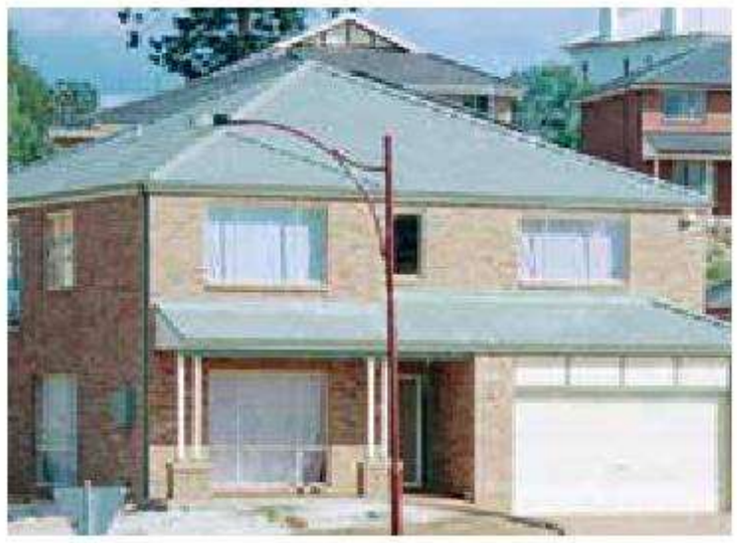
Use bulk insulation to walls, ceilings and exposed floors.

CLIMATE SENSITIVE DESIGN

The importance of climate sensitive design can not be overrated.



All round shading is appropriate for tropical climates only. This style does not work in warm, cool or cold climates.



Eaveless cold climate designs (borrowed from Europe) do not work in Australia.

Many homes are built without eaves to save as little as $2,500. Builders may then add an air conditioner to counteract the overheating effects of the sun. This environmental burden can easily be avoided.

Homeowners pay hundreds of dollars more than they need to each year in heating and/or cooling bills because they are not taking advantage of free heating and cooling from passive design.

HUMAN THERMAL COMFORT

The main factors influencing human comfort are:

> Temperature.

> Humidity.

> Air movement (breeze or draught).

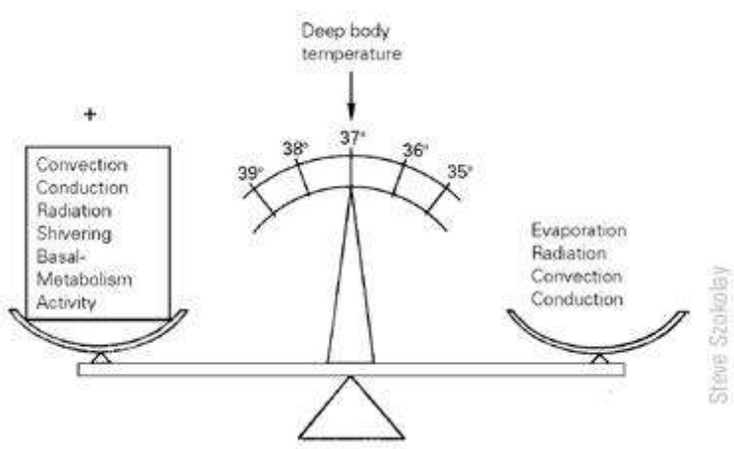
> Exposure to radiant heat sources.

> Cool surfaces to radiate for cooling.

Sound building envelope design will moderate all of these factors except humidity.

To do this effectively, envelope design should be varied to suit the climate. It can significantly improve comfort levels whilst reducing heating and cooling bills.

Humans are comfortable only within a very narrow range of conditions. Human body temperature must remain at a constant 36.9°C. The body generates heat – even while at rest. We must lose heat at the same rate as it is produced or gain heat at the same rate it is lost. The diagram below shows the various ways by which our bodies achieve this.



Losing body heat

We mainly lose heat through the evaporation of perspiration. High humidity levels reduce evaporation rates. When relative humidity exceeds 60 per cent, our ability to cool is greatly reduced.

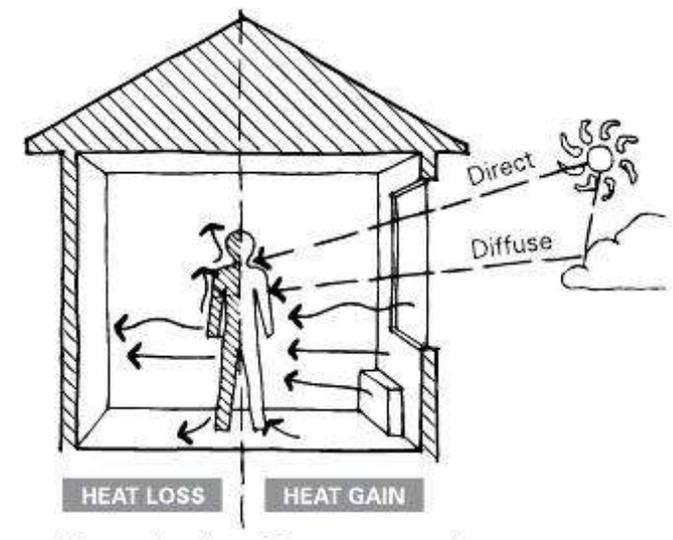
Evaporation rates are also influenced by air movement. Generally, a breeze of 0.5m per second provides a one off comfort benefit equivalent to a 3°C temperature reduction.

We also lose heat by radiating to surfaces cooler than our body temperature. The greater the temperature difference, the more we radiate. Whilst not our main means of losing heat, radiation rates are very important to our perception of comfort.

Gaining body heat

When the heat produced by our bodies is insufficient to maintain body temperature, we insulate by putting on more clothes, shelter from wind and draughts, or shiver (increasing the production of body heat).

This is because we generate most of the heat required from within. A secondary source of heat gain is radiation. As with cooling, radiation is very important to our perception of comfort.



ADDITIONAL READING

Contact your State / Territory government or local council for further information on passive design considerations for your climate.
www.gov.au

Australian Bureau of Meteorology
www.bom.gov.au/climate/environ/design/design.shtml

BEDP *Environment Design Guide*
DES 20 Arid Climates and Enhanced Natural Ventilation.
GEN 12 Residential Passive Solar Design.

Commonwealth of Australia, *Australian Model Code for Residential Development* (AMCORD) (1995), AGPS Canberra.

Hollo, N. (1997), *Warm House Cool House: Inspirational designs for low-energy housing*, Choice Books, Australia.

Wrigley, Derek (2004), *Making Your Home Sustainable: A Guide to Retrofitting*, Scribe, Carlton North, Victoria.

Principal Author:
Chris Reardon

Contributing Author:
Paul Downton

BUILDING THERMAL COMFORT

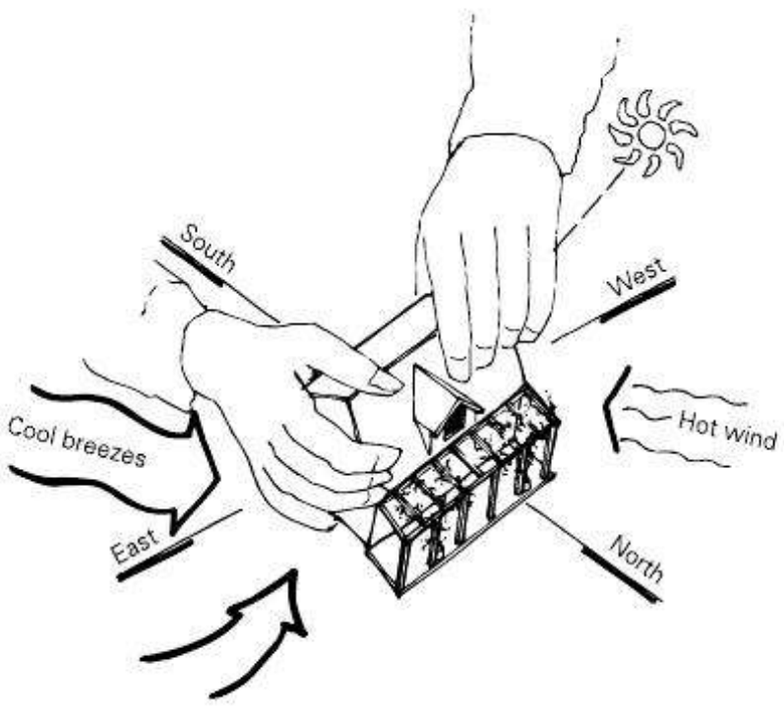
Thermal comfort rating (or building envelope performance) tools are computer programs that model the amount of heating and cooling energy required to maintain comfortable temperatures in a building. They take into account climate, season and envelope design. [See 1.5 Rating Tools]

A thermal comfort rating only reveals the energy performance of a building's design and fabric. It does not measure other areas of energy consumption (eg appliance efficiency, transport and embodied energy).

In warmer climates, these variables can account for more energy consumption during the lifespan of your home than the performance of the envelope.

Orientation

Good orientation increases the energy efficiency of a home, making it more comfortable to live in and cheaper to run. This fact sheet outlines the principals of good orientation and should be read in conjunction with the 4.5 Passive Solar Heating and 4.6 Passive Cooling fact sheets.



Principles of good orientation

With good orientation the need for auxiliary heating and cooling is reduced, resulting in lower energy bills and reduced greenhouse gas emissions.

Choose a site or home with good orientation for your climatic and regional conditions. Build or renovate to maximise the site's potential and to achieve the best possible orientation for living areas.

In high humid climates and hot dry climates with no winter heating requirements, orientation should aim to exclude sun year round and maximise exposure to cooling breezes.

In all other climates a combination of passive solar heating and passive cooling is required. The optimum degree of solar access and the need to capture cooling breezes will vary with climate.

Where ideal orientation is not possible, as is often the case in higher density urban areas, an energy efficient home can still be achieved with careful attention to design. [See: 4.5 Passive Solar Heating; 4.6 Passive Cooling]

Deciding the best orientation

Prioritise your heating and cooling needs. Are you in a climate that requires mainly passive heating, passive cooling, or a combination of both?

If unsure, compare your summer and winter energy bills, consult an architect or designer, your local energy authority or refer to local meteorological records. The website for the Australian Bureau of Meteorology is Research of your local climate may include:

> Temperature ranges- both seasonal and diurnal.

> Humidity ranges.

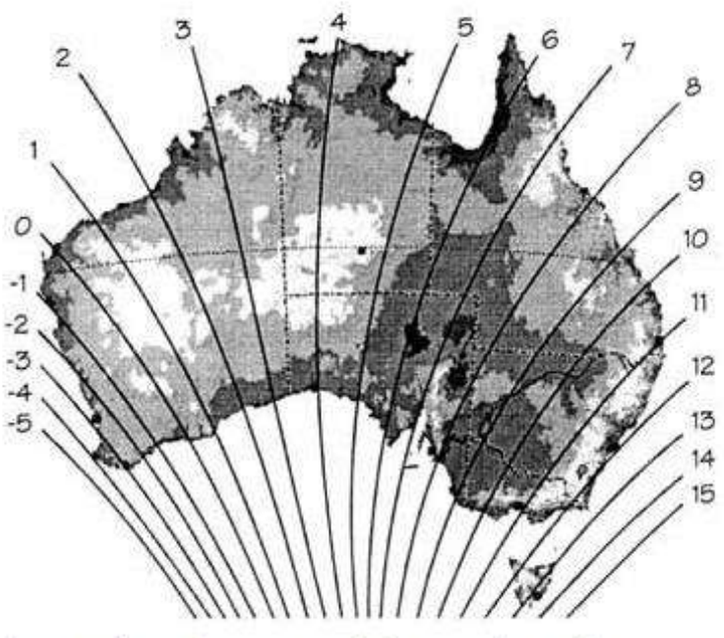
> Direction of cooling breezes, hot winds, cold winds, wet winds.

> Seasonal characteristics.

> Impact of local geographic features on climatic conditions. [See: 2.2 Choosing a Site]

Observe the impact of adjacent buildings and existing landscape on your site.

Establish true or solar north for your region. This is useful in all climates whether encouraging or excluding solar access. Maps and street directories can give this information. Alternatively, use a compass to establish magnetic north and then establish true or solar north by adding or subtracting the 'magnetic variation' for your area using the map below.



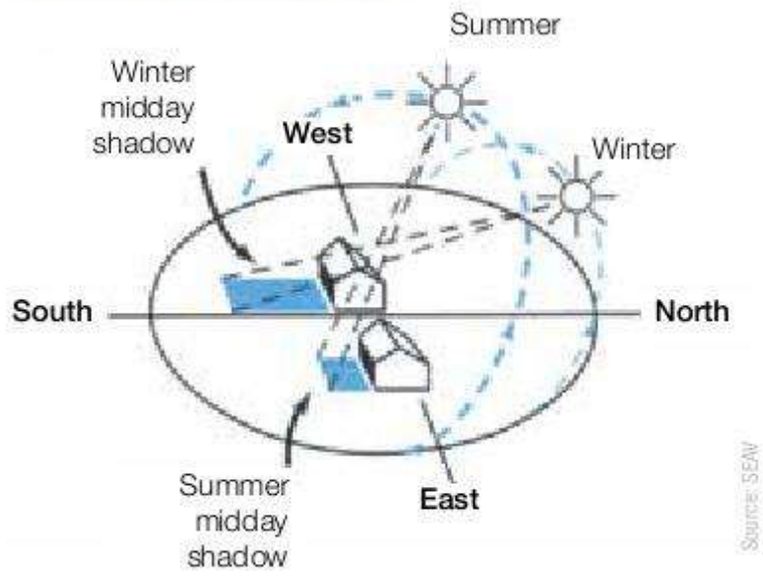
True north as degrees west of magnetic north.

Courtesy Dr Holger Wilhath – Solar Logic

Note that solar north deviates significantly from magnetic north throughout Australia and should be taken into account when orienting a home. All references to north in this guide are to solar north not magnetic north.

Your local council can assist you at the planning stage. Check the planning controls governing your site, for example building setbacks from boundaries and height limits, as they may affect how you build on your site.

ORIENTATION FOR PASSIVE HEATING



Source: SEAV

Orientation for passive heating is about using the sun as a source of free home heating. Put simply, it involves letting winter sun in and keeping unwanted summer sun out. This can be done with relative ease on northern elevations by using shading devices to exclude high angle summer sun and admit low angle winter sun. [See: 4.4 Shading]

In high humid climates, orientation should aim to exclude sun year round and maximise access to cooling breezes.



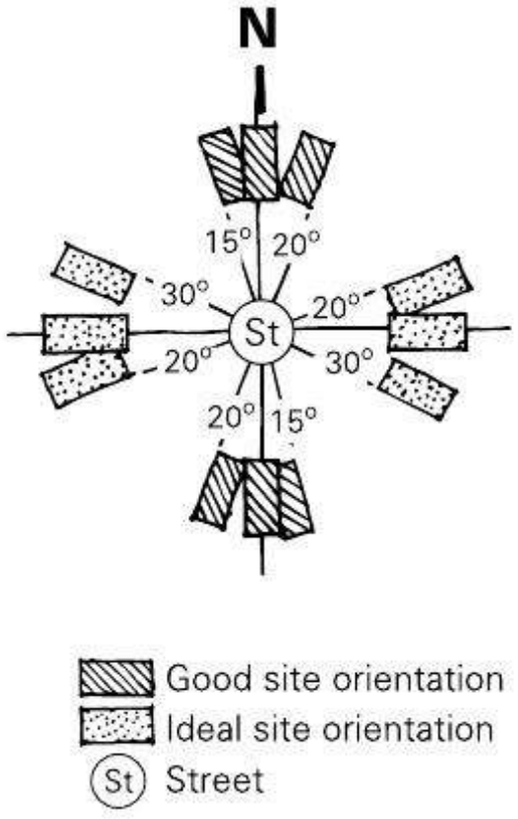
'Solar access' is the term used to describe the amount of useful sunshine reaching the living spaces of a home. The desired amount of solar access varies with climate.

Various techniques are available for measuring solar access when designing a new home or renovating, to ensure good solar access without compromising that of neighbours. These techniques include computer programs, charts and formulas.

The site

You can achieve good passive solar performance at minimal cost if your site has the right characteristics. Where possible, choose a site that can accommodate north-facing daytime living areas and outdoor spaces. [See: 2.2 Choosing a Site]

Permanent solar access is more likely to be achieved on a north-south block. However, on narrow blocks, careful design is required to ensure sufficient north facing glass is included for adequate passive solar heating. [See: 2.9 Challenging Sites]

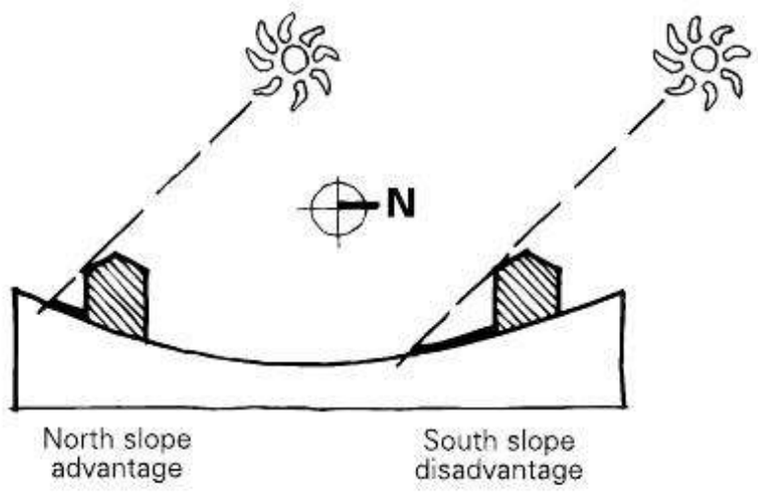


Sites running N-S are ideal because they receive good access to northern sun with minimum potential for overshadowing by neighbouring houses. In summer neighbouring houses can provide protection from low east and west sun.

N-S sites on the north side of the street allow north facing living areas and gardens to be located at the rear of the house for privacy.

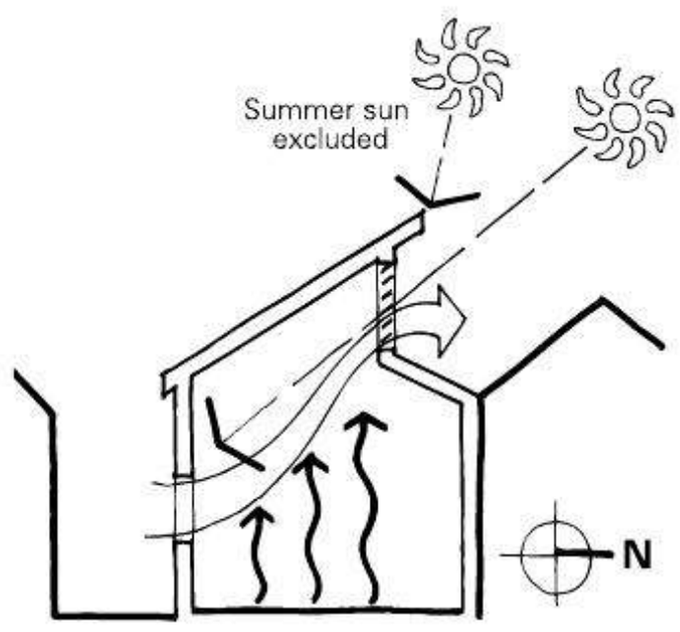
N-S sites on the south side of the street should be wide enough to accommodate an entry at the front as well as private north facing living areas. Set the house back to accommodate a north facing garden.

Sites running E-W should be wide enough to accommodate north facing outdoor space. Overshadowing by neighbouring houses is more likely to occur on these sites.



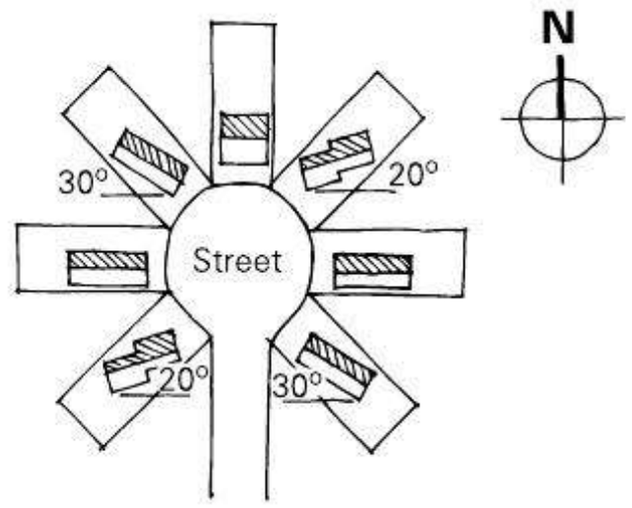
A north facing slope increases the potential for access to northern sun and is ideal for higher housing densities. A south facing slope increases the potential for overshadowing.

Views to the north are an advantage, as north is the best direction to locate windows and living areas. If the view is to the south avoid large areas of glass in order to minimise winter heat loss. West or east facing glass areas will cause overheating in summer if not properly shaded.



High level openable windows capture winter sun and create cooling currents in summer.

On sites with poor orientation or limited solar access due to other constraints, an energy efficient home is still achievable through careful design. A larger budget may be required. Use of advanced glazing systems and shading can achieve net winter solar gains from windows facing almost any direction while limiting summer heat gain to a manageable level. [See: 4.4 Shading; 4.5 Passive Solar Heating; 4.10 Glazing]



Day time living areas shown shaded.

The house

The ideal orientation for living areas is within the range 15°W-20°E of true or 'solar' north. (20°W-30°E of true north is considered acceptable). This allows standard eave overhangs to admit winter sun to heat the building and exclude summer sun, with no effort from the occupants and no additional cost. [See: 4.4 Shading; 4.5 Passive Solar Heating]

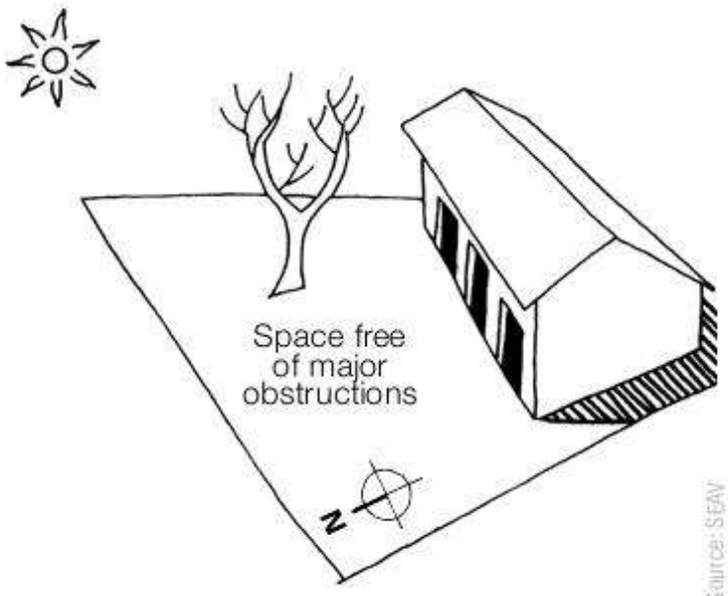
Poor orientation can exclude winter sun, and cause overheating in summer by allowing low angle east or west sun to strike glass surfaces.

Look for a house which has good orientation or can be easily adapted for better orientation.

Look for living spaces with good access to winter sun. North facing living areas and balconies or outdoor spaces are ideal.

Look for a suitable area of glass on north facing walls with access to winter sun. As a general guide this should be 10-25 per cent of the floor area of the room.

Check that west facing glazing is not excessive in area and is properly shaded to prevent overheating. West facing walls receive the strongest sun at the hottest part of the day.



Source: SEAV

Check that there is no significant detrimental over-shadowing by adjacent buildings and trees.

Ensure that there is year round solar access for clothes drying and solar collectors.

Project homes

Select a design that allows living areas to face north on your site. Most project home companies will mirror or flip a design to suit your needs at no extra cost.

Check and adjust north eave overhangs for passive performance. [See: 4.4 Shading]

Turn north facing verandahs into pergolas by replacing roofing material, such as, tiles or metal with slats or louvres, particularly over window areas.

Shade east and west facing glass by adding shade structures. Relocating verandahs and deep covered balconies to the east or west can improve shading on those elevations. [See: 4.4 Shading]

Reducing the amount of south, east and especially west facing glazing, or relocating some to north facing walls often adds no cost but significantly improves performance.

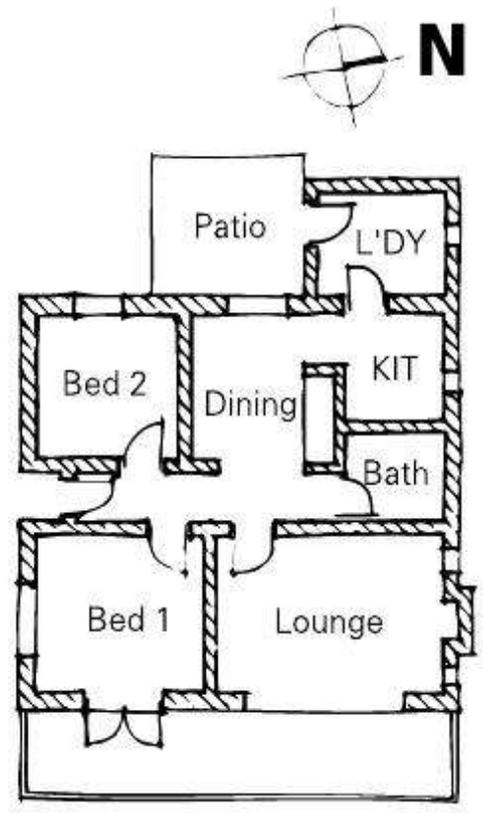
Smaller windows on south, east and west facing walls can aid cross ventilation.

Designing a new house or renovating

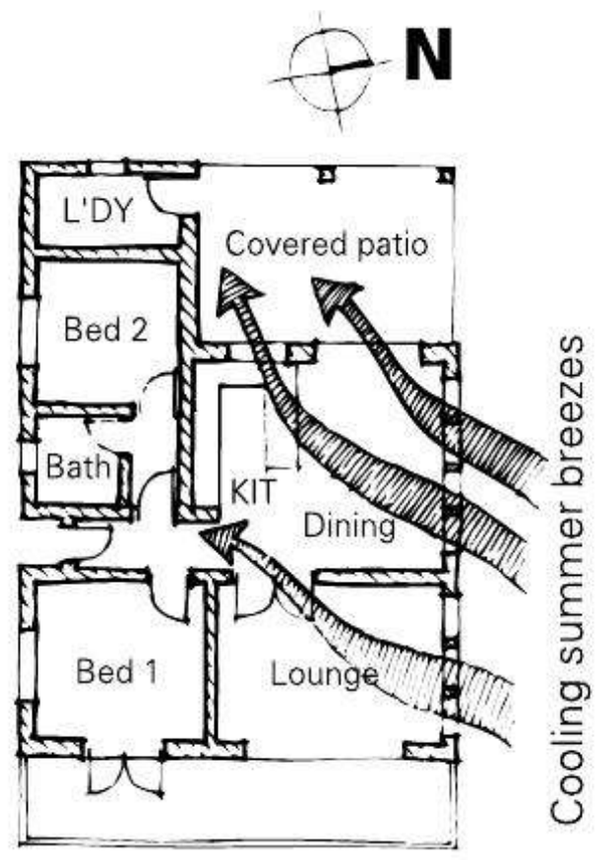
There are things you can do to maximise what your site has to offer when you build or renovate.

If renovating, check the existing floor plan. Do the living areas face the right way to take advantage of winter sun and cooling summer breezes?

It's easy to change the orientation of a house when renovating: swap room uses from one side of the house to another. Doing this enables the house to work better without necessarily becoming bigger. This saves building costs and long term running and maintenance costs.



Original floor plan.



New floor plan.

The diagrams above show how the layout of a house in a warm temperate climate was changed to let winter sun in and let summer breezes flow through.

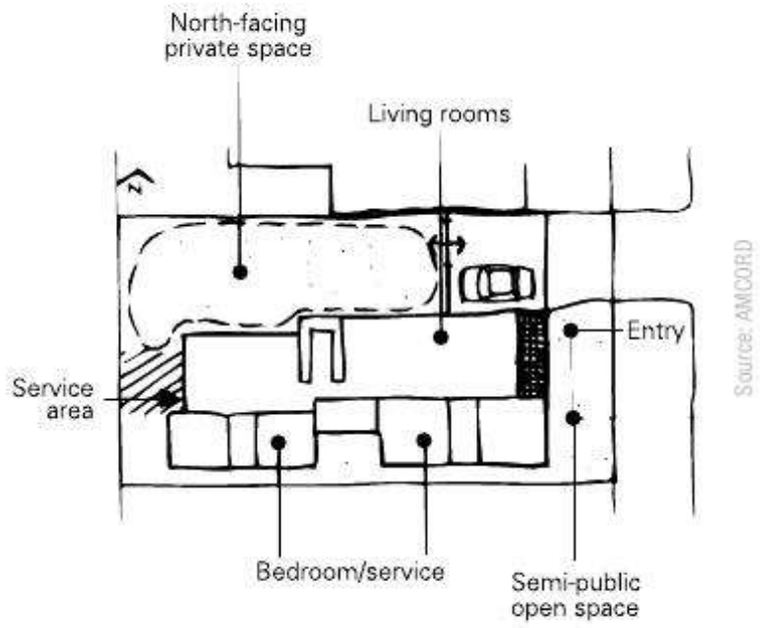
Maximise the amount of daytime living space that faces north, whether designing a new house or configuring renovations.

Provide passive solar shading to east, west and north facing elevations, particularly glass areas. Correctly designed eaves are generally all that is required to shade the northern elevations of single storey houses. [See: 4.4 Shading]

Place a suitable amount of glazing in north facing walls with solar access. The glazing area should be between 10 to 25 per cent of the floor area of the room, depending on climate and mass. [See: 4.5 Passive Solar Heating]

Glazing on other facades should ideally be less to prevent unwanted heat loss and gain. South facing glass facilitates winter heat loss, while east and particularly west facing glass encourages summer heat gain if not properly shaded. Smaller, well shaded windows are desirable for cross ventilation.

Avoid west facing bedrooms where possible. East facing bedrooms are acceptable as they capture morning sun but remain cool on summer evenings.



Source: AMCORD

Locate utility areas, such as, laundries, bathrooms, garages and sheds to the south, west and east to protect living areas from summer sun and winter winds.

Maximise the distance between the house and any building development to the north. Avoid placing obstructions, such as, carports or sheds to the north.

Building on the south boundary (if permitted by your local council) can be useful to increase the amount of north facing outdoor space. Avoid compromising the solar access of neighbours by overshadowing.

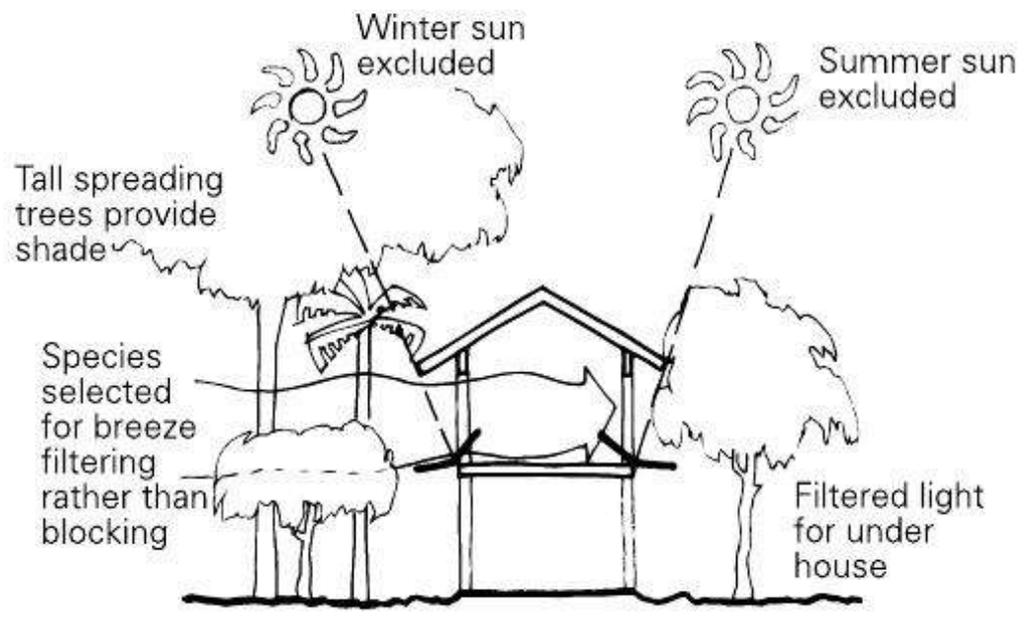
Plant shade trees in the appropriate locations. Landscaping can also be used to block or filter harsh winds. [See: 2.4 Sustainable Landscapes; 4.4 Shading]

Prune vegetation that blocks winter sun.

ORIENTATION FOR PASSIVE COOLING

Good orientation for passive cooling excludes unwanted sun and hot winds and ensures access to cooling breezes. A degree of passive cooling is necessary for most Australian climates.

In high humid climates and hot dry climates with warm winters, direct and reflected sunlight should be excluded at all times of the year. In all other climates a degree of controlled solar access is beneficial.



The site

Look for a site with good access to cooling breezes. Ensure that landscape and adjacent buildings do not block beneficial breezes. [See: 2.2 Choosing a Site]

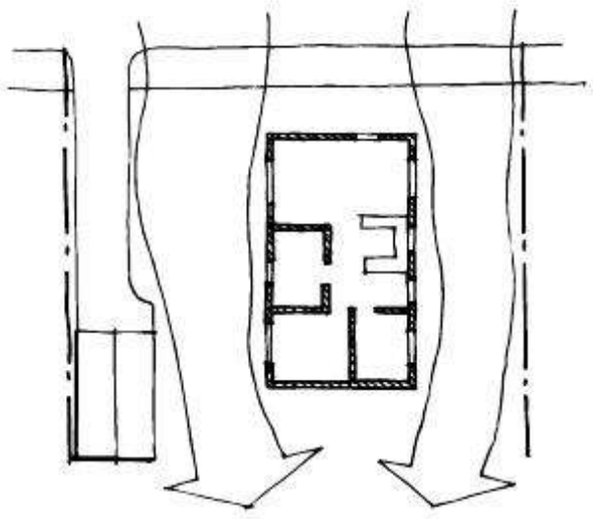
Look for a suitably shaded site. Land with a south facing slope will provide increased shade.

South is a good direction for views, as south facing windows require no shading from direct sun, or minimal shading above the Tropic of Capricorn.

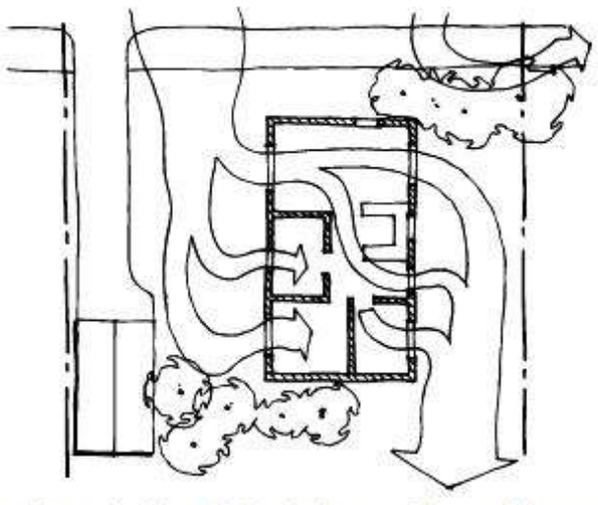
Solar access is beneficial for solar collectors, clothes drying and vegetable gardens in all climates.

On sites with poor orientation or no access to cooling breezes an energy efficient home is still possible with good design. Use high level windows and vents to create convection currents for cooling in the absence of breezes.

Landscape and building form can be designed to deflect and control the flow of breezes or to block unwanted sun. [See: 2.4 Sustainable Landscapes; 4.4 Shading; 4.6 Passive Cooling]



Prevailing breeze flows past house.



Dense tree planting deflects breeze through house.

The house

Choose or design a house with maximum exposure to cooling breezes and limited or no exposure to direct sun (depending on climate). Use careful design to improve performance in the case of poorly oriented sites or existing homes. [See: 4.6 Passive Cooling]

Security and noise can be an issue in many locations. Use security screens over openings to allow effective ventilation without compromising safety. In high noise areas early evening is a good time to ventilate the house. By night time the house has cooled and openings can be closed for a better sleep.

Look for a house that has good orientation or can be easily adapted for better orientation.

Look for a house that is well shaded and facilitates the flow of cooling breezes through it. [See: 4.6 Passive Cooling]



Narrow, elongated buildings facilitate passive cooling. Ideally the long elevation should open up to cooling breezes.

Avoid large, exposed areas of west facing wall if possible as they receive the strongest radiation at the hottest part of the day.

Open plan internal layouts facilitate ventilation. Houses of one-room depth are ideal.

Windows should be openable and located on more than one side of a room to improve ventilation.

Outdoor living areas, such as, courtyards, verandahs and balconies should be suitably shaded.

Project homes

Select a design that can be positioned on your site to capture cooling breezes, particularly to living areas. Avoid large areas of west facing windows.

Most project home companies will mirror or flip a design to suit your needs at no extra cost.

Moving windows or doors from one elevation to another to capture cooling breezes often adds no cost but makes significant improvements to performance.

Avoid windows with fixed glass. Ask for windows with a significant openable area for ventilation.

Ensure that all openings are suitably shaded. Use landscape as an effective means of providing additional shade. [See: 4.4 Shading]

Ask for eaves to be included if the design has omitted them.

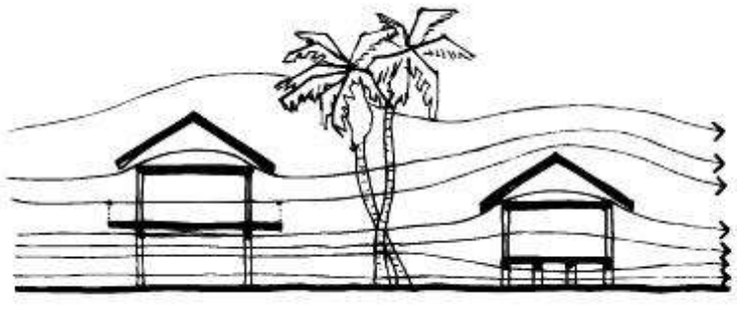
Designing a new house or renovating

There are things you can do to maximise what your site has to offer when you build or renovate.

If renovating, check the existing floor plan. Is the house configured to capture cooling breezes and let them flow through? It's easy to change the orientation of a house and the location of door and window openings when renovating.

Doing this enables the house to work better without necessarily becoming bigger. This saves building costs and long term running and maintenance costs.

Provide an appropriate level of shade and locate openings in the direction of cooling breezes. Shade the entire building in hot humid climates and hot dry climates with warm winters. [See: 4.6 Passive Cooling]



Design narrow, elongated building forms for best performance, with the long elevations opening up to cooling breezes. Elevating the house so that air can circulate beneath it will also assist performance.

Use landscape and building form to deflect cooling breezes into the interior and to exclude undesirable hot winds. Make use of shade or windbreaks provided by adjacent buildings or existing landscape.

Design extensions to open to cooling breezes, particularly if they are living areas.

Avoid large areas of exposed west facing wall.

East and west facing openings receive the strongest sun and are the most difficult to shade. Keep their size to a minimum if this does not compromise cooling by ventilation. Alternatively, ensure they are well shaded.

Ensure adequate north eaves overhangs, plus south eaves overhangs above the Tropic of Capricorn. [See: 4.4 Shading]

Design open plan interiors to facilitate ventilation. Homes of one-room depth with openings either side are ideal.

Design and position openings to control air flow. Use clerestory windows, roof ventilators, and vents in ridges, eaves and ceilings to create convection currents to cool the house in the absence of breezes. [See: 4.6 Passive Cooling]

Install windows that can be opened for maximum ventilation. When renovating, replace fixed windows with systems like casement windows or louvres.

Add additional small windows to rooms with only one window to improve ventilation.

Use vents above or in internal doors to facilitate cross ventilation.

Ensure outdoor living areas are shaded. Covered balconies and verandahs can be useful additions, providing shaded outdoor living space. Use landscape to provide additional shade.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on passive design considerations for your climate.
www.gov.au

Australian Bureau of Meteorology
www.bom.gov.au/climate/environ/design/design.shtml

BEDP *Environment Design Guide*
DES 8 Residential Sites – Analysis for Sustainability.
DES 9 Residential Sites – Sustainable Developments.
GEN 12 Residential Passive Solar Design.

Commonwealth of Australia (1995), *Australian Model Code for Residential Development* (AMCORD), AGPS Canberra.

Hollo, N. (1997), *Warm House Cool House: Inspirational designs for low-energy housing*, Choice Books, Australia.

Wrigley, Derek (2004), *Making Your Home Sustainable: A Guide to Retrofitting*, Scribe, Carlton North, Victoria.

Principal author:
Caitlin McGee

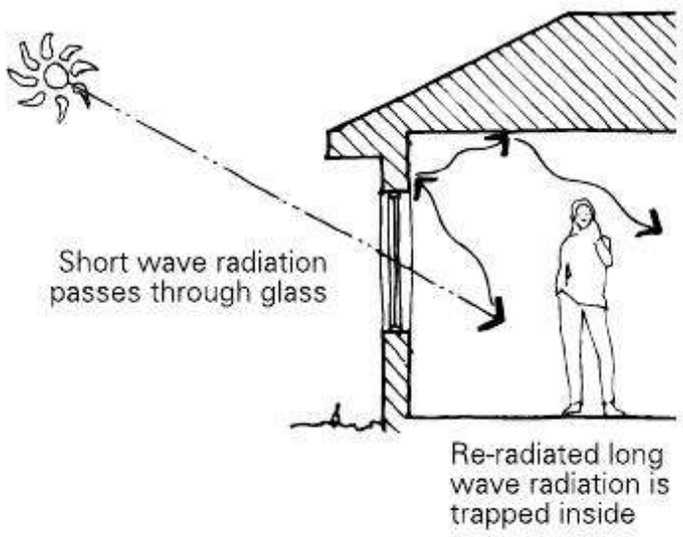
Contributing author:
Chris Reardon
Dick Clarke

Shading

Shading of the building and outdoor spaces reduces summer temperatures, improves comfort and saves energy. Direct sun can generate the same heat as a single bar radiator over each square metre of a surface. Shading can block up to 90 per cent of this heat.



Shading of glass to reduce unwanted heat gain is critical. Unprotected glass is often the greatest source of unwanted heat gain in a home.



Radiant heat from the sun passes through glass and is absorbed by building elements and furnishings, which then re-radiate it. Re-radiated heat has a different wavelength and cannot pass back out through the glass as easily. In most climates, 'trapping' radiant heat is desirable for winter heating but must be avoided in summer.

Shading of wall and roof surfaces is important to reduce summer heat gain, particularly if they are dark coloured and/or heavyweight.

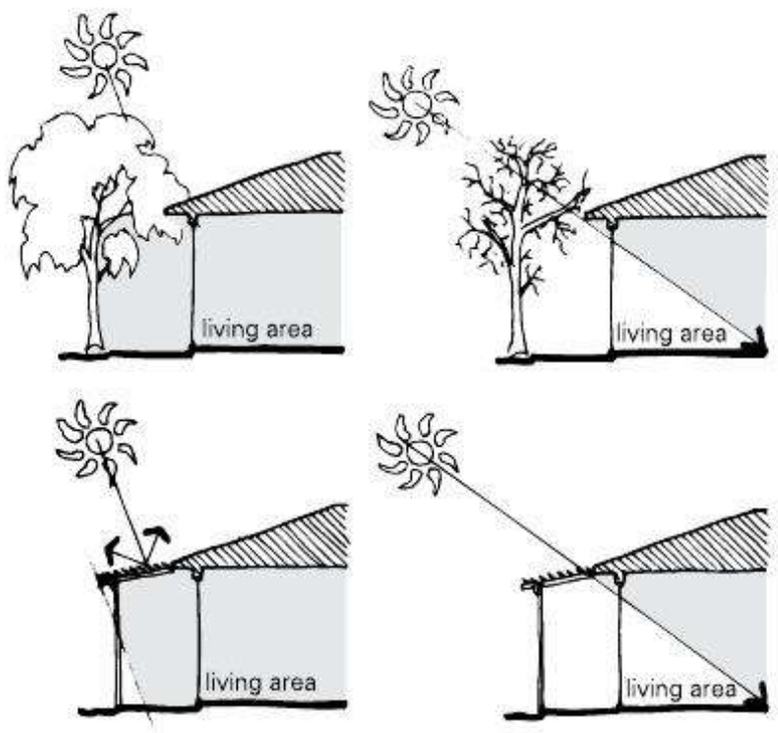
Shading requirements vary according to climate and house orientation. A general rule of thumb is described in the table below:

ORIENTATION	SUGGESTED SHADING TYPE
NORTH	fixed or adjustable shading placed horizontally above window
EAST and WEST	adjustable vertical screens outside window
NE and NW	adjustable shading
SE and SW	planting

GENERAL GUIDELINES FOR ALL CLIMATES

Use external shading devices over openings. Lighter-coloured shading devices reflect more heat. Internal shading will not prevent heat gain unless it is reflective.

Use plants to shade the building, particularly windows, to reduce unwanted glare and heat gain. Evergreen plants are recommended for high humid and some hot dry climates. For all other climates use deciduous vines or trees to the north, and deciduous or evergreen trees to the east and west.



With ideal north orientation sun can be excluded in summer and admitted in winter using simple horizontal devices, including eaves. For situations where ideal orientation cannot be achieved (eg existing house, challenging site) it is still possible to find effective shading solutions. [See: 4.3 Orientation; 4.5 Passive Solar Heating]

North facing openings (and south facing ones above the tropic of Capricorn) receive higher angle sun and therefore require narrower overhead shading devices than east or west facing openings. Fixed horizontal shading is often adequate above north facing glazing. Examples include eaves, awnings, and pergolas with louvres set to the correct angle, see 'Fixed shading for passive solar access' next page.

East and west facing openings require a different approach, as low morning and afternoon sun from these directions is more difficult to shade. Keep the area of glazing on east and west elevations to a minimum where possible, or use appropriate shading devices. Adjustable shading is the optimum solution for these elevations, see 'Adjustable shading'.



Deep verandahs, balconies or pergolas can be used to shade east and west elevations, but may still admit very low angle summer sun. Use in combination with planting to filter unwanted sun.



Pergolas covered with deciduous vines provide self adjusting seasonal shading. A 500mm gap between the wall and planted screens should be left for ventilation and cooling. Vines on walls (where appropriate) can also provide summer insulation to all orientations. Evergreen vines block winter sun and should only be used in tropical climates.

Use drought tolerant ground-cover plants instead of paving where possible, to keep the temperature of the ground and surrounding surfaces lower in summer.

Protect skylights and roof glazing with external blinds or louvres. This is crucial as roof glazing receives almost twice as much heat as an unprotected west facing window.

Position openable clerestory windows to face north with overhanging eaves to exclude summer sun.

Double glaze clerestory windows and skylights in cooler climates to prevent excessive heat loss.

Advanced glazing solutions, such as, solar films and tinted glass may be appropriate as a secondary measure on east and west elevations. They can exclude up to 60 per cent of the heat compared to plain glass.

Avoid using tinted glass on north facing windows designed to let in winter sun.
[See: 4.10 Glazing]

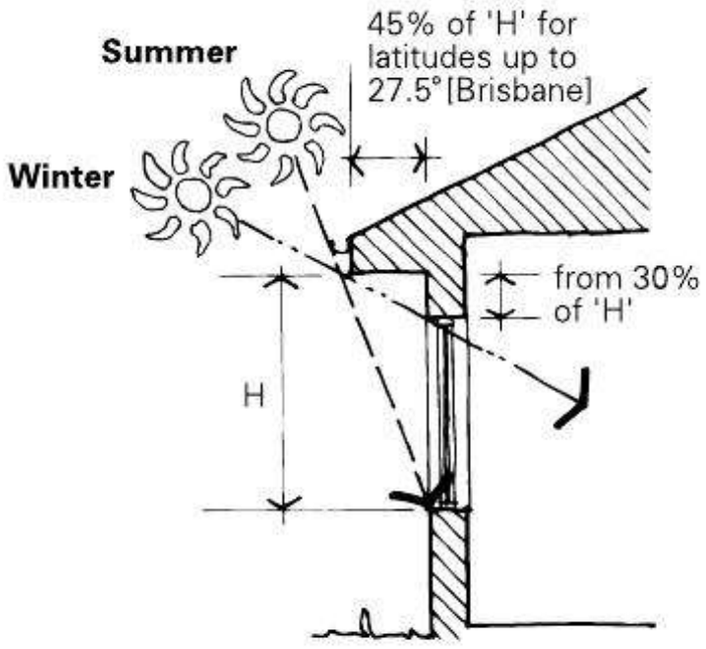
FIXED SHADING

Fixed shading devices (eaves, pergolas and louvres) can regulate solar access on northern elevations throughout the year, without requiring any user effort.

Summer sun from the north is at a high angle and is easily excluded by fixed horizontal devices over openings. Winter sun from the north is at a lower angle and will penetrate beneath correctly designed fixed horizontal devices.

Eaves

Correctly designed eaves are generally the simplest and least expensive shading method for northern elevations, and are all that is required on most single storey houses.



Rule of thumb for latitude south of and including 27.5ºS.

The general 'rule of thumb' for calculating eaves width for all latitudes south of and including 27.5°S (Brisbane, Geraldton) is given above.

Varying the rule of thumb may be beneficial:

> At high altitudes.

> Where cold winds or ocean currents are prevalent.

> In hot dry inland areas.

> In cold, high latitude areas [eg Tasmania].

For latitudes north of 27.5°S the response varies with climate. For high humid climates and hot dry climates with no passive heating requirements, shade the whole building at all times. For hot dry climates with passive heating requirements allow some low angle winter sun to reach walls, concrete floors and especially windows, see 'Climate-specific responses'.
[See: 4.5 Passive Solar Heating; 4.6 Passive Cooling]

Permanently shaded glass at the top of the window is a significant source of heat loss, especially in cool and cold climates. To avoid this, distances between the top of glazing and the eave underside should be at least 30 per cent of H.

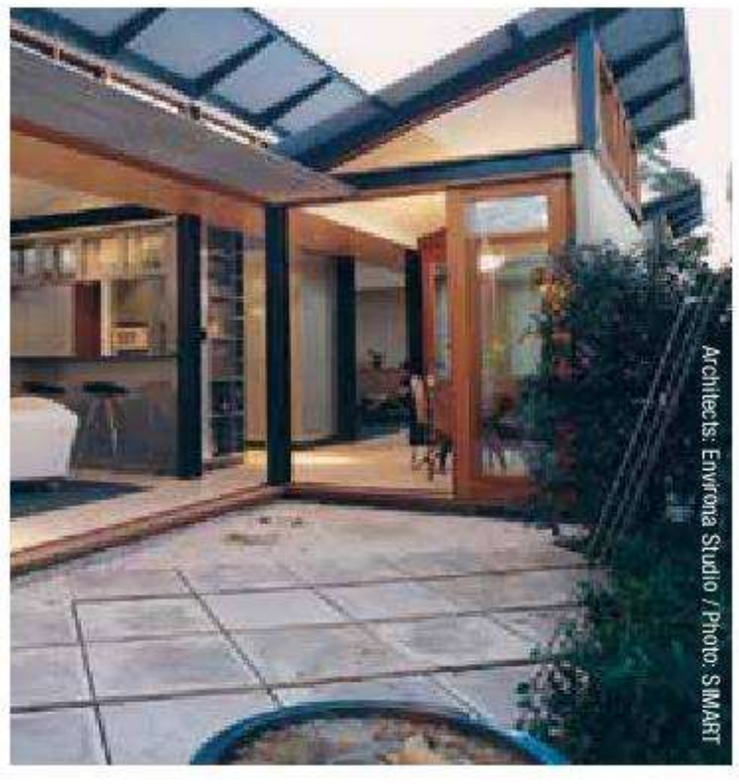
This is not always achievable with standard eave detailing which is flush with the 2100 head. The top 20 per cent of the window in the following image is in permanent shade.



In the image below, standard 2100 high doors are shaded by a 1000 eave (including gutter) set 300 above the head. Note the sun angle at midday in mid winter is above the glass line. This configuration provides full shading to glass from late October to late February at latitude 35°S (near Canberra) and is appropriate for a higher altitude cool climate winter.



In the image below, north facing upward raked eaves allow full exposure of glass to winter sun and shade larger areas in summer, without compromising the solar access of neighbours to the south. A separate horizontal projection of louvres shades lower glazing. This allows 100 per cent winter solar access and excludes all sun between the spring and autumn equinoxes.



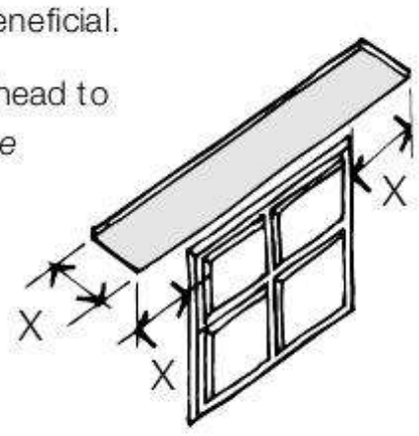
In colder higher latitudes, such as, Canberra, Armidale, Coonawarra, Mt Gambier, Albany, Ballarat, Colac, and all of Tasmania.

> Reduce eaves width to 42-43 per cent of H to extend the heating season past the equinox.

> Increase window head to eave distance.

In lower latitudes, such as, Alice Springs, Toowoomba, and Kingaroy, where the need for winter heating is significant but hot summers are common, varying eaves width may not be beneficial.

> Increase window head to eave distance. *See* 'Climate-specific responses' next page for more information.



Awnings and pergolas

Awnings and pergolas need to extend beyond the width of the north facing opening by the same distance as their outward projection.

For locations north of the Tropic of Capricorn (23.5ºS) in high humid climates or hot dry climates with warm winters, the building and outdoor living spaces should generally be shaded throughout the year.

Louvres

Fixed horizontal louvres set to the noon midwinter sun angle and spaced correctly allow winter heating and summer shading in locations with cooler winters.

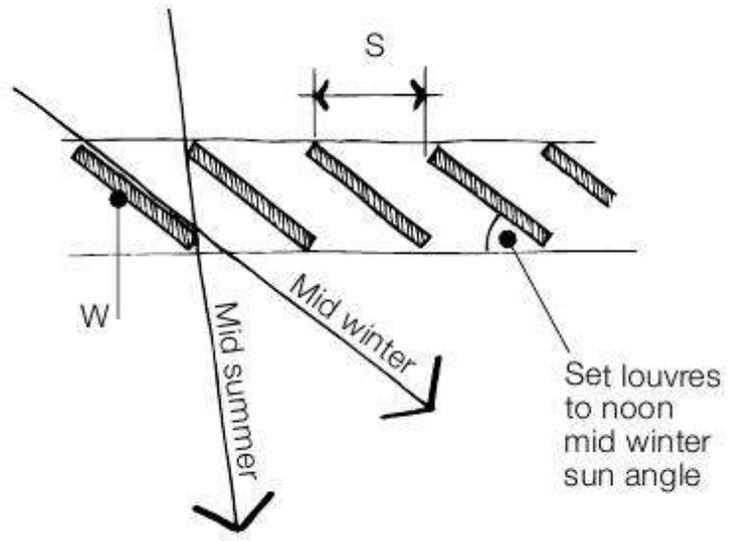
Midwinter and midsummer noon sun angles for locations can be calculated using the formulas below, where L is the latitude of your home.

Midwinter noon sun angle	= 90 – (L+23.5)
Midsummer noon sun angle	= 90 – (L–23.5)
Equinox noon sun angle	= 90 – L

The Geoscience Australia website (www.ga.gov.au/geodesy/astro) allows you to find the latitude of more than 250,000 place names in Australia, and will calculate the sun angle at any time of the day, on any day of the year.

As a rule of thumb, the spacing (S) between fixed horizontal louvres should be 75 per cent of their width (W).

The louvres should be as thin as possible to avoid blocking out the winter sun.



ANGLES OF LOUVRES TO THE HORIZONTAL	
Hobart	24º
Melbourne	29º
Sydney, Canberra, Adelaide	31º
Perth, Broken Hill, Port Augusta	34º
Brisbane, Geraldton	38º

ADJUSTABLE SHADING

Adjustable shading allows the user to choose the desired level of shade. This is particularly useful in spring and autumn when heating and cooling needs are variable. Note: active systems require active users.

Climate Change

Climate change does not affect sun angles, but the desirability of shade or solar gain may change, this affecting the overall design strategy.

Adjustable shading (mechanical or seasonal vegetation) will facilitate adaptation to changing climatic conditions.

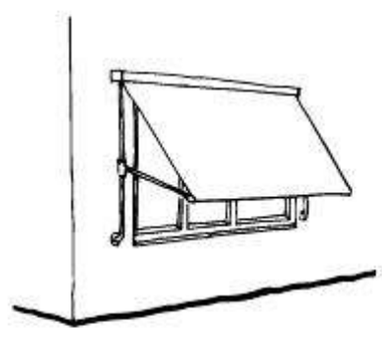


Northern elevations

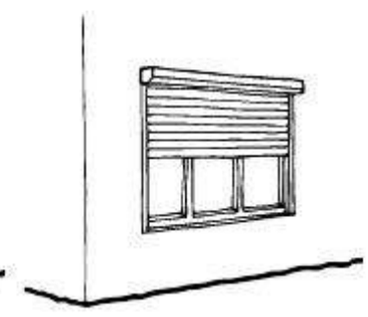
Adjustable shading appropriate for northern elevations includes adjustable awnings or horizontal louvre systems above glazing, and removable shadecloth over pergolas or sails. Shadecloth is a particularly flexible and low cost solution.

Eastern and western elevations

Adjustable shading is particularly useful for eastern and western elevations, as the low angle of the sun makes it difficult to get adequate protection from fixed shading. Adjustable shading gives greater control while enabling daylight levels and views to be manipulated. Appropriate adjustable systems include sliding screens, louvre screens, shutters, retractable awnings and adjustable external blinds.



Awning blind.

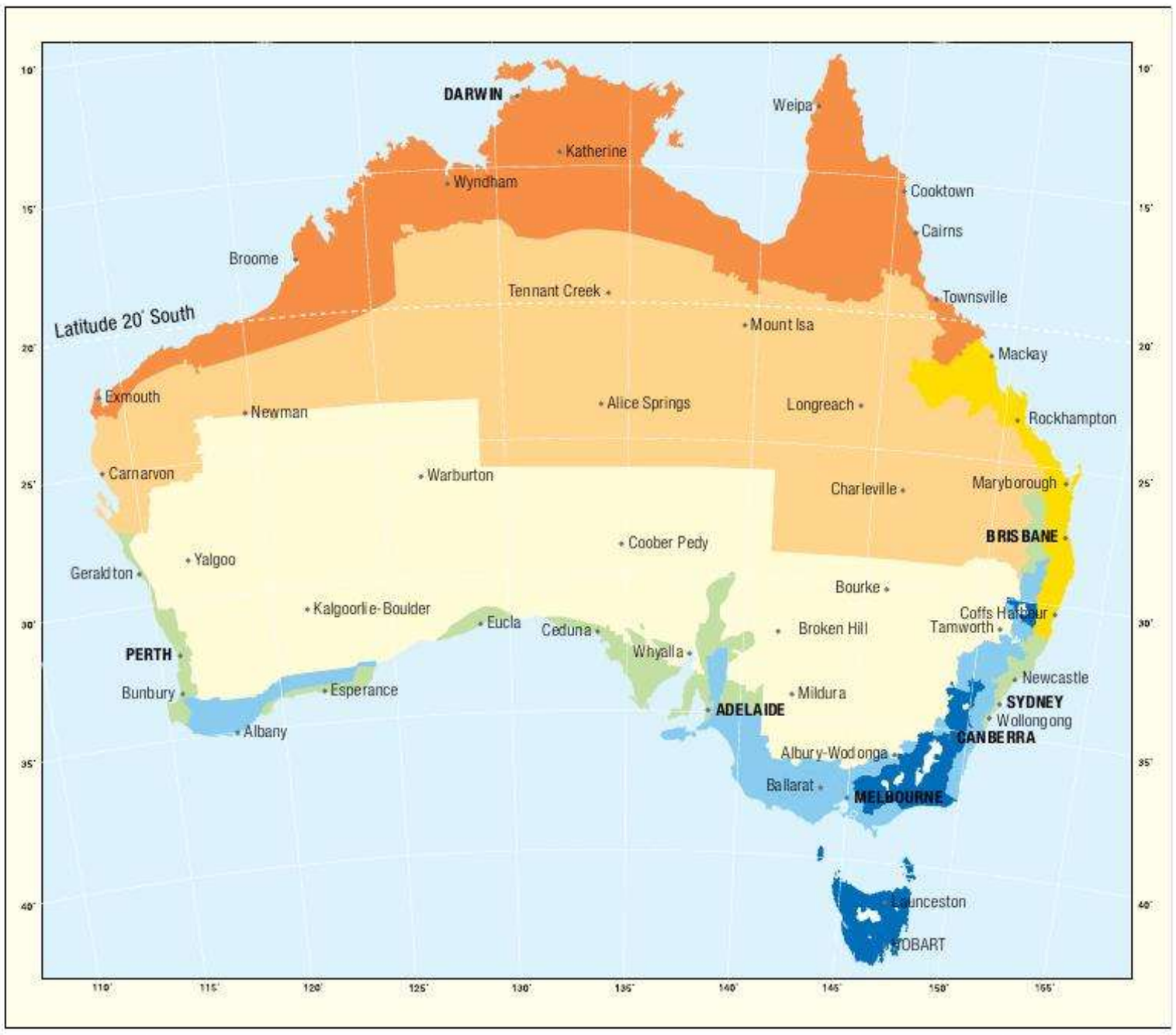


Roller shutter.

North-east and north-west elevations

Adjustable shading is recommended for these elevations as they receive a combination of high and low angle sun throughout the day. Typical responses for northern and eastern or western elevations need to be integrated. Select systems which allow the user to exclude all sun in summer, choose full sun in winter, and manipulate sun levels at other times.





ZONE	DESCRIPTION
1	High humid summer, warm winter
2	Warm humid summer, mild winter
3	Hot dry summer, warm winter
4	Hot dry summer, cool winter
5	Warm temperate
6	Mild temperate
7	Cool temperate
8	Alpine

CLIMATE SPECIFIC RESPONSES

High humid climates and hot dry climates with warm winters: Shade the building and outdoor living spaces throughout the year.

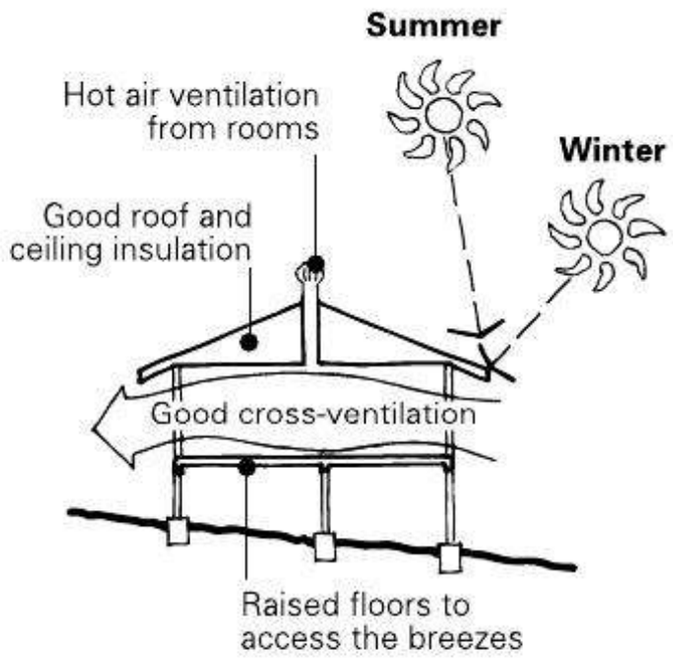
All other climates: Use appropriate passive solar design principles. [See: 4.1 Passive Design; 4.5 Passive Solar Heating; 4.6 Passive Cooling]

High humid climates

> Shade all external openings and walls including those facing south.

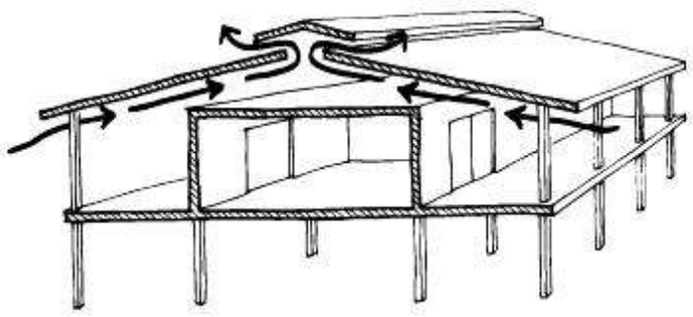
> Use covered outdoor living areas such as verandahs and deep balconies to shade and cool incoming air.

> Use shaded skylights to compensate for any resultant loss of natural daylight.



> Choose and position landscape to provide adequate shade without blocking access to cooling breezes.

> Use planting instead of paving, to reduce ground temperature and the amount of reflected heat.



> A 'fly roof' can be used to shade the entire building. It protects the core building from radiant heat and allows cooling breezes to flow beneath it.

Hot dry climates

> Shade all external openings in regions where no winter heating is required.

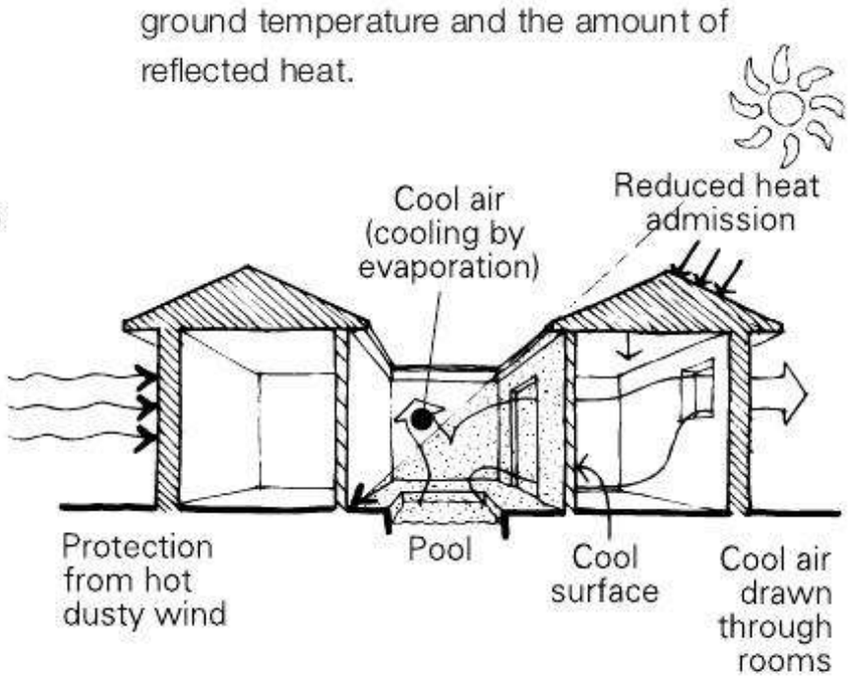
> Provide passive solar shading to north facing openings in regions where winter heating is required.

> Avoid shading any portion of the glass in winter – use upward raked eaves to allow full winter solar access, or increase the distance between the window head and the underside of the eave.

> Use adjustable shade screens or deep overhangs (or a combination of both) to the east and west. Deep covered balconies or verandahs shade and cool incoming air and provide pleasant outdoor living space.

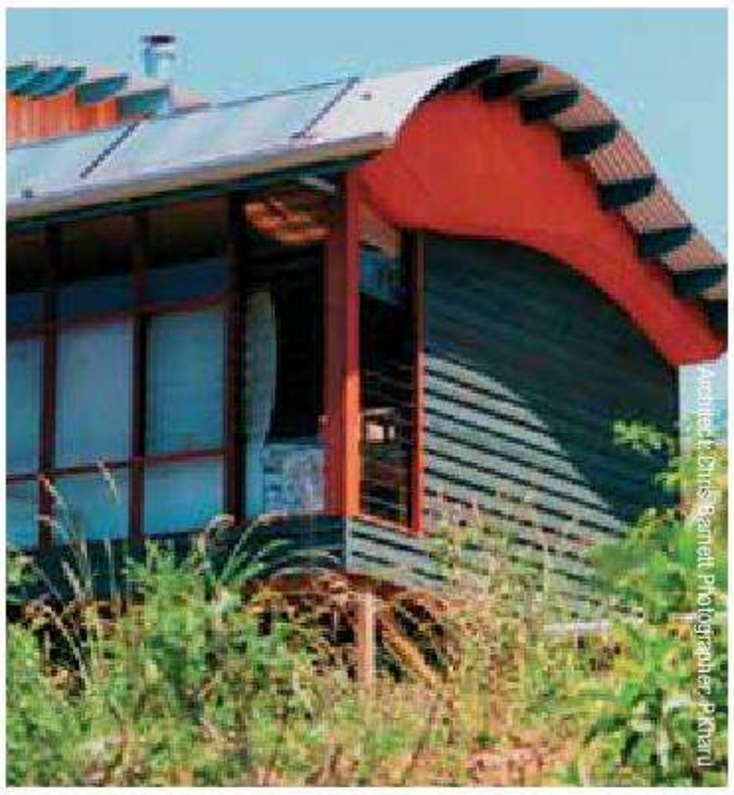
> Place a shaded courtyard next to the main living areas to act as a cool air well. Tall, narrow, generously planted courtyards are the most effective when positioned so that they are shaded by the house.

> Use planting instead of paving, to reduce ground temperature and the amount of reflected heat.



Warm humid and warm/mild temperate climates

> Provide passive solar shading to all north facing openings, using shade structures or correctly sized eaves.



> Use adjustable shade screens or deep overhangs to the east and west. Adjustable shade screens are the most effective at excluding low angle sun.

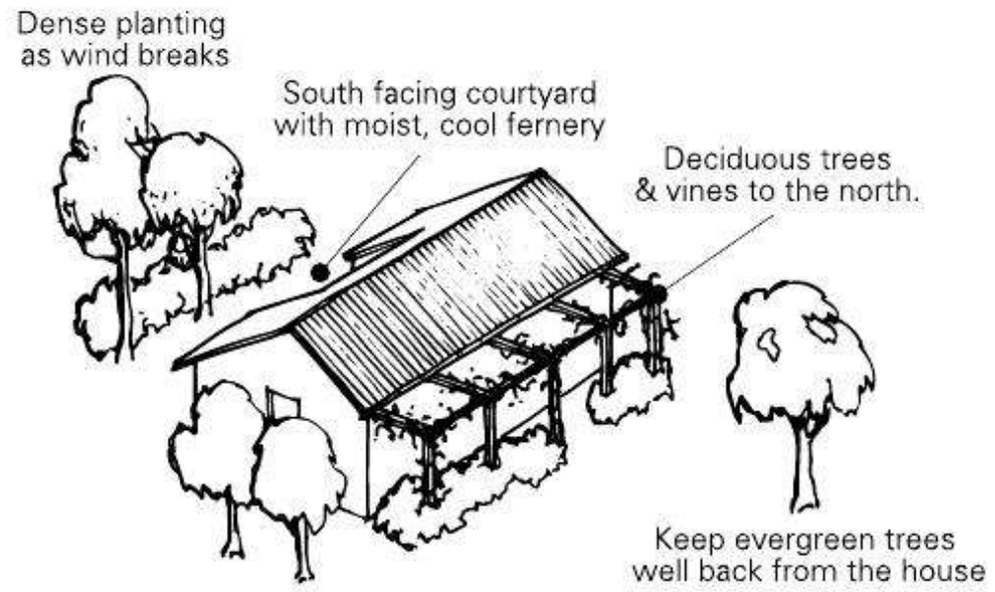
Cool temperate climates

> Do not place deep covered balconies to the north as they will obstruct winter sun. Balconies to the east or west can also obstruct winter sun to a lesser extent.



> Avoid shading any portion of the north facing glass in winter – use upward raked eaves to allow full winter solar access, or increase the distance between the window head and the underside of the eave.

> Use deciduous planting to the east and west. Avoid planting to the north which obstructs solar access.



USING PLANTS FOR SHADING

Match plant characteristics (such as foliage density, canopy height and spread) to shading requirements. Choose local native species with low water requirements wherever possible.

In addition to providing shade, plants can assist cooling by transpiration. Plants also enhance the visual environment and create pleasant filtered light. [See: 2.4 Sustainable Landscapes]

> Deciduous plants allow winter sun through and exclude summer sun.

> Trees with high canopies are useful for shading roofs and large portions of the building structure.

> Shrubs are appropriate for more localised shading of windows.

> Wall vines and ground cover insulate against summer heat and reduce reflected radiation.

SHADING AND DAYLIGHT

Choose shading methods that allow adequate amounts of daylight into the building while preventing unwanted heat gain.

> Select plants that allow filtered light into the building. [See: 2.4 Sustainable Landscapes]

> Design glazing to admit maximum light for minimum heat gain. Clear sections in verandah roofs can be useful. [See: 4.10 Glazing]

> Light coloured external surfaces or shading devices reflect more light into the building. Depending on the situation this can be beneficial, or it can create unwanted glare.

SHADING FOR A HEALTHIER ENVIRONMENT

Appropriate shading practices reduce the chance of exposure to harmful UV rays. Planting is a low cost, low energy provider of shade that improves air quality by filtering pollutants.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on passive design considerations for your climate.
www.gov.au

Australian Bureau of Meteorology
www.bom.gov.au/climate/environ/design/design.shtml

Commonwealth of Australia, *Australian Model Code* for Residential Development (AMCORD) (1995), AGPS Canberra.

Hollo, N. (1997), *Warm House Cool House: Inspirational designs for low-energy housing*, Choice Books, Australia.

Wrigley, Derek (2004), *Making Your Home Sustainable: A Guide to Retrofitting*, Scribe, Carlton North, Victoria.

Principal author:
Caitlin McGee

Passive Solar Heating

This fact sheet explains how the passive design principles discussed in other fact sheets can be applied to utilise free heating direct from the sun.

On average, 38 per cent of energy consumed in Australian homes is for space heating and cooling. Using passive solar design dramatically reduces this figure.

WHAT IS PASSIVE SOLAR HEATING?

Passive solar heating is the least expensive way to heat your home. It is also:

> Free when designed into a new home or addition.

> Appropriate for all climates where winter heating is required.

> Achievable when building or renovating on any site with solar access – often with little effort.

> Achievable when buying a project home, with correct orientation and slight floor plan changes.

> Achievable when choosing an existing house, villa or apartment. Look for good orientation and shading.

> Achievable using all types of Australian construction systems.

Put simply, design for passive solar heating is about keeping out summer sun and letting in winter sun.

Passive solar heating requires careful application of the following passive design principles:

> Northerly orientation of daytime living areas.

> Appropriate areas of glass on northern facades.

> Passive shading of glass.

> Thermal mass for storing heat.

> Insulation and draught sealing.

> Floor plan zoning based on heating needs.

> Advanced glazing solutions.

This will maximise winter heat gain, minimise winter heat loss and concentrate heating where it is most needed.



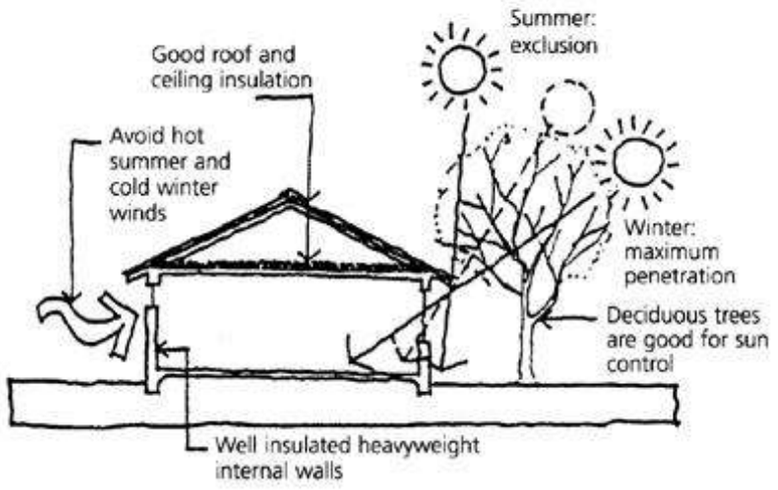
Passive solar houses can look like other homes but cost less to run and are more comfortable to live in.

HOW PASSIVE SOLAR HEATING WORKS

Solar radiation is trapped by the greenhouse action of correctly oriented (north facing) windows exposed to full sun. Window frames and glazing type have a significant effect on the efficiency of this process. [See: 4.10 Glazing]

Trapped heat is absorbed and stored by materials with high thermal mass (usually masonry) inside the house. It is re-released at night when it is needed to offset heat losses to lower outdoor temperatures. [See: 4.9 Thermal Mass]

Passive shading allows maximum winter solar gain and prevents summer overheating. This is most simply achieved with northerly orientation of appropriate areas of glass and well designed eaves overhangs. [See: 4.4 Shading]



Heat is re-radiated and distributed to where it is needed. Direct re-radiation is the most effective means. Design floor plans to ensure that the most important rooms (usually day-use living areas) face north for the best solar access. Heat is also conducted through building materials and distributed by air movement.

Heat loss is minimised with appropriate window treatments and well insulated walls, ceilings and exposed floors. Thermal mass must be insulated to be effective. Slab-on-ground (SOG) edges need to be insulated if located in climate zone 8, or when in-slab heating or cooling is installed within the slab. [See: 4.7 Insulation; 4.9 Thermal Mass]

Air infiltration is minimised with airlocks, draught sealing, airtight construction detailing and quality windows and doors.

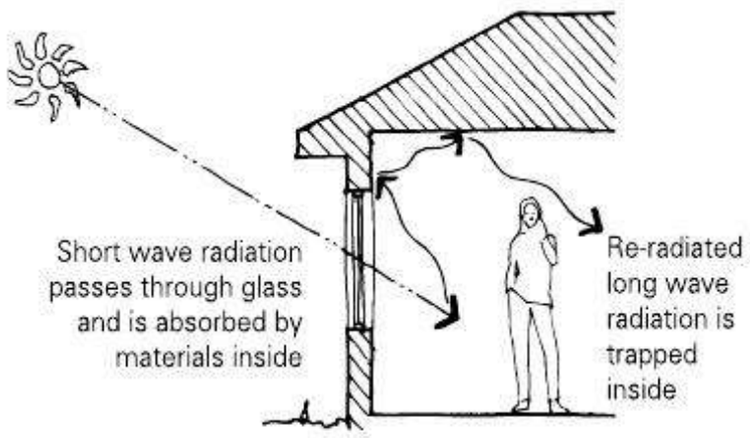
Appropriate house shape and room layout is important to minimise heat loss, which occurs mostly through the roof and then through external walls. In cool and cold climates, compact shapes that minimise roof and external wall area are more efficient. As the climate gets warmer more external wall area is appropriate.

PASSIVE SOLAR DESIGN PRINCIPLES

Greenhouse (glasshouse) principles

Passive design relies on greenhouse principles to trap solar radiation.

Heat is gained when short wave radiation passes through glass, where it is absorbed by building elements and furnishings and re-radiated as longwave radiation. Longwave radiation cannot pass back through glass as easily.



This diagram shows the percentage of solar heat gain through standard 3mm glazing. For comparison to advanced glazing materials. [See: 4.10 Glazing]

Heat is lost through glass by conduction, particularly at night. Conductive loss can be controlled by window insulation treatments, such as, close fitting heavy drapes with snug pelmets, double glazing and other advanced glazing technology.

Orientation for passive solar heating

For best passive heating performance, daytime living areas should face north. Ideal orientation is true north and can be extended to between 15° west and 20° east of solar north. [See: 4.3 Orientation]

Where solar access is limited, as is often the case in urban areas, energy efficiency can still be achieved with careful design.

Homes on poorly oriented or narrow blocks with limited solar access can employ alternative passive solutions to increase comfort and reduce heating costs. [See: 2.9 Challenging Sites; 4.4 Shading; 4.7 Insulation; 4.9 Thermal Mass; 4.10 Glazing]

Passive solar shading

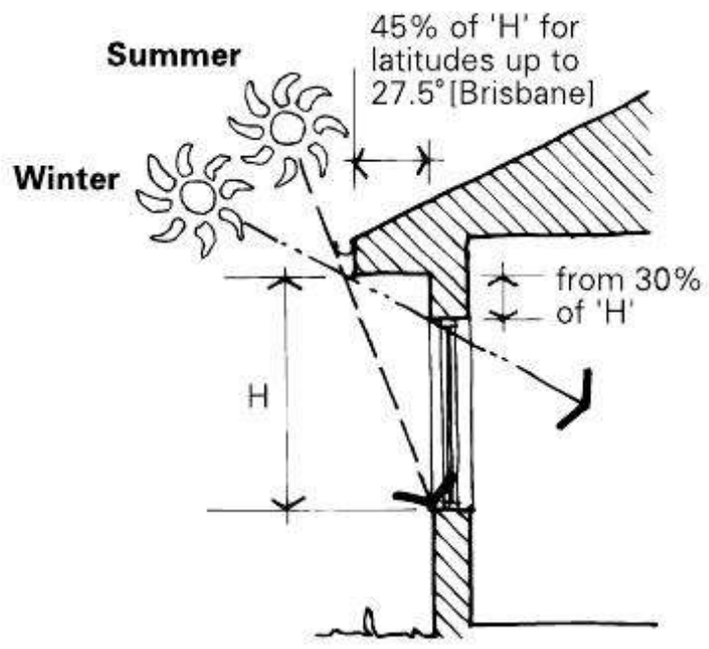
Fixed shading devices can maximise solar access to north facing glass throughout the year, without requiring any user effort. Good orientation is essential for effective passive shading.

Fixed shading above openings excludes high angle summer sun but admits lower angle winter sun.

Use adjustable shading to regulate solar access on other elevations.

Correctly designed eaves are the simplest and least expensive shading method for northern elevations.

The 'rule of thumb' for calculating eaves width is given below. This rule applies to all latitudes south of and including 27.5° (Brisbane, Geraldton). For latitudes north of this the response varies with climate. [See: 4.4 Shading]



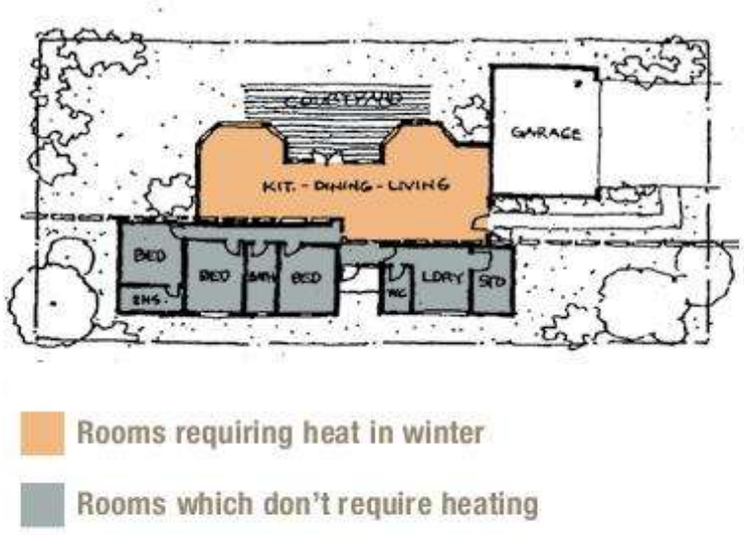
Permanently shaded glass at the top of the window is a significant source of heat loss. To avoid this, the distance between the top of glazing and eaves underside should be 50 per cent of overhang or 30 per cent of window height. [See: 4.4 Shading]

Heat loss through glass (and walls) is proportional to the difference between internal and external temperatures. Because the hottest air rises to the ceiling, the greatest temperature difference occurs at the top of the window.

PLANNING AND DESIGN

Floor planning

Plan carefully to ensure passive solar gain to the rooms that most need it.



Source: Amcord, 1995

In general, group living areas along the north facade and bedrooms along the south or east facade.

Living areas and the kitchen are usually the most important locations for passive heating as they are used day and evening.

Bedrooms require less heating. It is easy to get warm and stay warm in bed. Children's bedrooms can be classified as living areas if considerable hours are spent there.

Utility and service areas, such as, bathrooms, laundries and garages are used for short periods and generally require less heating. These areas are best located:

> To the west or south west, to act as a buffer to hot afternoon sun and the cold westerly winds common to many regions.

> To the east and south east, except where this is the direction of cooling breezes.

Detached garages to the east and west can protect north facing courtyards from low angle summer sun and direct cooling breezes into living spaces.

Compact floor plans minimise external wall and roof area, thereby minimising heat loss. Determine a balance between minimising heat loss and achieving adequate daylighting and ventilation.

Consider specific regional heating and cooling needs and the site characteristics to determine an ideal building shape.

Locating heaters

Internal thermal mass walls are ideal for locating heaters next to. Thermal lag will transfer heat to adjoining spaces over extended periods. [See: 6.2 Heating and Cooling]

External wall locations can result in additional heat loss, as increasing the temperature differential between inside and out increases the rate of heat flow through the wall. Heaters should not be located under windows.

Heaters create draughts when operating, see above. Try to locate heaters where they can draw cooled air back via passageways rather than through sitting areas.

Locating thermal mass

As a first priority, locate thermal mass where it is exposed to direct solar radiation or radiant heat sources. Thermal mass will also absorb reflected radiant heat.

Additionally, thermal mass should be located predominantly in the northern half of the house where it will absorb most passive solar heat.

Consider use of low thermal mass materials and high levels of insulation in south facing rooms.

Use thermal mass dividing walls between north facing living rooms and south facing bedrooms. Thermal lag will distribute some of the heat to bedrooms.

Air movement within the house will heat or cool thermal mass. Locate mass away from cold draught sources (eg. entries) and expose it to convective warm air movement within the house (eg. hallways to bedrooms). Consider the balance between heating and cooling requirements. [See: 4.9 Thermal Mass]



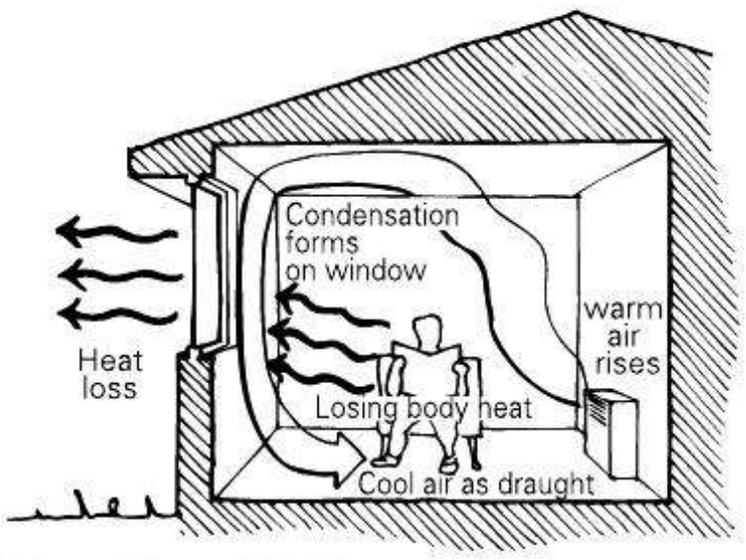
Air movement and comfort

Air movement creates a cooling effect by increasing the evaporation of perspiration. Draughts increase the perception of feeling cold. [See: 4.1 Passive Design]

Avoid convection draughts by designing floor plans and furnishing layouts so that cooled return air paths from windows and external walls to heaters or thermal mass sources are along traffic areas (hallways, stairs, non-sitting areas).

Create draught free nooks for sitting, dining and sleeping.

Use ceiling fans to circulate warm air evenly in rooms and push it down from the ceiling to living areas. For low ceilings, use fans with reversible blade direction.



Adverse effects of draughts.

DESIGN FOR CONVECTIVE AIR MOVEMENT

Convection currents are created when heat rises to the ceiling and air cooled by windows and external walls is drawn back along the floor to the heat source.

Convective air movement can be used to great benefit with careful design or can be a major source of thermal discomfort with poor design.

> Analyse warm air flows by visualising a helium filled balloon riding the thermal currents. Where would it go? Where would it be trapped?

> Analyse cool air flows by visualising where water would run if you left an upstairs tap on.

Single storey homes

Minimise convective air movement in winter with insulation of walls, glazing and ceilings. Some convection will still occur and is a major means of passive heat distribution in any home.

Controlled convection can be used to warm rooms not directly exposed to heat sources. It can also reduce unwanted heat loss from rooms that do not require heating.

Opening or closing doors will control the return air flow but impact on privacy. Use vents that can be opened or sealed.

Highlight louvres or transom panels over doors promote and control movement of the warmest air at ceiling level whilst retaining privacy.

Floor to ceiling doors are effective in facilitating air movement.

Multi-storey homes

> Place the majority of thermal mass and the main heating sources at lower levels.

> Use high insulation levels and lower (or no) thermal mass at upper levels.

> Ensure upper levels can be closed off to stop heat rising in winter and overheating in summer.

> Use stairs to direct cool air draughts back to heat sources, located away from sitting areas.

> Avoid open balcony rails. They allow cool air to fall like a waterfall into spaces below.

> Use ceiling fans to push warm air back to lower levels.

> Minimise window areas at upper levels and double glaze. Use close fitting drapes with snug pelmet boxes.

> Maximise the openable area of upper level windows for summer ventilation. Avoid fixed glazing.

> Locate bedrooms upstairs in cold climates so they are warmed by rising air.

PREVENTING HEAT LOSS

Preventing heat loss is an essential component of efficient home design in most climates. It is even more critical in passive solar design as the heating source is only available during the day.

The building fabric must retain energy collected during the day for up to 16 hours each day and considerably longer in cloudy weather. To achieve this, careful attention must be paid to each of the following factors.

> Insulation.

> Draught sealing.

> Windows and glazing.

> Air locks.

Insulation

For housing, the insulation requirements are regulated by BCA Volume Two. The BCA references AS/NZS 4859.1:2002 (incorporating amendment 1) covers materials for the thermal insulation of buildings.

High insulation levels are essential in passive solar houses. Insulate to at least the minimum levels recommended in the Building Code of Australia, Volume Two, Part 3.12.1. [See: 4.7 Insulation]

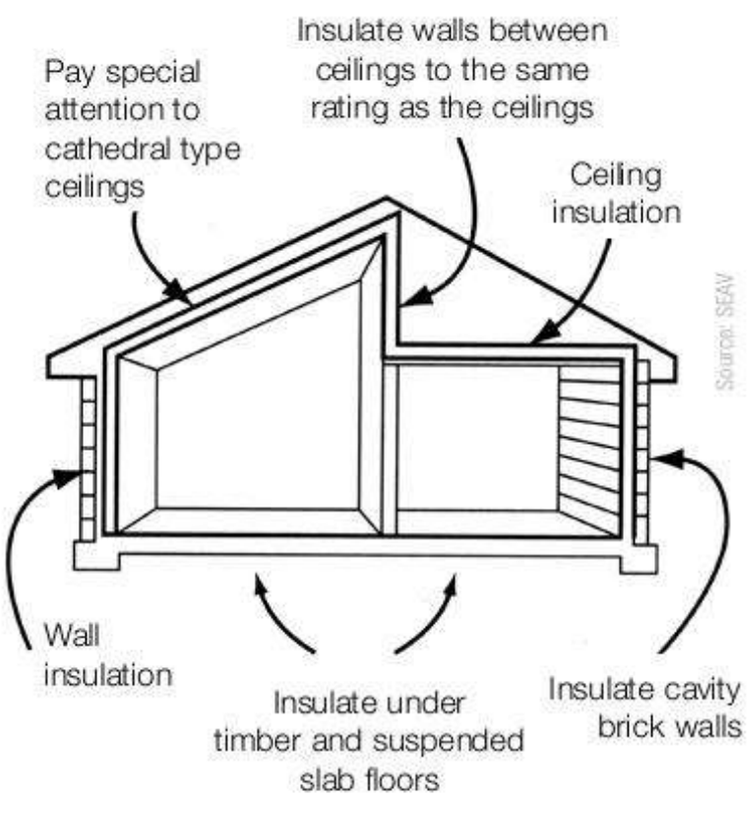
Ceilings and roof spaces account for 25 to 35 per cent of winter heat loss and must be well insulated. To prevent heat loss, locate most of the insulation next to the ceiling as this is where the greatest temperature control is required.

Floors account for 10 to 20 per cent of winter heat loss. In cool climates insulate the underside of suspended timber floors and suspended concrete slabs. Insulate the edges of ground slabs. Insulation under ground concrete slabs is not required, however, installation may be desirable when ground water is present. [See: 4.8 Insulation Installation]

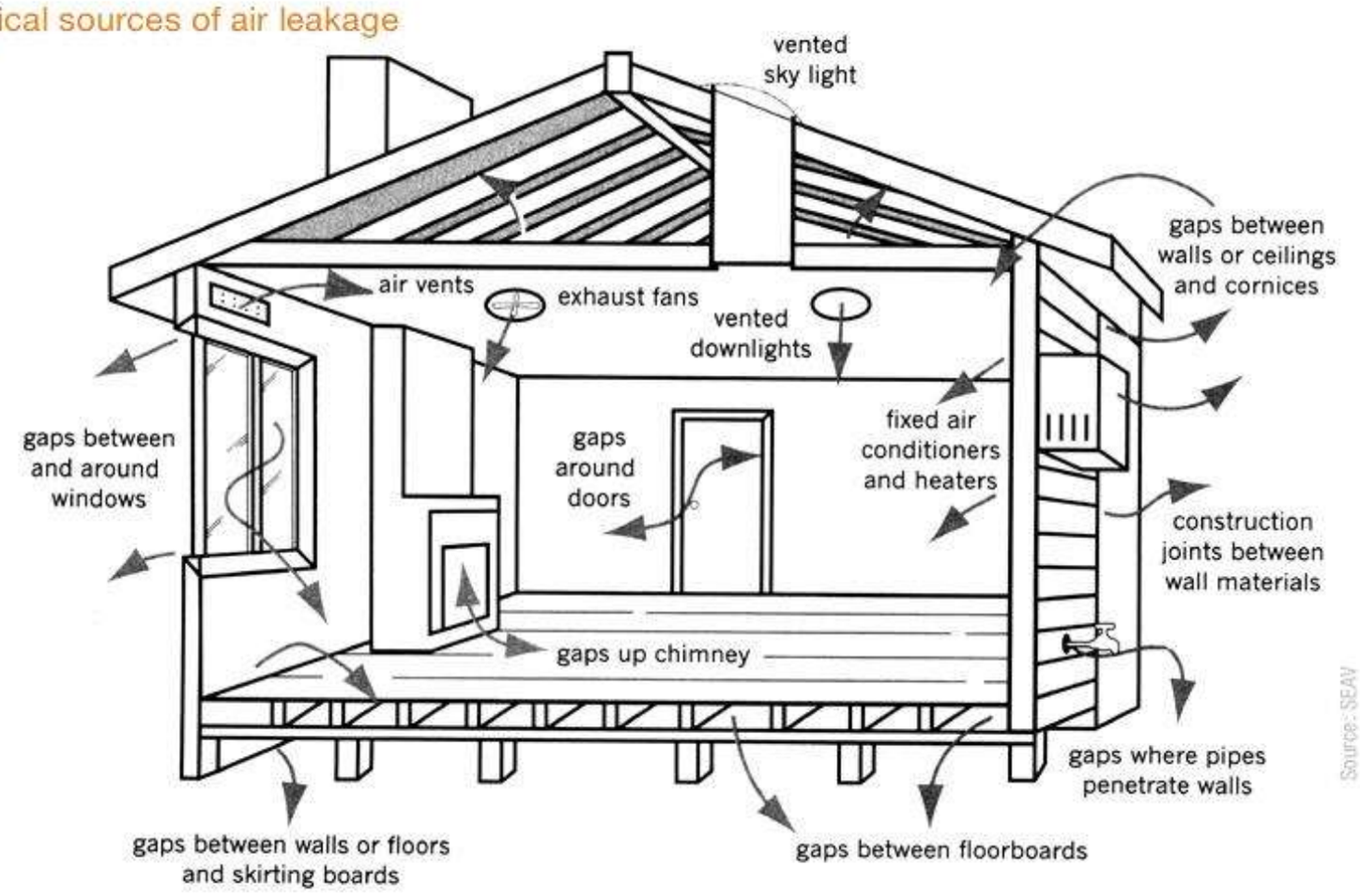
Walls account for 15 to 25 per cent of winter heat loss. Insulation levels in walls are often limited by cavity or frame width. In cold climates, alternative wall construction systems that allow higher insulation levels are recommended.

In high mass walls (double brick, rammed earth, straw bale and reverse brick veneer) thermal lag slows heat flow on a day/night basis. Insulation is still required in most instances (straw bale walls are an exception as they have a high insulation value). [See: 4.9 Thermal Mass]

Internal walls and floors between heating and non heating zones can be insulated to minimise heat loss.



Typical sources of air leakage



Draught sealing

Air leakage accounts for 15 to 25 per cent of winter heat loss in buildings.

> Use airtight construction detailing, particularly at wall/ceiling and wall/floor junctions.

> Control ventilation so it occurs when and where you want it.

> Choose well made windows and doors with airtight seals.

> Improve the performance of existing windows and doors by using draught-proofing strips. Use between the door and frame, at the door base and between the openable sash of the window and the frame.

> Seal gaps between the window/door frame and the wall prior to fitting architraves.

> Avoid using downlights that penetrate ceiling insulation.

> Duct exhaust fans and install non-return baffles.

> Avoid open fires and fit dampers to chimneys and flues.

> Do not use permanently ventilated skylights.

> Use tight fitting floor boards and insulate the underside of timber floors in cooler climates.

> Seal off air vents, use windows and doors for ventilation as required. This may not be advisable for homes with unflued gas heaters that require a level of fixed ventilation.

Windows and glazing

In terms of energy efficiency, glazing is a very important element of the building envelope. In insulated buildings it is the element through which most heat is lost and gained. Glazing transfers both radiant and conducted heat.

Avoid over-glazing – excessive areas of glass can be an enormous energy liability.

Daytime heat gain must be balanced against night time heat loss when selecting glazing areas.

Window frames can conduct heat. Use timber or thermally separated metal window frames in cooler climates.

Views are an important consideration and often the cause of over-glazing or inappropriate orientation and shading. Careful planning is required to capitalise on views without decreasing energy efficiency.

Shading and advanced glazing options are critical in achieving this. There are many ways to reduce heat loss through glazing. [See: 4.10 Glazing]

Air locks

Air locks at all regularly used external openings (including wood storage areas) are essential in cool and cold climates. They prevent heat loss and draughts.

For efficient use of space, airlocks can be double purpose rooms. Laundries, mud rooms and attached garages are excellent functional airlocks. Main entry airlocks can include storage spaces for coats, hats, boots and a small bench.

Allow sufficient space between doors so that closing the outer door before opening the inner door (or vice versa) can be done with ease of movement. Inadequate space often leads to inner doors being left open.

Avoid sliding doors in airlocks. They are invariably left open, are difficult to seal and can't be closed with a hip when both hands are full.

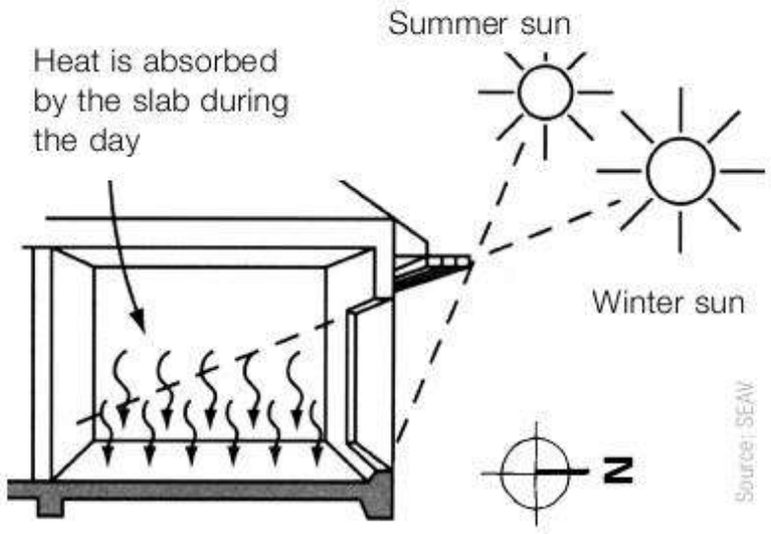
Always design door swings from airlocks so that they will blow closed if left open in strong winds, or consider using door closers on external doors.

THERMAL MASS AND THERMAL LAG

Thermal mass is used to store heat from the sun during the day and re-release it when it is required, to offset heat loss to colder night time temperatures. It effectively 'evens out' day and night (diurnal) temperature variations.

[See: 4.9 Thermal Mass]

When used correctly, thermal mass can significantly increase comfort and reduce energy consumption. Thermal mass is essential for some climates and can be a liability if used incorrectly.



Source: SEAV

Adequate levels of exposed (ie. not covered with insulative materials, such as, carpet) internal thermal mass in combination with other passive design elements will ensure that temperatures remain comfortable all night (and successive sunless days). This is due to a property known as thermal lag.

Thermal lag is a term describing the amount of time taken for a material to absorb and then re-release heat, or for heat to be conducted through the material.

Thermal lag times are influenced by:

> Temperature differentials between each face.

> Exposure to air movement and air speed.

> Texture and coatings of surfaces.

> Thickness of material.

> Conductivity of material.

Rates of heat flow through materials are proportional to the temperature differential between each face.

External walls have significantly greater temperature differential than internal walls. The more extreme the climate, the greater the temperature difference.

In warmer temperate climates, external wall materials with a minimum time lag of ten to 12 hours can effectively even out internal/external diurnal (day/night) temperature variations. In these climates, external walls with sufficient thermal mass moderate internal/external temperature variations to create comfort and eliminate the need for supplementary heating and cooling.

In cool temperate and hot climates (or where the time lag is less than ten to 12 hours), external thermal mass walls require external insulation to slow the rate of heat transfer and moderate temperature differentials. In these climates, thermal mass moderates internal temperature variations to create comfort and reduce the need for heating and cooling energy.

The following table indicates the relative thermal lag of some common building materials.

MATERIAL	THICKNESS mm	TIME LAG hours
AAC	200	7.0
Adobe	250	9.2
Compressed Earth Blocks	250	10.5
Concrete	250	6.9
Double Brick	220	6.2
Rammed Earth	250	10.3
Sandy Loam	1000	30 days

Source: Baggs, S.A. et al. 1991, Australian Earth-Covered Buildings, NSW University Press, Kensington.

Low mass solutions with high insulation levels work well in milder climates with low diurnal ranges.

Glass to mass and floor ratios

Optimum (solar exposed) glass to floor area ratios vary between climates and designs. This is due to varying diurnal ranges and the balance required between heating and cooling.

Location and exposure of thermal mass to direct and reflected radiation is also an important factor.

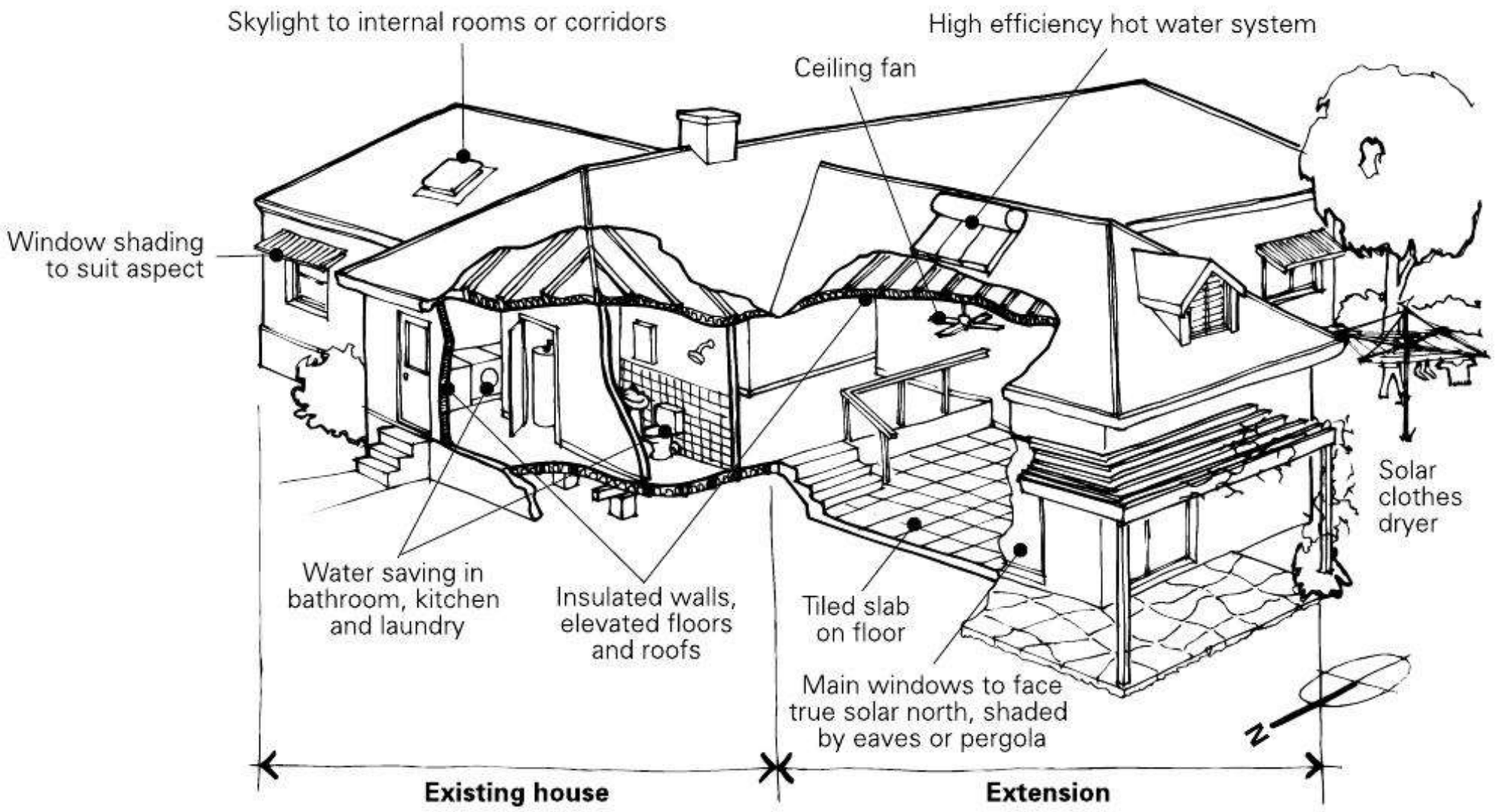
The useful thickness of thermal mass is the depth of material that can absorb and re-release heat during a day/night cycle. For most common building materials this is 100 to 150mm.

An exception is when thermal mass is used to even out seasonal temperature variations. Summer temperatures warm the building in winter and winter temperatures cool it in summer. In these applications, lag times of 180 days are required in combination with the stabilising effect of the earth's core temperature.

A 'rule of thumb' for best performance is the exposed internal area of thermal mass in a room should be around 6 times the area of north facing glass with solar access.

In mixed climates where heating and cooling needs are equally important (for example Sydney, Adelaide, Perth) the amount of thermal mass used should be proportional to diurnal range. Higher diurnal ranges (inland) require more mass, lower diurnal ranges (coastal) require less.

In heating climates with minor cooling requirements (such as Canberra and Melbourne) larger glass areas with solar access can be beneficial providing that heat loss through glazing is adequately minimised and passive shading optimised. This requires double glazing and close fitting heavy drapes with snug pelmets.



Maximise externally insulated, internally exposed thermal mass. Edge insulation is desirable for earth coupled slabs, especially in colder areas. Earth coupling should be avoided where ground water action or temperatures can draw heat from slabs.

In cooling climates with minor heating requirements (for example Brisbane) thermal mass levels are dependent on diurnal range as above but, additionally, the cooling effect of earth coupling (where achievable) can provide significant benefits. Slab on ground construction is ideal provided that slabs are protected from summer heating and contact with sun.

In predominantly cooling climates (for example Cairns, Darwin) solar exposed glass areas should be eliminated and thermal mass minimised. Some exceptions apply for advanced design solutions. [See: 4.6 Passive Cooling]

Detailed analysis of glass to mass and floor area is complex and can be confusing. Detailed coverage appears in other publications. Refer to the Additional Reading at the end of this sheet.

PASSIVE HEATING IN RENOVATIONS

General principles

Many opportunities exist for improving or including passive solar design features when renovating an existing home. They include:

> Design extensions to allow passive solar access and to facilitate movement of passive heat gains to other parts of the house.

> Include thermal mass in areas with solar access. (Use slab on ground, reverse brick veneer or other insulated mass walls). [See: 4.9 Thermal Mass]

> Increase existing insulation levels and insulate any previously uninsulated ceilings and walls (and floors in cool climates). Access to roof spaces and walls is often easier during a renovation. [See: 4.7 Insulation, 4.8 Insulation Installation]

> Use high performance windows and glazing for all new windows and doors. Replace poorly performing windows where possible – glazing is normally the biggest area of heat loss in any building.

> Double glaze windows to reduce winter heat loss. Double glazing does not prevent radiant heat from entering a home, but slows down conducted and convective heat losses. Expose the glazing to winter sun, but maintain summer shading. [See: 4.4 Shading, 4.10 Glazing]

> Seal existing windows and external doors, replace warped or poorly fitted doors. There is a wide range of seals available through hardware retailers which can be fitted to doors and windows at any time, but renovations are an ideal opportunity.

> Create air locks at entrances in cool climates. In southern Australia, unwelcome winter winds come from the west and south. If entrances face these directions, it is important to provide a buffer to prevent freezing winds blowing straight into the house whenever someone opens the door.

> Add doors and walls to group areas with similar heating needs into zones.

> Consider a solar conservatory to maximise solar gains in cool climates. Ensure it can be sealed off from the rest of the house at night.

> Install curtains with pelmet boxes where practical. Windows are generally the area of greatest heat loss. Solid topped pelmets with heavy double lined drapes which touch the walls at either side of the window and also touch the floor are a very effective way of reducing that heat loss to a trickle.

> Improve natural ventilation with operable roof vents and maximum window opening areas. Even in cool climates some degree of ventilation is necessary. Some window designs provide better ventilation than others – casements and louvres are generally the best – but louvres need to be well sealed. [See: 4.6 Passive Cooling]

Increase natural daylighting with new appropriately shaded skylights and windows. The following rules of thumb are a useful guide:

NORTH	Maximise windows, especially to living areas, provide shading to the correct angle
EAST	Minimise windows where possible, provide deep overhangs, external blinds or pergolas
WEST	Eliminate windows where possible, provide the ability for complete shading by deep pergolas or other operable devices
SOUTH	Minimise large windows, provide some weather protection

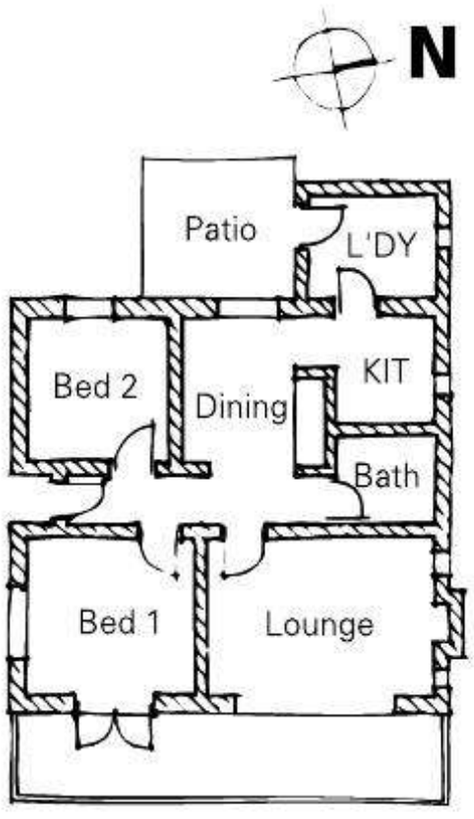
Views or other demands may necessitate large windows on east, south or west facades. If this is the case, creative design of shading and glazing should be used to minimise unwanted heat loss and gain.
[See: 4.4 Shading, 4.10 Glazing]

Some quick renovation tips

1. Turn the house around:

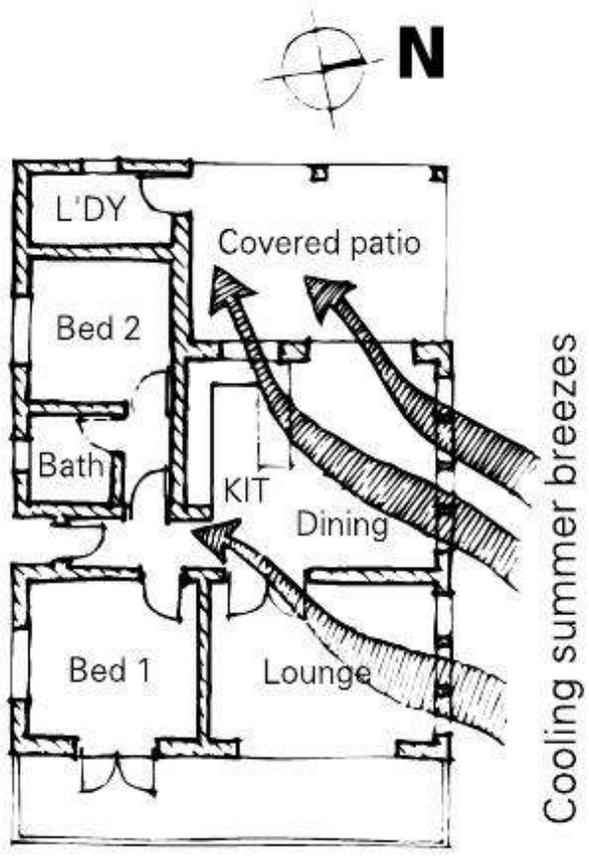
The ideal time to rethink the way a house works is when planning a renovation.

Reorienting as much of the living space as possible to the north side of the house achieves major improvements in the winter comfort of a house in cooler climates.



Original floor plan.

North facing bedrooms can become living rooms, while south facing living areas can become bedrooms. Very often this can be done without increasing the scale of the renovations, thus providing great benefit at effectively no cost.



New floor plan.

2. Turn the bricks around to add thermal mass:

It is often a simple matter to add thermal mass to timber framed structures, by adding an internal skin of brickwork.

Most houses are brick veneer – they have a light timber wall frame clad in a non-load bearing brick skin, or veneer. The bricks are effectively doing the same job as weatherboards. The bricks have high thermal mass, but the outside of a wall is not the ideal place to locate thermal mass.

Reverse Brick Veneer (RBV) is a building system which places thermal mass (the brick skin) on the inside of the wall frame. The highly insulated wall frame protects the thermal mass from external temperature extremes.

The thermal mass in RBV is in contact with the house interior and helps to regulate indoor temperatures, for the benefit of the occupants.

This system is best used in conjunction with north oriented living areas, so the solar gain from the winter sun can add useful heat to these walls.

3. Double glaze existing windows:

If the windows do not need replacing for other reasons, they can be double glazed in-situ quite effectively and economically by adding a second pane of suitable glass to the existing window sash or frame.

It is important to remove humidity from the air gap, which can be done by adding a small quantity of dessicant when the new glazing is fitted, or fitting the glazing during a period of very low humidity (20 per cent or less). [See: 4.10 Glazing]

4. 'Zone' areas with similar heating needs:

Most houses built since the 1980s are open plan, with no walls or divisions between living areas. The idea first started when kitchens were opened up to adjacent eating areas, which was useful.

As houses have become bigger, with multiple living areas, open plan design has allowed very large areas to lose thermal control and acoustic separation.

In most climates in Australia a very open plan layout is not advisable. It is only ideal in warm humid climates, where it facilitates a high degree of cross-ventilation.

Adding walls and doors to group areas with similar heating needs into separate zones allows spaces to be heated separately, reducing energy bills.

For example, more commonly used areas like living rooms can be heated separately without the heat dissipating to other areas of the house. This saves the expense of having to heat the whole house.

Zoning the floor plan in such a way also allows different family members and their friends to enjoy their often loud activities without disturbing the whole house.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on passive design considerations for your climate.
www.gov.au

Australian Bureau of Meteorology
www.bom.gov.au/climate/environ/design/design.shtml

BEDP *Environment Design Guide*
DES 18-19 Urban Autonomous Servicing.
GEN 12 Residential Passive Solar Design.

Commonwealth of Australia (1995), *Australian Model Code for Residential Development* (AMCORD), AGPS Canberra.

Department of the Environment, Water, Heritage and the Arts (2008), *Australian Residential Sector Baseline Energy Estimates 1990 – 2020.*

Hollo, N. (1997), *Warm House Cool House: Inspirational designs for low-energy housing*, Choice Books, Australia.

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Passive Cooling

This fact sheet examines ways to design and modify homes to achieve summer comfort through passive cooling.

Passive cooling is:

> The least expensive means of cooling a home.

> The lowest environmental impact.

> Appropriate for all Australian climates.



Passive cooling maximises the efficiency of the building envelope by minimising heat gain from the external environment and facilitating heat loss to the following natural sources of cooling:

> Air movement.

> Cooling breezes.

> Evaporation.

> Earth coupling.

(A detailed description of these sources can be found later in this fact sheet).

Passive cooling also maximises the ability of the occupants to lose heat to natural sources of cooling.

Cooling requirements in houses are generated predominantly by climate. Household activities have a lesser impact but are still important – especially during periods of extreme weather conditions.

Heat enters and leaves a home through the roof, walls, windows and floor. Internal walls, doors and room arrangements affect heat distribution within a home. These elements are collectively referred to as the building envelope.

Envelope design is the integrated design of building form and materials as a total system to achieve optimum comfort and energy savings.

Good envelope design responds to climate and site conditions to optimise the thermal performance. It can lower operating costs, improve comfort and lifestyle and minimise environmental impact.

Passive design should include passive heating provision for winter in all climates except high humid (tropical). The degree of winter heating can be adjusted for climate with appropriate passive solar shading. [See: 4.5 Passive Solar Heating; 4.4 Shading]

Four key approaches for achieving thermal comfort in cooling applications are examined:

> Envelope design.

> Natural cooling sources.

> Hybrid cooling systems.

> Adapting lifestyle.

All Australian climates require some degree of cooling.

ENVELOPE DESIGN

General design principles

Reduce or eliminate external heat gains during the day with sound envelope design.

Design to allow lower night time temperatures and air movement to cool the building and its occupants.

The main elements of design for passive cooling are:

> Orientation for exposure to cooling breezes.

> Increase natural ventilation by reducing barriers to air paths through the building.

> Provision of fans to provide ventilation and air movement in the absence of breezes.

> Provide paths for warm air to exit the building.

> Floor plan zoning to maximise comfort for daytime activities and sleeping comfort.

> Appropriate windows and glazing to minimise unwanted heat gains and maximise ventilation.

> Effective shading (including planting).

> Adequate levels of appropriate insulation.

> High thermal mass construction in regions with significant diurnal ranges.

> Low thermal mass construction in regions with low diurnal range.

> Use of light coloured roofs and walls to reflect more solar radiation and reduce heat gain.

See the relevant fact sheets for detailed information on each of the above elements, particularly the use of thermal mass in best practice design solutions in climates with modest diurnal range.

Floor plan and building form

> Maximise the indoor/outdoor relationship and provide appropriate screened, shaded, rain protected outdoor living spaces.

> Maximise convective ventilation with high level windows, ceiling and roof space vents.

> Zone living and sleeping areas appropriately for climate – vertically and horizontally.

> Locate bedrooms for sleeping comfort.

> Design ceilings and furnishing positions for optimum efficiency of fans, cool breezes and convective ventilation.

> Locate mechanically cooled rooms in thermally protected areas.

Varied responses are required for each climate zone and even within each zone depending on local conditions and the microclimate of a given site. General solutions exist for the main cooling climate categories:

> High humid.

> Hot dry.

> Warm humid.

CLIMATE SPECIFIC DESIGN PRINCIPLES

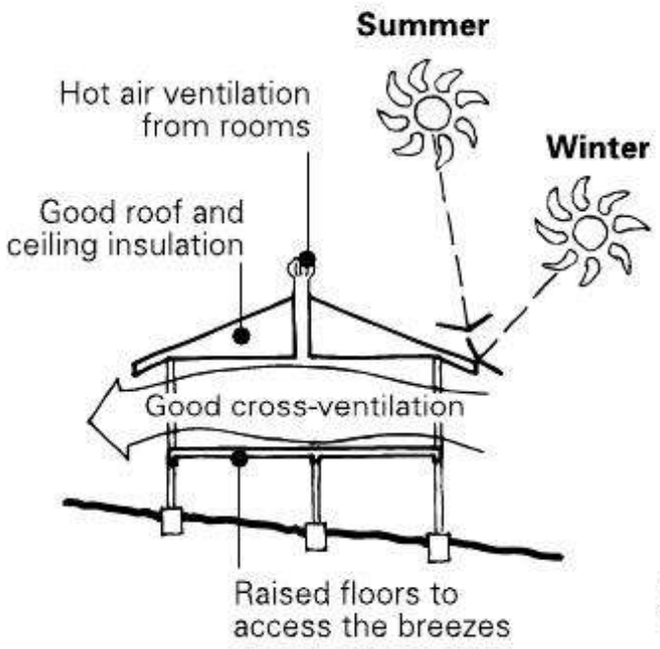
High humid (tropical) climates

In these climates:

> High humidity levels limit the body's ability to lose heat by evaporation of perspiration.

> Sleeping comfort is a significant issue – especially during periods of high humidity.

> Design eaves and shading to permanently exclude solar access to rooms. [See: 4.4 Shading]



> Consider shading the whole building with a fly roof. [See: 4.4 Shading]

> Maximise shaded external wall areas and exposure to (and funneling of) cooling breezes through the building.

> Use single room depths where possible with maximum shaded openings to enhance cross ventilation and heat removal.

> Design unobstructed cross ventilation paths.

> Provide hot air ventilation at ceiling level for all rooms with spinnaways, shaded opening clerestorey windows or ridge vents.

> Shade outdoor areas around the house with planting and shade structures to lower ground temperatures.

> Use insulation solutions that minimise heat gain during the day and maximise heat loss at night. Advanced reflective insulation systems and reflective air spaces can be effective. [See: 4.8 Insulation Installation]

> Choose windows with maximum opening areas (louvres or casement) and avoid fixed glass panels.

> Include ceiling fans to create air movement during still periods.

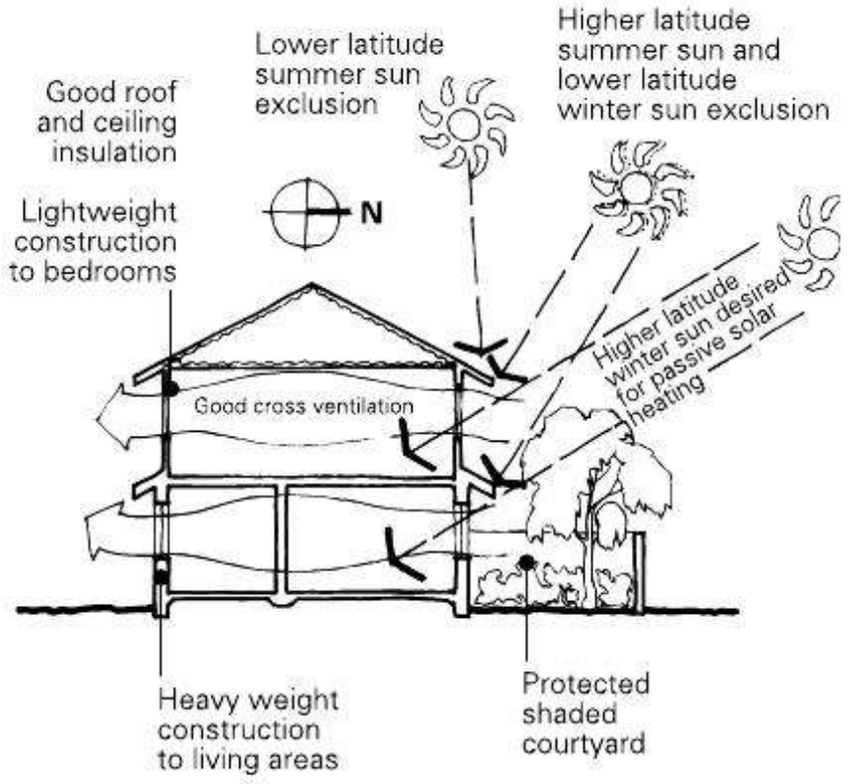
> Consider using whole of house fans with smart switching to draw cooler outside air into the house at night when there is no breeze.

> Use low thermal mass construction generally. (Note: high mass construction can be beneficial in innovative, well considered design solutions).

> Use planting design to funnel cooling breezes and filter strong winds. (Appropriate in all cooling climates).

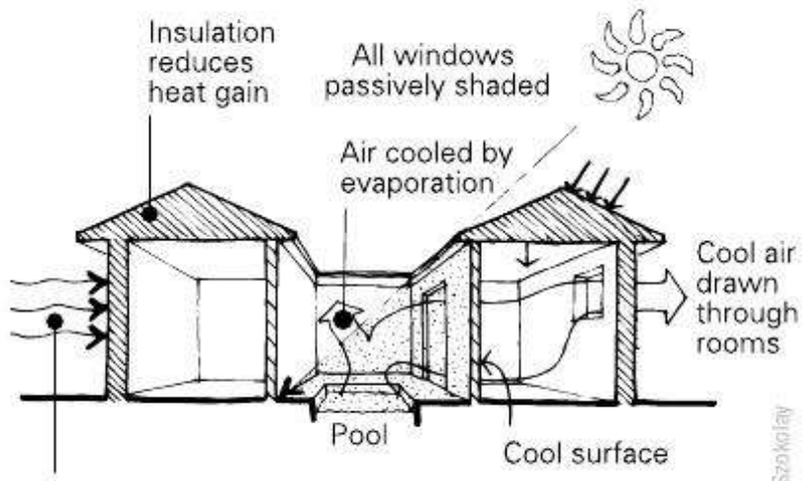
Hot dry climates with warm and cool winters

> Hot dry climates occur in a wide range of latitudes and geographic locations. This creates a variety of diurnal ranges and winter heating requirements with hot to very hot, dry summers.



Two storey solution for hot dry climate with low diurnal range.

> Evaporative cooling from ponds, water features and 'active' or mechanical cooling systems is ideal for arid climates where low humidity promotes high evaporation rates.

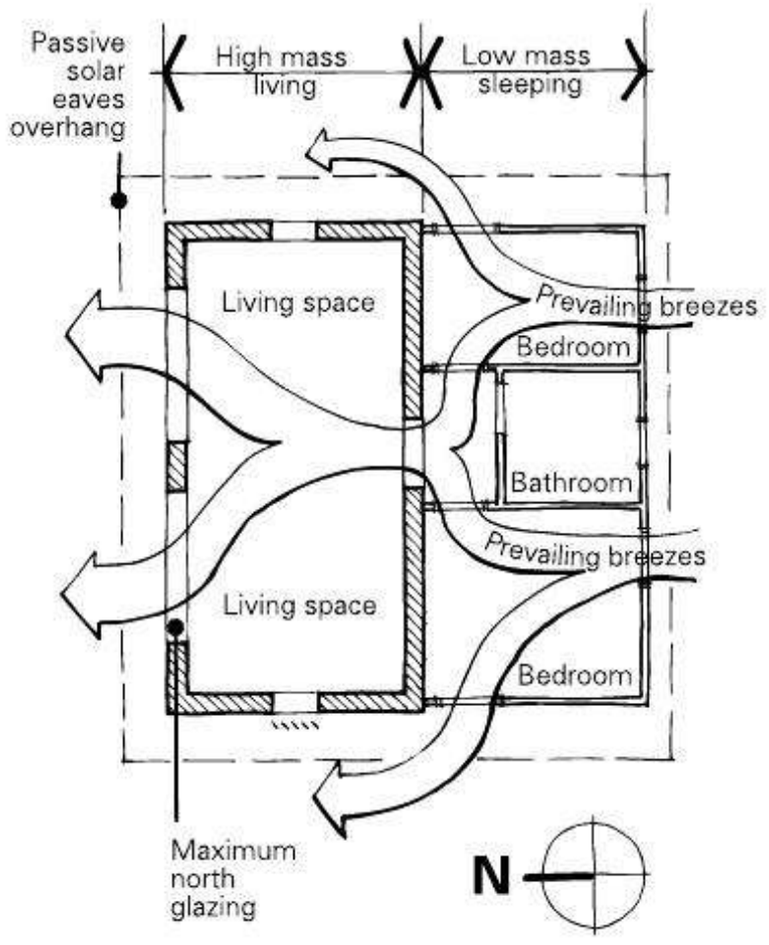


Courtyard design with evaporative cooling pond.

> Evaporative cooling or a ceiling fan should be used if required.

> Use high mass solutions with passive solar winter heating where winters are cool or cold and diurnal ranges are significant.

> Use low mass elevated solutions where winters are mild and diurnal ranges are lower.



Minimise east and west glazing or provide adjustable external shading. High mass living areas are more comfortable during waking hours. Low mass sleeping areas cool quickly at night. High insulation prevents winter heat loss.

> Consider high mass construction for rooms with passive winter heating and low mass for other rooms.

> Shade all windows in summer and east and west windows year round.

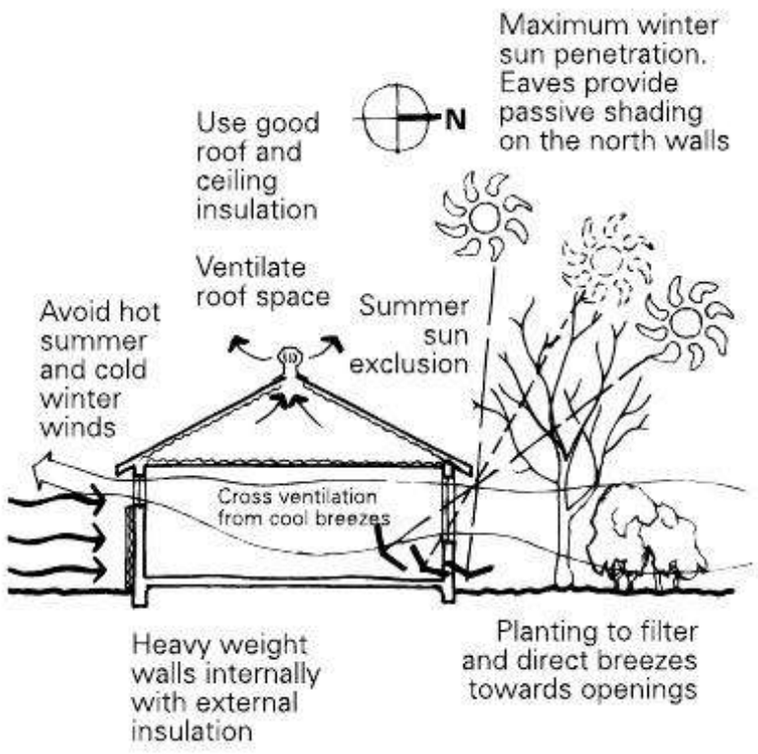
> Well sealed windows and doors with maximum opening area allow maximum exposure to cooling breezes and exclude hot, dry and dusty winds.

Warm humid climates

In benign climates like coastal areas of south east Queensland, energy consumption for heating and cooling accounts for over 6 per cent of total household energy use. Achieving thermal comfort in these climates is a relatively simple task.

> Passive solar heating is required during winter months.

> Adjust eave overhangs to suit the particular micro-climate. [See: 4.4 Shading]



High mass solution for warm humid climate with high diumal range.

> Use high mass construction in areas with significant diurnal range (usually inland).

> Use low mass construction where diurnal ranges are low (usually coastal). [See: 4.9 Thermal Mass]

> Orient to maximise exposure to cooling breezes and use ceiling fans and convective ventilation to supplement them.

> Elevated structures can increase exposure to breezes.

> Include evaporative cooling and water features.

> Use insulation to prevent heat loss and heat gain.

Warm, mild and cool temperate climates

Temperate climates require less cooling. Good orientation, passive shading, insulation and design for cross ventilation generally provide adequate cooling. Additional solutions from the range explained in this fact sheet can be used where site conditions create higher cooling loads.

NATURAL COOLING SOURCES

In combination with sound envelope design for cooling climates and appropriate lifestyle, air movement, evaporative cooling and earth coupled thermal mass can provide adequate thermal comfort in all Australian climate zones.

AIR MOVEMENT

Air movement is the most important element of passive cooling. It increases cooling by increasing evaporation rates.

Generally, cross ventilation is most effective for air exchange (building cooling) and fans for air movement (people cooling).

Air movement provides useful cooling in all climates but may be less effective in tropical climates during periods of high humidity.

An air speed of 0.5m per second equates to a 3 degree drop in temperature at relative humidity of 50 per cent.

This is a one off physiological cooling effect that occurs when still air is moved at 0.5m per second.

In higher humidity, greater airspeeds are required to achieve the same cooling benefits.

Cooling breezes

Maximising the flow of cooling breezes through a home is an essential component of passive design.

Coastal breezes are usually from an onshore direction (southeast, east to northeast in most east coast areas and southwest in most west coast areas, eg. the Fremantle Doctor).

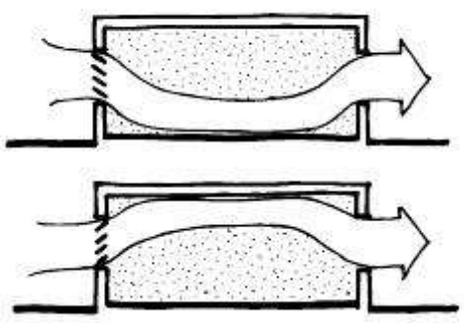
In mountainous or hilly areas, cool breezes often flow down valleys in late evening and early morning as night cooling creates cool air currents.

Thermal currents are common in flatter, inland areas, created by diurnal heating and cooling. They are often of short duration in early morning and evening but can yield worthwhile cooling benefits with good design.

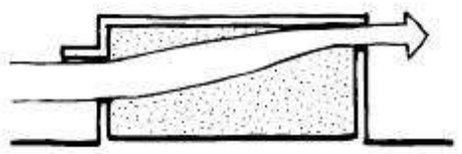
Design to maximise beneficial cooling breezes by providing multiple flow paths and minimising potential barriers (single depth rooms are recommended).

Use windows designed to deflect breezes from varying angles. Locate windows on walls with best exposure to common cooling breezes and design for effective cross flow of air through the building.

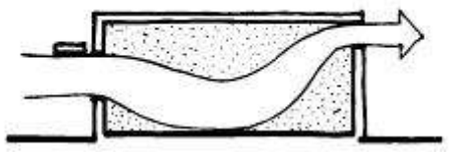
Consider directing airflow at levels suitable for the activity proposed for the room.



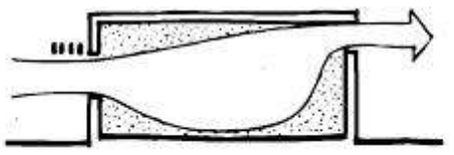
Louvres can direct airflow upward or downward.



A canopy over a window tends to direct air upward.



A gap between canopy and wall ensures a downward pressure.



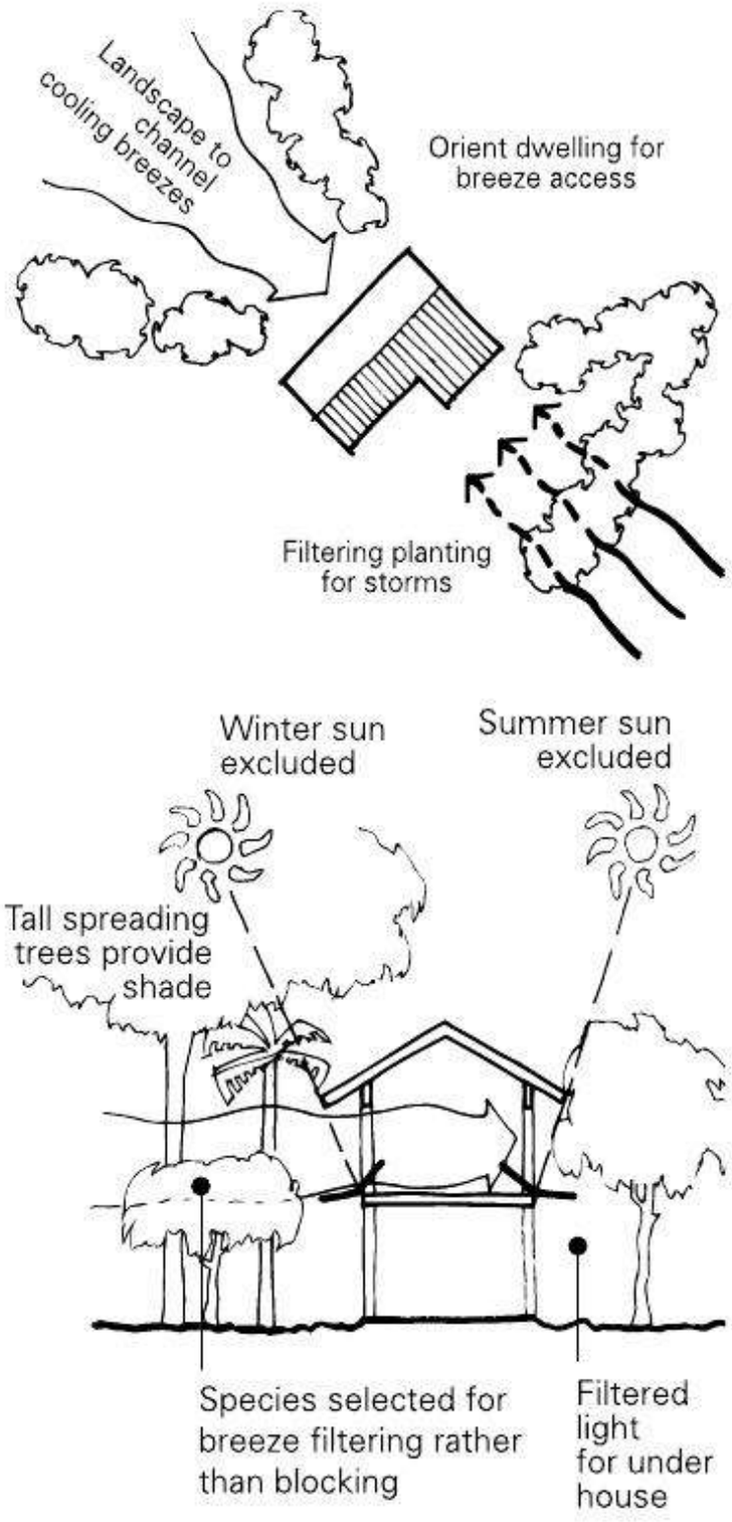
Steve Szokolay

Downward pressure is improved further in the case of a louvered sunshade.

Use window styles with 100 per cent opening area, such as, louvre and casement.

Understand your regional climate and how various features (topographic and man made) influence the microclimate of your site.

Design planting to funnel breezes into and through the building, filter stronger winds and exclude adverse hot or cold winds.



Convective air movement

Convective air movement relies on hot air rising and exiting at the highest point, drawing in cool air from shaded external areas over ponds or cool earth.

Convection produces air movement capable of cooling a building but has insufficient air speed to cool the occupants.

Solar chimneys can also be used to ensure effective convective air monement.

Clerestory windows, spinnaway roof ventilators, and vented ridges, eaves and ceilings will allow heat to exit the building in nil breeze situations through convection.



Fans

In all cooling climates, exposure to cooling breezes should be maximised. However, during still periods mechanical fans are required to supplement breezes.

The maximum useful air speed for comfort is approximately 7.5m per second. Higher air speeds do not create more cooling and can be unsettling.

Standard ceiling fans create adequate air speeds to achieve comfort when dry bulb temperature and relative humidity are within acceptable levels.

In a lightweight Brisbane house, fans to all living and bedroom areas will more than halve cooling requirements. They can typically turn a 3 star house into a 5 star house.

Whole of roof fans can be beneficial in cooling applications, particularly where cross ventilation design is inadequate. They do not create sufficient air speed to cool occupants.

Air intakes are usually located in the centre of the house (hallway) and are used to draw cooler outside air into the building through multiple rooms when conditions are suitable. They exhaust the air through eave or gable vents via the roof space. This cools the roof space.

Control systems for whole of roof fans should prevent operation when external air temperatures are higher than internal.

Condensation can be increased by drawing large volumes of humid air through the roof space. A dew point occurs when this humid air comes in contact with roof elements (eg. reflective insulation) which has been cooled by radiation to night skies. [See: 6.2 Heating and Cooling]

EVAPORATIVE COOLING

Large amounts of heat are consumed by water as it evaporates. This is called the latent heat of evaporation. This heat is partially drawn from surrounding air, causing cooling.

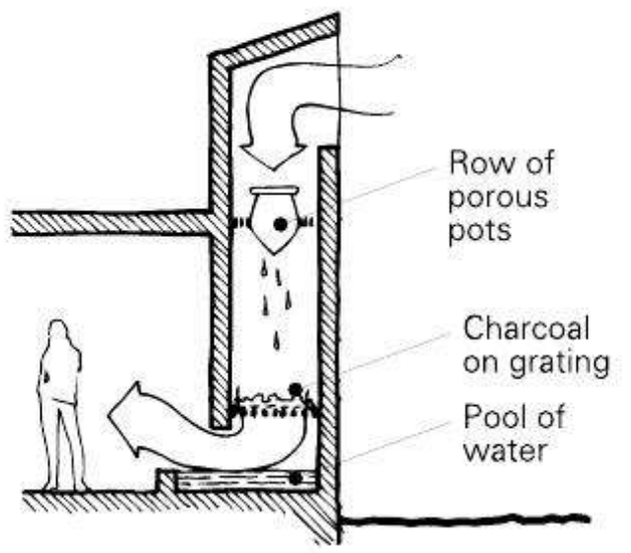
Evaporation is an effective passive cooling method. It works best when relative humidity is lower (70 per cent or less during hottest periods) and the air has a greater capacity to take up water vapor.



Rates of evaporation are increased by air movement.

The surface area of water exposed to moving air is also important. Fountains, mist sprays and waterfalls can increase evaporation rates.

Passive evaporative cooling design solutions include the use of pools, ponds and water features immediately outside windows or in courtyards to pre-cool air entering the house. Carefully located water features can create convective breezes.



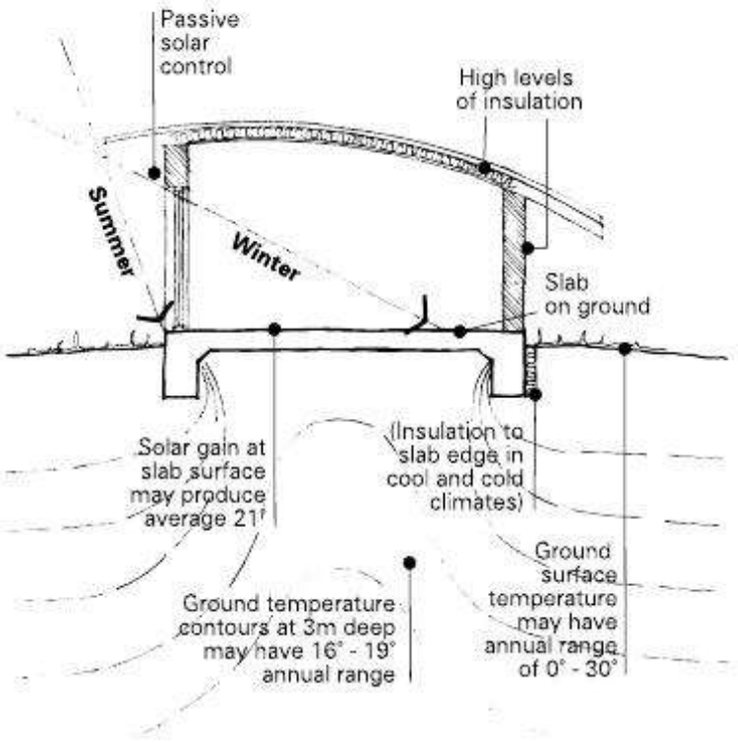
Steve Szokolay

Active evaporative cooling systems like the above wind scoop, originating in ancient Persia, can be useful to catch cooling breezes and direct them into the house via an evaporative cooling system.

Mechanical evaporative coolers are common in low humidity climates. They use less energy than refrigerated air conditioners and work better with doors and windows left open. Water consumption can be considerable.
[See: 6.2 Heating and Cooling]

EARTH COUPLING

Earth coupling of thermal mass (floor slabs) protected from external temperature extremes can substantially lower temperatures by absorbing heat as it enters the building or is generated by household activities.



Passively shaded areas around earth coupled slabs keep surface ground temperatures lower during the day and allow night time cooling.

Poorly shaded surrounds can lead to earth temperatures exceeding internal comfort levels in many areas. In this event, an earth coupled slab can become an energy liability.

Ground and soil temperatures vary throughout Australia.

Earth covered/earth bermed construction utilises stable ground temperatures at lower depths to absorb household heat gains.

HYBRID COOLING SYSTEMS

These are appropriate for tropical climates with high summer humidity or where mechanical cooling (especially refrigerated air-conditioning) is used to overcome problems of extreme climate, existing house/ site constraints or poor design.

Hybrid cooling systems are whole house cooling solutions employing a variety of cooling options (including air-conditioning) in the most efficient and effective way. They take maximum advantage of passive cooling when available and make efficient use of mechanical cooling systems during extreme periods.

Refrigerated air-conditioning can provide thermal comfort during periods of high temperature and humidity by lowering air temperature and humidity.

However it is expensive to install, operate and maintain and has a high economic and environmental cost because it consumes significant amounts of electricity. It also requires the home to be closed off from the outside environment and this can interfere with acclimatisation.

Air-conditioning is often used to achieve comfortable sleeping conditions by lowering temperatures and humidity. The number of operating hours required for air-conditioning to achieve thermal comfort can be substantially reduced (or eliminated) by careful design of new homes, alterations and additions.

Efficient air-conditioning requires more than simply installing an air conditioner.

Well designed Australian homes do not require air-conditioning (either refrigerated or evaporative). Most of those that do are concentrated in the high humid and hot dry climate zones.

More than 50 per cent of Queensland homes are mechanically cooled. This proportion is rapidly increasing – often because inadequate shading, insulation and ventilation, or poor orientation for passive cooling and sun control, cause unnecessary overheating.

Decide early in the design stages whether air-conditioning is to be used. Many inefficient air-conditioning installations occur when they are added as an afterthought to improve comfort.

Passive design principles are beneficial in maximising the efficiency of naturally and mechanically cooled homes.

Design of air conditioned spaces

Envelope design

> Minimise external air infiltration.

> Use higher insulation levels – particularly bulk insulation in walls, ceiling and floors. [See: 4.7 Insulation]

> Reduce glass areas. [See: 4.10 Glazing]

> Reduce total volume of air space (room size/ceiling height).

Planning and layout

> Minimise heat loads with good orientation, insulation and shading of the whole building.

> Locate unit in the coolest zone in the house to minimise running costs.

> Carefully choose rooms to be air-conditioned according to use. Do not air-condition all rooms.

> Avoid air-conditioning rooms that have high level indoor – outdoor traffic or use air-locks to minimise hot air infiltration.

> Locate sleeping spaces so that convective air-movement and conduction through walls shared with air-conditioned spaces will provide indirect cooling benefits.

> Decide which rooms will receive most benefit depending on use. Often one or two rooms will be sufficient to provide comfort during periods of high humidity and temperatures.

> Design these rooms with high levels of insulation and lowest exposure to external temperature influences (usually in the centre of the house).

> Ensure that rooms not requiring mechanical cooling have maximum passive cooling as described above and use them as a thermal buffer to cooled spaces.

> Use fans and cross ventilation to improve comfort in non-air-conditioned spaces.

A very different approach is required for design and construction of air-conditioned rooms to maximise efficiency.

Other considerations

> Address condensation in externally ventilated rooms surrounding air-conditioned rooms.

> When insulated walls surround an air-conditioned space, a vapor barrier should be installed between the warm humid air and the insulation material to prevent saturation of the insulation by condensation.

Dewpoints form where humid air comes into contact with a cooled surface.

> Any linings placed over the vapor barrier should be resistant to damage from condensation by choosing appropriate materials and finishes.

Eg. Placing reflective foil insulation under a plasterboard wall lining will cause the dewpoint to form under the plasterboard. A wet area lining, such as, compressed fibre cement with a waterproof finish is a better solution.

> Identify the months and times of day mechanical cooling will be required.

> Use advanced control systems, sensors and timers to reduce total operating hours.

> Use low mass construction in mechanically cooled spaces to facilitate quick response and reduce running time.

> Use split systems with low energy heat exchangers, such as, air to water or air to earth. [See: 6.2 Heating and Cooling]

> Set thermostats to warmest setting that still achieves comfort.

> Adapt your lifestyle where possible to take advantage of comfortable external conditions when they exist to minimise operating periods for mechanical cooling systems.

> De-humidifiers use less energy than refrigerated air conditioners and can overcome evaporative cooling inefficiency in high humidity. They require sealing of rooms but have lower requirement for bulk insulation allowing use of one way valve reflective insulation principles. [See: 4.7 Insulation]

In a closed room, running an air conditioner for about an hour will lower humidity levels to the point where air movement from fans can provide sufficient evaporative cooling to achieve thermal comfort.

ADAPTING LIFESTYLE

Applicable in all climates, especially high humid and hot dry.

Adapting lifestyle involves adopting living, sleeping, cooking and activity patterns to adapt to and work with the climate rather than using mechanical cooling to emulate an alternative climate.

High humid climates present the greatest challenge in achieving thermal comfort because high humidity levels reduce evaporation rates. [See: 4.2 Design for Climate]

Acclimatising is a significant factor in achieving thermal comfort. The majority of people living in tropical climates choose to do so. They like the climate and know how to live comfortably within its extremes by adopting appropriate living patterns to maximise the outdoor lifestyle opportunities it offers.

Sleeping comfort at night during the hottest and most humid periods is a significant thermal comfort issue for many people living in tropical climates. Unlike cooler climates, sleeping comfort is a high priority when choosing, designing or building a home.

Different members of a household will have different thermal comfort thresholds. Children often adapt to seasonal changes more easily than adults do.

Understanding the sleeping comfort requirements of each member of the household can lead to better design, positioning or allocation of bedrooms, resulting in increased thermal comfort for all and less dependence on mechanical cooling.

Live outside when time of day and seasonal conditions are suitable – particularly in the evenings. Radiation by the body to cool night skies is an effective cooling mechanism – particularly in the early evening when daytime heat loads have not been allowed to escape from the interior of the house.

Cooking outside during hotter months will reduce heat loads inside the house. This is an Australian lifestyle tradition developed to suit our climate but it is not often directly connected to thermal comfort.

Locate barbeques outdoors, under cover in close proximity to the kitchen with good access either by servery or screened door.

Shaded, insect screened barbecue and outdoor eating areas facilitate outdoor living and increased comfort.

Sleep outs are an ideal way to achieve sleeping comfort and can provide low cost additional space for visitors who often arrive during the hotter Christmas period.

Vary active hours to make best use of comfortable temperature ranges at different times of year. The siesta regime of most Central American countries is a practical lifestyle response to specific climatic conditions that are also experienced in high humid and hot dry regions of Australia.

PASSIVE COOLING IN RENOVATIONS

Renovations provide the ideal opportunity to improve a home's potential for passive cooling.

All Australian houses can use passive cooling to great advantage. In many climates passive cooling is critical to comfort. [See: 4.2 Design for Climate]

The principles and ideas outlined in the preceding pages of this fact sheet can be combined to achieve passive cooling in a renovation.

When renovating, ensure you make things better, never worse. Design renovations and extensions that improve rather than compromise performance.

Orientation and layout

Consider changing the orientation of the home so that the major openings face the breeze, and openings on the opposite side of the house draw the breeze through and out. [See: 4.3 Orientation]

Design a layout that allows cool breezes to pass right through the house, aligning windows with internal doors in a way that does not block weaker breezes.

Open plan interiors are best for encouraging natural ventilation in high humid climates. Solid-bladed louvres can be provided in internal walls to let breezes pass right through the building.

Improved natural ventilation can be achieved without altering the existing footprint, just by changing the use of existing rooms and moving and/ or increasing the size of windows and doors.

Consider combining the laundry with the kitchen or bathroom (compact European style) and incorporate the old laundry space as extra open space for living areas, allowing better breeze penetration through the house.

Kitchens which back onto hallways or other living areas can have their back walls lowered (or large openings created in them) to allow air to flow over the top and through the whole house.

When adding new rooms, locate them so they do not block breeze paths. In high humid climates the ideal house plan is long and narrow (single room depth), with large openings on either side. To preserve this form, locate additions at the ends of the building where possible.

Windows and doors

Use windows with a large opening area, and doors that open fully to allow the free passage of breezes. If the existing windows and doors do not work like this, consider changing some of them.

Casement sashes (side hinged) are good on the windward side of the house, and louvers or hoppers (short awnings) on the leeward side. Tall awning windows are not good ventilators, as the effective opening area is quite small. In tropical areas, where wet weather accompanies breezes, louvres are the best choice for external windows.

In climates where winters are cold, windows and doors must be well-sealed to prevent heat loss when closed. Double glazed widows can be made to open wide so that they work well in winter and summer. Low-e coatings can limit heat gain in hot conditions, but must be used carefully in regions with cold winters so as not to limit winter heat gains. [See: 4.10 Glazing]

Shading and landscape

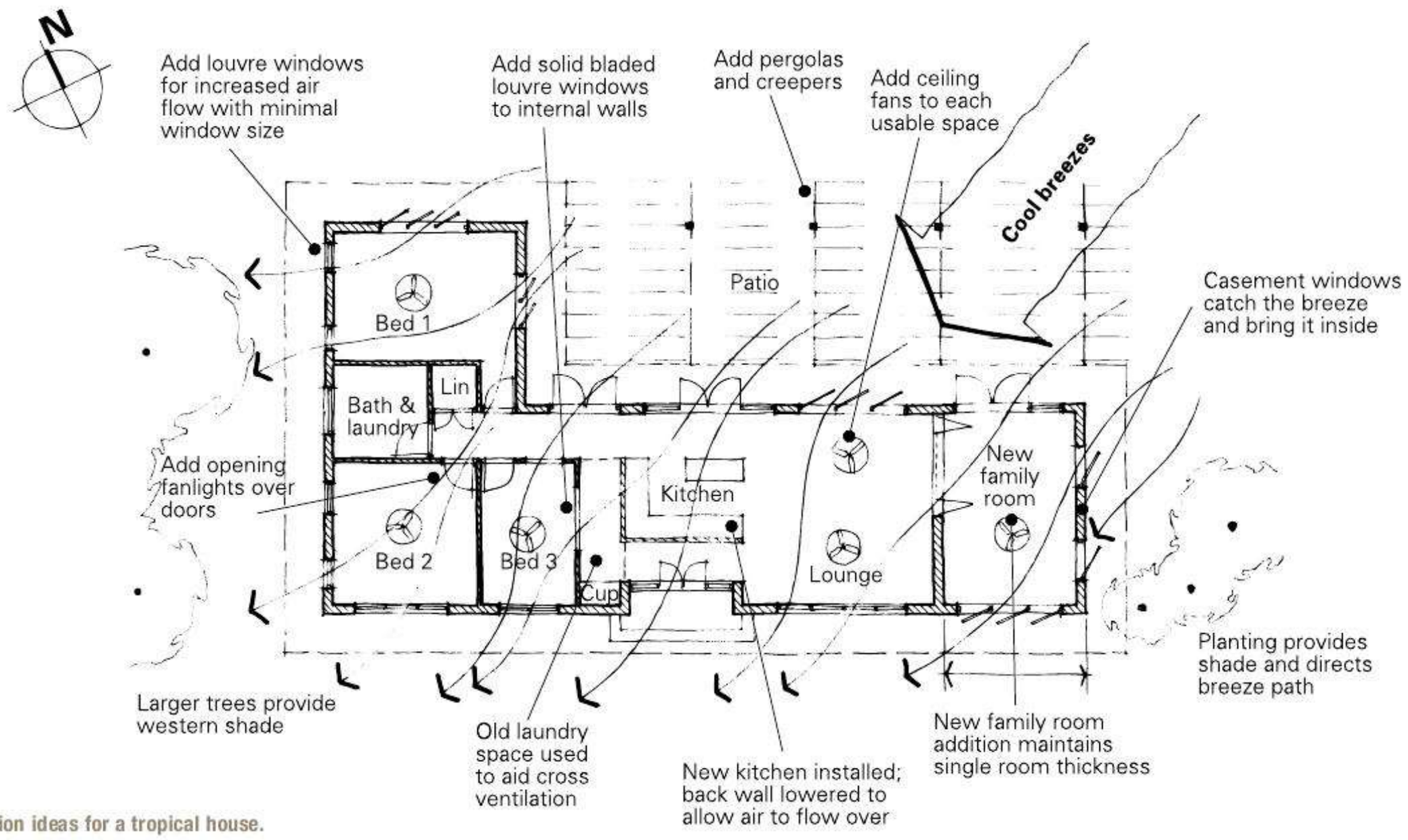
Renovations provide the ideal opportunity to improve shading. If adding a new roof, ensure the north facing eave overhang is appropriately sized. [See: 4.4 Shading]

Alternatively, add a pergola, shade frame or suitably sized shade projections above north facing windows. North of the tropic of Capricorn, south facing openings will need shading too.

Shade structures added to the external face of the window (louvres, shutters, etc.) or deep pergolas are suitable for east and west facing walls. Deciduous vines, such as, decorative grape can be pruned in autumn to allow filtered winter sun through, while quickly growing in spring to cover the whole pergola.

Use planting to shade the house.
In climates where winter sun is desirable, plant tall or deciduous trees to the north. Lower trees or shrubs are suitable for shading east and west facades. Ensure plantings do not obscure breezes, but channel them toward the openings. [See: 2.4 Sustainable Landscapes; 4.4 Shading]

Where shading cannot be provided,, such as, when too close to the boundary or prevented by body corporate rules, use ‘smart glass’ or apply a reflective film to reduce heat gain. Note that these techniques will reduce natural light levels and winter heat gain.



Renovation ideas for a tropical house.

Active ventilation

Assist the breeze by installing ceiling fans where necessary. Ceiling fans are an energy efficient way of cooling building occupants. Locate fans centrally in each space, one for each grouping of furniture. An extended lounge/ dining area will need two fans. In bedrooms, locate the fan near to the centre of the bed. [See: 6.2 Heating and Cooling]



Solar air heaters and cooling systems

These are proprietary devices which capture solar energy to warm the air in a flat solar orientated roof mounted box. Warm air can be drawn through ducting into internal spaces of the house. The same device can also be used to exhaust or take out warm air from the home, acting as a kind of active solar chimney.

Insulation and reflectivity

Add insulation to existing roofs, which are a major source of radiant heat gain. Reflective insulation provides the most effective resistance to radiant heat. Multiple layers of foil batts can be easily installed between roof rafters during renovations.

Add insulation to existing walls wherever possible. When internal linings are removed it is easy to install insulation to timber framed walls. It is also possible to insulate existing cavity brick walls, however this is more complex and specialist consultants may be required. [See: 4.7 Insulation; 4.8 Insulation Installation]

An ideal time to change the colour scheme of a building is during renovation. Light-coloured surfaces reflect heat, while dark surfaces absorb heat. However, many local councils prohibit light coloured external surfaces, especially roofs, to prevent built form from overpowering the surrounding landscape.

The best compromise is to use lighter neutral colours on external walls and mid-range roof colours. Avoid black or dark grey for roofs. Blandness can be avoided by using contrasting or complimentary trims.

Thermal mass

In renovations, a concrete slab or masonry wall can provide extra thermal mass. The thermal mass needs access to winter sun and cooling summer breezes.

Many timber framed buildings (including brick veneer) can have thermal mass added effectively and economically using reverse brick veneer construction. The brick can be any high mass material, including rammed earth or core filled concrete block. [See: 4.9 Thermal Mass]

Low mass construction is generally the most appropriate solution for warm humid climates. It must be combined with good insulation and cross ventilation.

When used to construct permanently inhabited rooms, low mass walls must be well insulated. In colder climates, it may be necessary to add wall thickness to achieve adequate insulation levels. Minimum structural timber sizes may not provide enough thickness for the appropriate insulation.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on passive design considerations for your climate.
www.gov.au

Australian Bureau of Meteorology
www.bom.gov.au/climate/environ/design/design.shtml

BEDP *Environment Design Guide*
DES 20 Arid Climates and Enhanced Natural Ventilation.
DES 59 Passive Cooling Building Systems.

Commonwealth of Australia, Australian *Model Code for Residential Development* (AMCORD) (1995), AGPS Canberra.

Hollo, N. (1997), *Warm House Cool House: Inspirational designs for low-energy housing*, Choice Books, Australia.

Wrigley, Derek (2004), *Making Your Home Sustainable: A Guide to Retrofitting*, Scribe, Carlton North, Victoria.

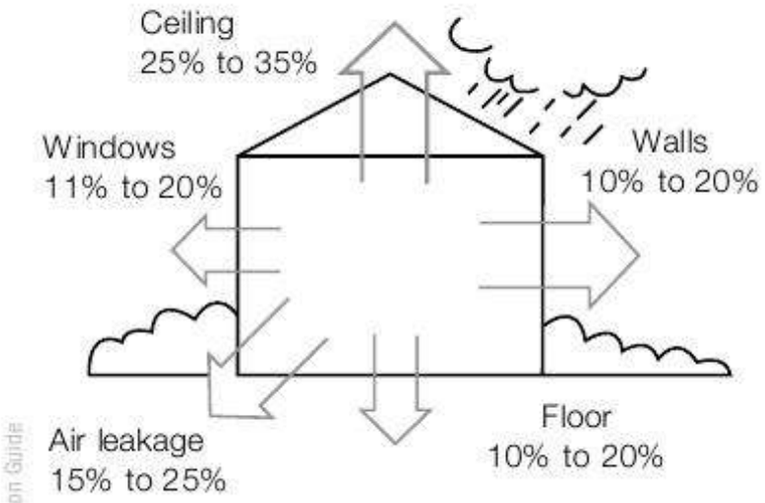
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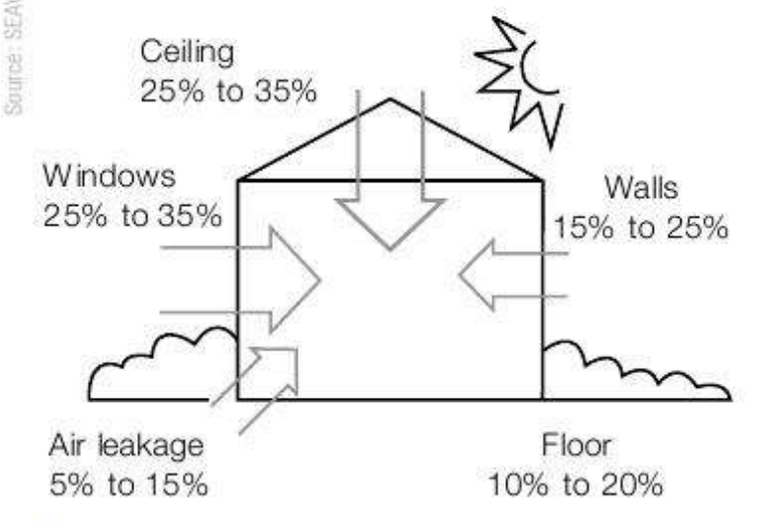
Insulation

Insulation acts as a barrier to heat flow and is essential to keep your home warm in winter and cool in summer. A well insulated and well designed home will provide year-round comfort, cutting cooling and heating bills by up to half. This, in turn, will reduce greenhouse gas emissions.

Climatic conditions will influence the appropriate level and type of insulation. Establish whether the insulation will be predominantly needed to keep heat out or in (or both). Insulation must cater for seasonal as well as daily variations in temperature, see 'Insulation levels for your Climate'.



Source: SEAV Insulation Guide



Typical heat gains and losses in a temperate climate.

Passive design techniques should be used in conjunction with insulation. For example, if insulation is installed but the house is not properly shaded, built up heat can be kept in by the insulation creating an 'oven' effect. Draught sealing is important, as draughts can account for up to 25 per cent of heat loss from a home in winter. [See: 4.5 Passive Solar Heating; 4.6 Passive Cooling]

Insulation can assist with weatherproofing and eliminate moisture problems, such as, condensation. Some types of insulation also have soundproofing qualities.

The most economical time to install insulation is during construction. For information on retro-fitting insulation, see 'Adding insulation to existing buildings'.

There is little insulating value in most common construction materials, but there are some exceptions where little or no additional insulation may be required. Suitable materials include aerated concrete blocks, hollow expanded polystyrene blocks, straw bales and rendered extruded polystyrene sheets. Check with your local building information centre for more details.

> Total R-values for roofs, ceilings, walls and floors may provide only one value for total thermal resistance of construction which may not be adequate to achieve compliance with the Building Code of Australia (BCA) requirements for energy efficiency of building fabric.

> Under the BCA, total R-values of the building fabric vary depending on climate zone and the height above the Australian Height Datum at the location where the building is to be constructed.

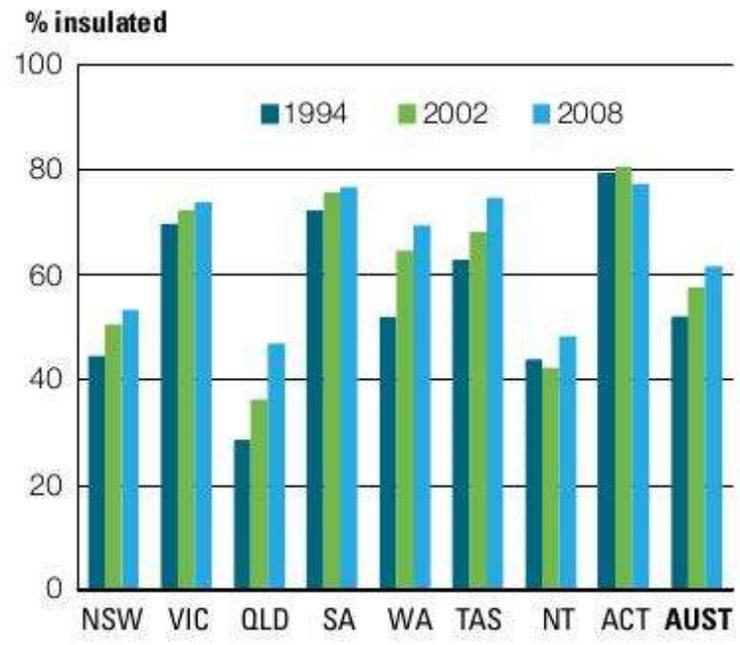
CHOOSING INSULATION

Insulation products come in two main categories – bulk and reflective. These are sometimes combined into a composite material. There are many different products available, see 'Insulation types and their applications' for further information.

To compare the insulating ability of the products available look at their R-value, which measures resistance to heat flow. The higher the *R-value* the higher the level of insulation. Products with the same R-value will provide the same insulating performance if installed as specified.

Check the information supplied on the product, including the R-value, the price per square metre and whether it must be installed professionally or can be DIY – some types of insulation require the use of masks and protective clothing. Ensure that it suits your particular application and will fit within the space available. Ask if performance guarantees or test certificates are available.

Insulation in Australian homes (2008)



Source Australian Bureau of Statistics, 2008.

Compare the environmental benefits of different products. Ask about recycled content and how easily the product can be recycled after use. For example, some brands of glasswool, polyester and cellulose fibre insulation contain significant amounts of recycled context. Contact the manufacturer or industry association to find out more.

The appropriate degree of insulation will depend on climate, building construction type, and whether auxiliary heating and/or cooling is to be used. Refer to the section headed 'Insulation levels for your climate'.

The Building Code of Australia (BCA) sets out minimum requirements for the R-values of materials used in construction of buildings. For reference, please refer to BCA 2010 Volume Two Part 3.12. It is generally advisable to exceed these for greater comfort and energy savings.

The higher the R-value the better the thermal performance.

Material R-values are supplied with bulk insulation and refer to the insulating value of the product alone. The higher the R-value the better the thermal performance.

Total R-values are supplied with reflective insulation and depend on the product being installed as specified.

R-values can differ depending on the direction of heat flow through the product. The difference is generally marginal for bulk insulation but can be pronounced for reflective insulation.

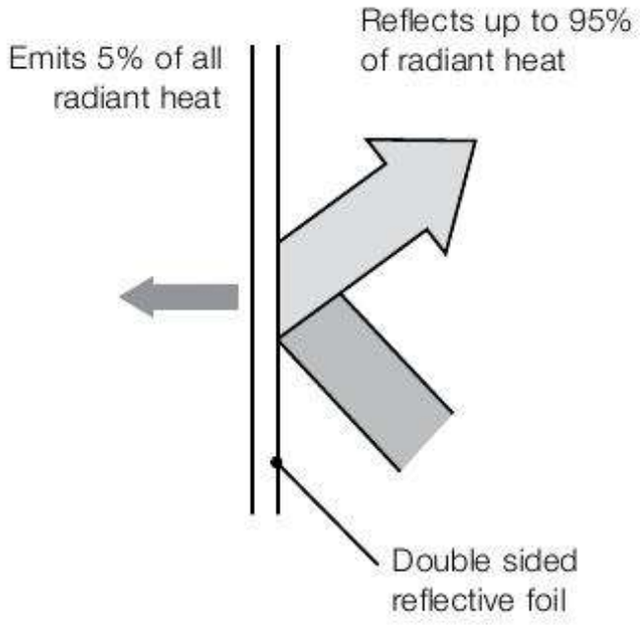
> **Up R-values** describe resistance to heat flow upwards (sometimes known as 'winter' R-values).

> **Down R-values** describe resistance to heat flow downwards (sometimes known as 'summer' R-values).

Up and down R-values should be quoted when installing reflective insulation in roofs, ceilings and floors.

Reflective insulation is usually shiny aluminium foil laminated onto paper or plastic and is available as sheets (sarking), concertina-type batts and multi-cell batts. Together these products are known as reflective foil laminates or RFL.

Dust settling on the reflective surface will greatly reduce performance. Face reflective surfaces downwards or keep them vertical. The anti-glare surface of single sided foil insulation should always face upwards or outwards.

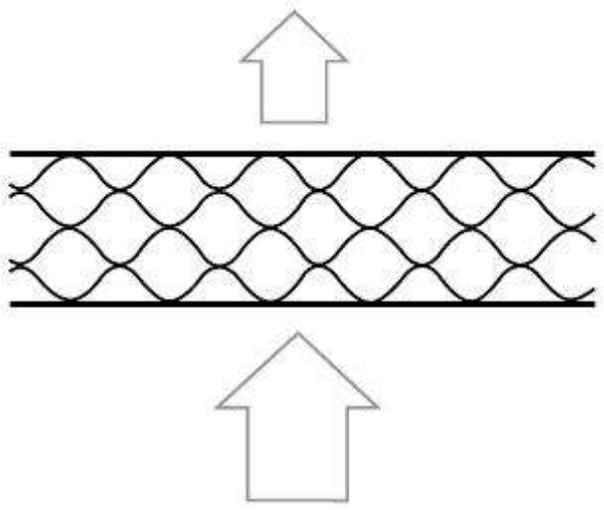


The Total R-values for reflective insulation are supplied as up and down values. Total values depend on where and how the reflective insulation is installed. Ensure system values provided by the manufacturer relate to your particular installation situation.

Composite bulk and reflective materials are available that combine some features of both types. Examples include reflective foil faced blankets, foil backed batts and foil faced boards.

The properties and uses of some common insulation materials are shown in the table at the end of this sheet.

INSULATION TYPES AND THEIR APPLICATIONS



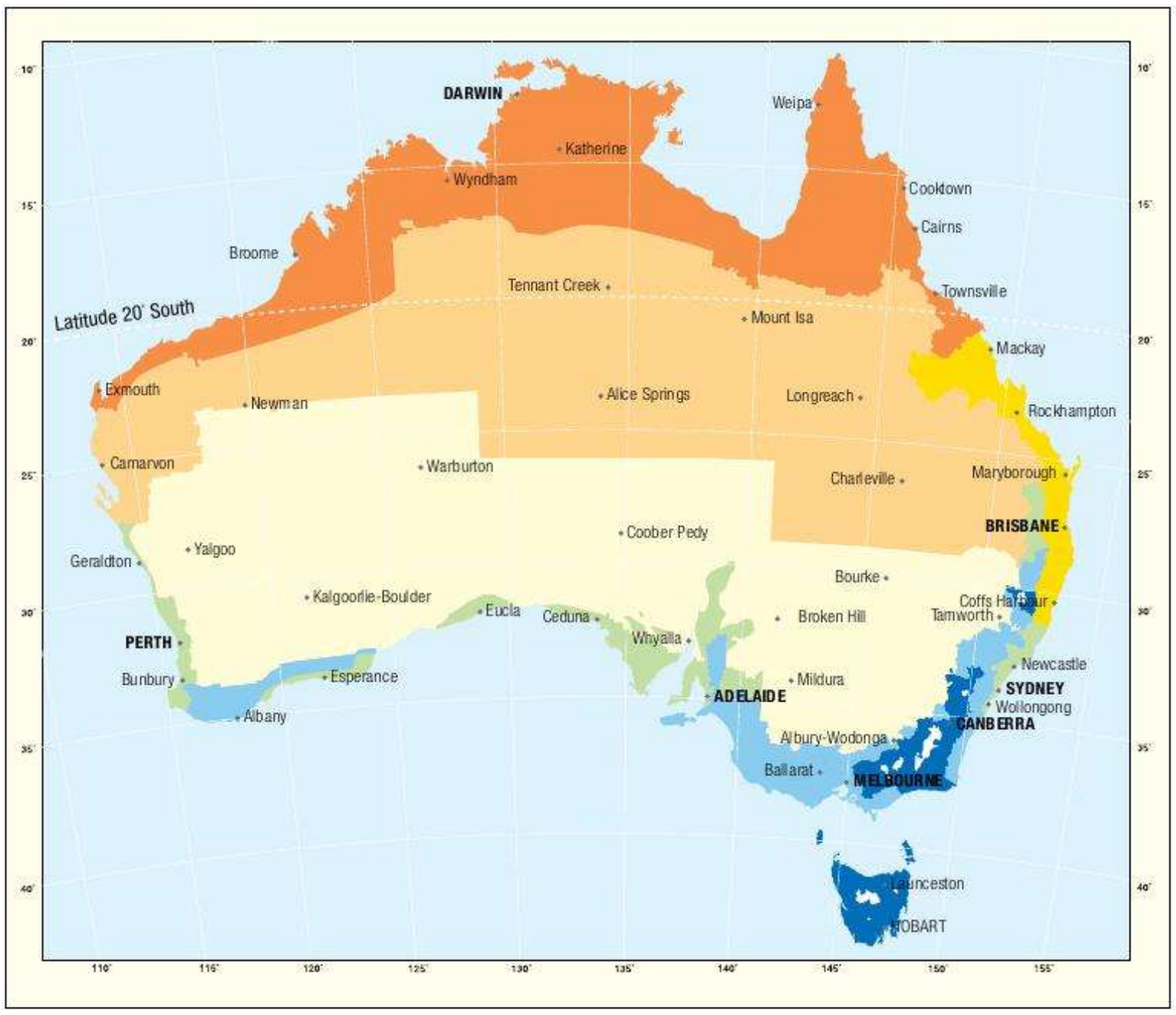
Bulk insulation traps air in still layers.

Bulk insulation mainly resists the transfer of conducted and convected heat, relying on pockets of trapped air within its structure. Its thermal resistance is essentially the same regardless of the direction of heat flow through it.

Bulk insulation includes materials, such as, glasswool, wool, cellulose fibre, polyester and polystyrene. All bulk insulation products come with one Material R-value for a given thickness.

Reflective insulation mainly resists radiant heat flow due to its high reflectivity and low emissivity (ability to re-radiate heat). It relies on the presence of an air layer of at least 25mm next to the shiny surface. The thermal resistance of reflective insulation varies with the direction of heat flow through it.

Source: SEAV Insulation Guide



ZONE	DESCRIPTION
1	High humid summer, warm winter
2	Warm humid summer, mild winter
3	Hot dry summer, warm winter
4	Hot dry summer, cool winter
5	Warm temperate
6	Mild temperate
7	Cool temperate
8	Alpine

INSULATION LEVELS FOR YOUR CLIMATE

The following table gives recommended minimum insulation levels for a range of locations.

These are the minimum requirements of the building code. Some experts believe that additional insulation can further improve building performance.

The table does not distinguish between directional R-values for roofs and ceilings. The most important thing to remember is that in high humid climates where houses are naturally ventilated, high down values and lower up values are appropriate for roofs and ceilings.

CLIMATE TYPE AND EXAMPLE LOCATIONS	MINIMUM INSULATION LEVELS (Material or Total R-values)	
	ROOF/ CEILING*	WALL
Cool Temperate and Alpine		
Reducing heat loss is the main priority		
Melbourne, VIC	4.1	2.8
Canberra, ACT	4.1	2.8
Hobart, TAS	4.1	2.8
Mt Gambier, SA	4.1	2.8
Ballarat, VIC	4.1	2.8
Thredbo, NSW	6.3	3.8
High humid and Hot Dry		
Reducing heat gain is the critical priority		
Darwin, NT	4.1	2.8
Cairns, QLD	4.1	2.8
Broome, WA	4.1	2.8
Marble Bar, WA	4.1	2.8
Mt Isa, QLD	4.1	2.8
Tennant Creek, NT	4.1	2.8
Townsville, QLD	4.1	2.8
Warm/Mild Temperate and Warm Humid		
Reducing heat loss and heat gain are equally important		
Brisbane, QLD	4.1	2.8
Perth, WA	4.1	2.8
Alice Springs, NT	4.1	2.8
Bourke, NSW	4.1	2.8
Sydney, NSW	4.1	2.8
Adelaide, SA	4.1	2.8
Katoomba, NSW	4.1	2.8

* Note: These minimum insulation levels will be higher if your roof has an upper surface absorptance value of more than 0.4.

Source BCA 2010 Volume Two

WHERE TO INSTALL INSULATION

Roofs and ceilings work in conjunction when it comes to insulation.

> Install insulation under the roofing material to reduce radiant heat gain.

> Install insulation in the ceiling to reduce heat gain and loss. In most cases ceiling insulation is installed between the joists.

[See: 4.8 Insulation Installation]

Verandah roofs should be insulated in hot climates where outdoor living spaces are used extensively, to reduce radiant heat gain. Heat build up under verandahs not only affects the space below but can affect conditions inside the house.

Bulkheads (wall sections between ceilings of different heights) must be insulated to the same level as the ceiling, as they are subjected to the same temperature extremes.

Save up to 45 per cent on heating and cooling energy with roof and ceiling insulation.

External walls should be insulated to reduce radiant, conducted and convected heat transfer. Wall insulation can be installed:

> Within cavities.

> Within stud frames.

> On the outside of stud frames.

> On the inside or outside of solid walls.

Depending on the particular situation, some forms of insulation can double as a vapour or moisture barrier.

Save up to an additional 20 per cent of heating and cooling energy with wall insulation.

Floors require insulation in cool climates and often in other climates.

Insulate the underside of suspended floors:

> In cool temperate and alpine climates.

> In temperate climates in some cases (See previous section).

> In high humid and hot dry climates where air conditioning is used.

Insulate the edge of slabs on ground:

> In cool temperate and alpine climates.

> In temperate climates where slab heating is used.

Insulate the underside of slabs on ground:

> In alpine climates.

> Where groundwater is present.

Enclosing sub-floor spaces in mixed climates may be sufficient to reduce heat loss.

Save up to 5 per cent on winter energy costs with appropriate floor insulation.

ADDING INSULATION TO EXISTING BUILDINGS

Insulation can be added to existing buildings with varying effectiveness and cost depending on the construction type and where the insulation is being placed.

Ceilings and suspended floors with easy access are relatively simple to insulate post-construction.

Insulation board can be laid beneath floor finishes if there is no under-floor access.

Walls and skillion roofs are the hardest to insulate post-construction, as the internal or external lining must be removed. A good time to insulate walls is during re-cladding or re-plastering. Specialised products are available to insulate existing walls. Check with your local building information centre. External insulation or (if local building regulations permit) cavity fill are often appropriate solutions for double brick walls.

RETROFITS AND RENOVATIONS

Adding (or 'retrofitting') insulation to existing buildings provides a major opportunity to increase comfort and reduce energy costs and greenhouse gas emissions. An ideal time for doing this is during renovations.

This section explains how to retrofit insulation to various construction types. Refer to the previous sections of this sheet to determine the appropriate type and level of insulation for your climate.

Walls

Most walls will benefit from added insulation, and it is possible to add insulation to most construction types used in Australia. Autoclaved aerated concrete (AAC) already has a reasonable degree of insulation built into the blocks themselves, and straw bale is an extremely highly insulated system.

Apart from these exceptions, added wall insulation is essential in all climates. If it is not already fitted, or if existing insulation levels are not high enough, there are ways of installing it as a retrofit.

Cavity Brick Walls

Cavity brick walls have high thermal mass, but without insulation are usually too cold in winter, and often too hot in summer if exposed to prolonged heat wave conditions. If the cavity is insulated, the internal thermal mass (ie. the internal brick skin) is protected from external temperature changes, and becomes highly effective at regulating temperatures within the home.

Insulate existing cavities by sealing the bottom of the cavity if it is open to the subfloor, and pumping in loose bulk material to a measured density. This has been common practice in the UK and Europe for many years, and is becoming available in Australia, usually in one of the following forms:

> Small polystyrene balls (produced with CO_2) coated in a non-toxic bonding agent are pumped in at regular points around the building. The bonding agent solidifies and locks all the balls in place.

> Mineral fibres can be blown into the cavity either through a series of small holes as above, or into the top of the cavity if it is accessible. This material is mineral wool. It is treated with a moisture repellent to keep the insulation and cavity dry.

It is important that such materials are installed by reputable manufacturers whose products meet either the Australian, UK or European standards.

Brick veneer, reverse brick veneer and timber framed walls

Brick veneer walls have the brick skin on the outside, which is not the ideal location for thermal mass. The bricks heat up in summer and radiate heat late into the evening, while in winter they stay cold and absorb heat from the house. Insulation is essential to protect the occupants from external temperature extremes that are exacerbated by the external brick skin.



Reverse brick veneer is much more thermally efficient because the thermal mass is on the inside, however good insulation is still important to maintain thermal comfort.
[See: 4.9 Thermal Mass]

Timber framed walls are low mass construction, and rely entirely upon insulation to maintain thermal comfort.

The two cavity fill methods previously described (polystyrene balls or mineral fibres) can be used to insulate these wall types if the lining or cladding is not being removed. More material may be required, as it will fill up not only the cavity but the width of the wall frame (brick veneer and reverse brick veneer). Note that the effectiveness of existing reflective insulation is greatly diminished by replacing the airspace with fill material. For timber frame walls, insulation is pumped into the voids between studs and noggings, but this can be labour intensive.

The ideal option, if the scope of the renovation permits, is to remove the internal plasterboard linings or external cladding and fit insulation into the stud frame.

Either bulk or reflective insulation can be retro-fitted to existing wall frames by either cutting up a roll and fitting the pieces between each wall stud, or by using a factory prepared product like bulk batts, concertina foil batts or multi-cell foil batts, which are easy to install and expand or fold into place. Reflective foil-backed plasterboard is also a useful material.

There is usually sufficient depth in a wall frame to add more than one layer of reflective insulation, including the necessary air gap of 25mm between layers. When installing from the room side, the foil should not have an antiglare coating on it.

R 2.0 (70mm) or R 2.5 (90mm) bulk insulation can be fitted between studs. It is important to choose the correct thickness of insulation to suit the thickness of the cavity.

Bulk insulation can be fitted between studs in the conventional manner and, depending on the thickness of the studs and the selected R-value, may or may not fill the entire wall frame width. Do not compress bulk insulation.

When used in conjunction with a layer of wall wrap foil, ensure there is an air space of at least 25mm between the batt and the wall wrap foil.
[See: 4.8 Insulation Installation]

Other wall types

Single skin high mass walls, such as, concrete block, rammed earth or mud brick can have their thermal performance radically improved by installing insulation on the wall exterior. The simplest method is to use polystyrene board with an external render, or batts fixed between battens at around 600mm centres, covered with a waterproof cladding.
[See: 4.8 Insulation Installation; 4.9 Thermal Mass]

Ceilings and roofs

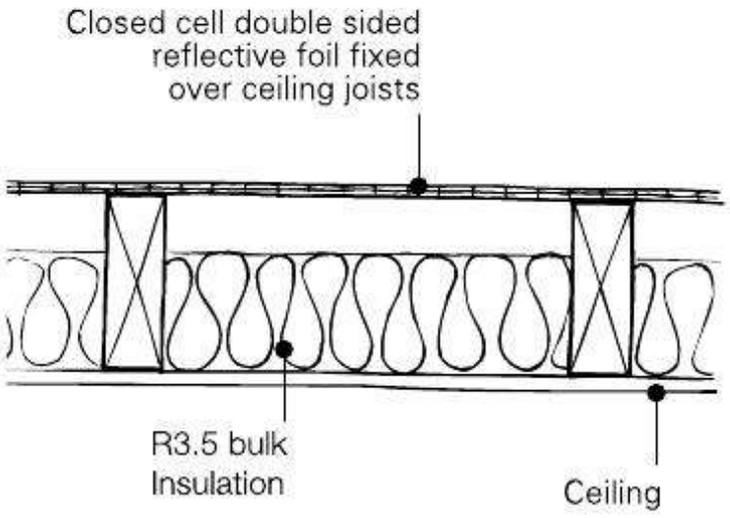
It is possible to add insulation to all roof types common in Australia, and even if some effort is required to lift roofing, the benefit is well worth it.

Ceiling fires have increased significantly with the more common use of downlights that penetrate the ceiling. Care must be taken to ensure that minimum clearances around downlights are maintained and that transformers are not underneath the insulation. Wherever possible avoid recessed light fittings as these are a major source of heat loss.

Tiled roofs without foil insulation can have it added easily if the roof is being re-tiled. If the tiles are to remain in place and access is available to the roofspace, double sided foil or foil batts can be added between the rafters or trusses, directly under the tile battens.

Metal roofs need a condensation barrier directly beneath them: a layer of reflective foil insulation is an effective membrane and barrier to radiant heat, thus doing two jobs at once. It is usually necessary to remove the roofing to install this, but most metal roofing can be removed and reinstalled easily, without damage.

If foil insulation has been fitted it may still be necessary to fit extra layer/s of foil beneath it. A minimum air gap of 25mm should always be maintained between layers. If the roof is being painted to restore colour, select the lightest permissible colour (heat-reflective roof paints are also an option), and then match the remaining colour scheme to it.



Ceiling insulation is simple to fit if the roof space is accessible. If the house has a flat roof or raked ceilings, there will be no access into the space except by removing and reinstalling the roofing or the ceiling lining. If the ceiling is being replaced, it's a simple job to install insulation from below. Reflective foil backed plasterboard is a useful material in this situation, but may not provide sufficient insulation if used on its own.
[See: 4.8 Insulation Installation]

Floors

Floors do not always require insulation. Refer to the previous sections of this sheet to determine whether floor insulation is required for your situation.

Raised timber floors should have subfloor access, with soil clearance of around 400mm below the lowest timbers. This provides sufficient access to install insulation. Foil or bulk insulation will work well, but in either case care must be taken to ensure it is well supported and will not sag or fall down in time. Vermin also need to be accounted for. Insulation board can be laid beneath floor finishes if there is no subfloor access.

Concrete slabs are either suspended or slab on ground. Suspended slabs can be insulated in a similar way to raised timber floors.

A suspended concrete slab with an in-slab heating or cooling system installed must be insulated around the vertical edge of its parameter and underneath the slab with insulation having R-value of not less than 1.0.

A concrete slab-on-ground with an in-slab heating or cooling system must have insulation installed around the vertical edge of its perimeter. The insulation must achieve a minimum R value of 1.0 in zones 1 to 7 and a minimum R value of 2.0 in zone 8. The insulation must be water resistant and be continuous from the adjacent finished ground level to a depth of 300mm or for at least the full depth of the vertical edge of the concrete slab-on-ground.

To install slab-on-ground edge insulation you can excavate a shallow trench around the slab edge, but you should avoid excavating right down to the bottom of the slab, as destabilisation of the foundation may occur.

Install a 40mm closed cell polystyrene board and fibre cement cover board around the entire slab edge, up to the height of the wall cladding. Ensure the termite barrier remains intact. For more effective performance (if needed) an additional fin of closed cell polystyrene board can be laid horizontally from the slab edge underneath paving, extending about 1-1.5m.
[See: 4.8 Insulation Installation]

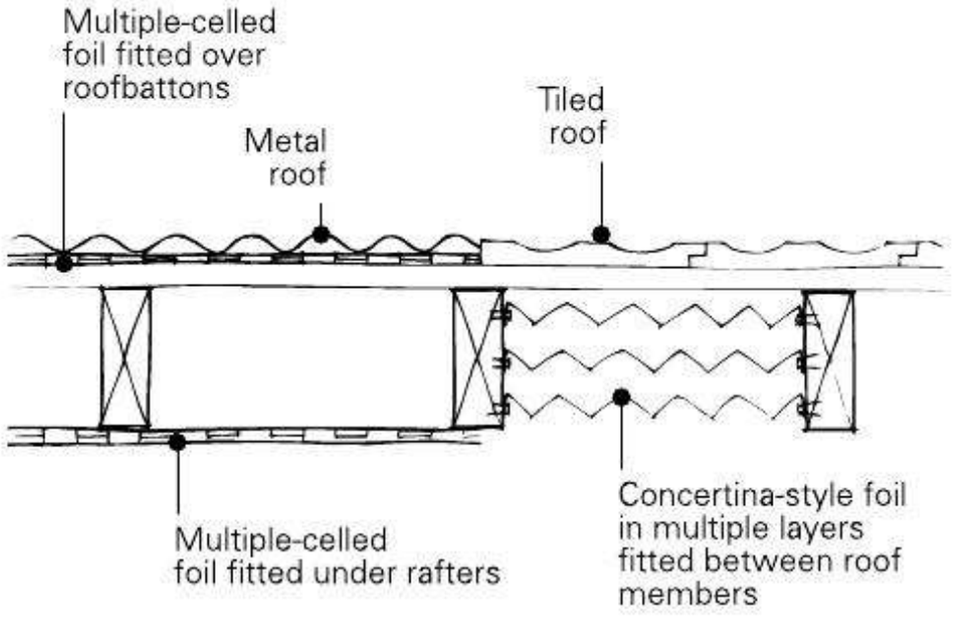
Air Leakage

Householders can improve the energy efficiency of most existing and new homes by weathersealing. Overseas standards and research recognise that the weather proofing or draught sealing of houses is the most effective method of achieving direct energy savings, whilst maintaining healthy indoor air quality. It is estimated that Australian buildings leak 2-4 times as much air as Northern American or European buildings, suggesting a tremendous opportunity for energy savings in Australia.

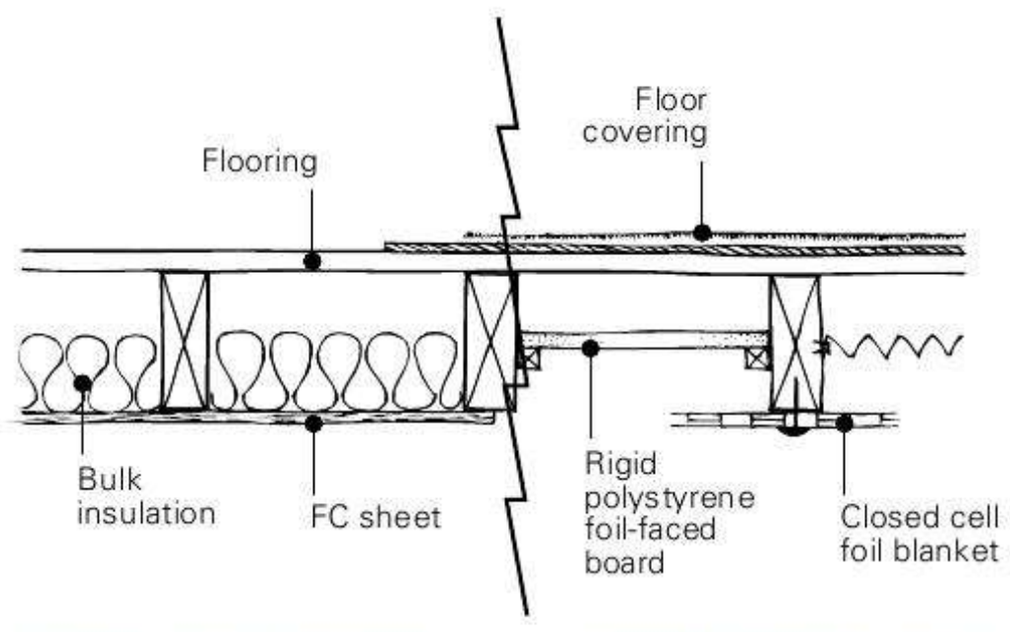
In Australia, households produce around 20 per cent of our total annual greenhouse gas emissions, of which heating and air-conditioning account for around 38 per cent. Draughts can account for up to 25 per cent of heat loss from a home.

According to the Mobile Architecture and Built Environment Laboratory there are currently no scientific programs on air leakage performance for Australian residential construction and the challenge is to identify where weather sealing can be improved and to develop appropriate methods of construction, repair and detailing.

Roof



Floor



Exposed subfloor (Pole home).

Enclosed or ventilated subfloor (brick, brick veneer, timber frame).

PROPERTIES AND USES OF COMMON INSULATION TYPES

Common types of reflective insulation

MATERIAL	DESCRIPTION	Flat ceilings Pitched Roof	Cathedral or raked ceilings	Timber floors	Framed walls
Reflective Foil Laminate [RFL] insulation	> Aluminium foil laminated with glasswool reinforcement > Requires a sealed air space of at least 25mm between foil and solid surface to provide full insulation > Useful as a barrier against moisture > Dust build up on foil reduces performance > Available in rolls, often with one side painted with anti-glare paint	✓	✓	✓	✓
Multi-cell Foil Batts	> Batts made from layers of RFL with enclosed air cavities between the layers > Other characteristics identical to RFL insulation > Double or triple cell batts available > 25mm air space to be maintained between product and other material	✓	✓	✓	✓
Concertina – type Foil Batts	> Concertina-folded foil/ paper laminate > Expandable, and can be adjusted to suit varying gaps > Other characteristics identical to RFL	✓	✓	✓	✓

Common types of bulk insulation

MATERIAL	DESCRIPTION	Flat ceilings Pitched Roof	Cathedral or raked ceilings	Timber floors	Suspended slabs	Slab edges	Full masonry walls	Framed walls
Glasswool Batts	> Made from melted glass spun into a mat of fine fibres > Easy to cut and install, commonly sold in DIY packs as rolls or batts > Should not be compressed or moistened > Can cause irritation, wear protective clothing during installation	✓	✓	✓				✓
Rockwool Batts	> Made from melted volcanic rock spun into a mat of fine fibres > Higher R-values than glasswool per unit thickness > Good sound absorption properties > Other characteristics- see glasswool	✓	✓	✓				✓
Rockwool Loose-fill	> Supplied as granules, properties as for Rockwool batts > Can be difficult to install in weatherboard walls > Treat with water repellent and install evenly > Should not be compressed or moistened	✓	✓*					✓
Polyester	> Made from polyester threads spun into a mat, produced in rolls and batts > Similar physical properties to fibreglass and rockwool > Should not be compressed or moistened > Protecive clothing is not required during installation	✓	✓	✓				✓
Wool Batts	> Made from spun sheep's wool, treated against vermin and rot > Available with polyester blend to reduce settling and compression > Check the quality and fire resistance of the product	✓	✓	✓				✓
Wool Loose-fill	> Properties as for wool batts, but quality and density can vary and affect the R-value	✓	✓*					
Cellulose Fibre Loose-fill	> Made from pulverised recycled paper > Borax and boracic acid are added as fire retardant and to deter vermin > Usually pumped into ceiling, must be a consistent density and thickness > Should not be compressed or exposed to moisture > Some settling may occur, decreasing performance	✓	✓*					
Extruded polystyrene [styrofoam]	> Rigid boards that retain air but exclude water > High R-value per unit thickness, suitable where space is limited > Easy to cut and install and can be rendered > Greater structural strength and moisture resistance than EPS		✓	✓	✓	✓	✓	✓
Expanded polystyrene [EPS]	> Semi-rigid boards of polystyrene beads > Easy to cut and install and can be rendered > Available as pre-clad panels		✓	✓	✓	✓	✓	✓

*Consult manufacturers for maximum roof slope to which loose fill insulation can be installed

Composite insulation combines the benefits of bulk and reflective insulation

MATERIAL	DESCRIPTION	Flat ceilings Pitched Roof	Cathedral or raked ceilings	Timber floors	Suspended slabs	Slab edges	Full masonry walls	Framed walls
Glasswool or Rockwool Batts and blankets with RFL	> Reflective foil is bonded to one side of the batt > Characteristics as for batts, plus: > Higher 'down' R-values due to foil > Increased moisture resistance due to foil	✓	✓	✓	✓			
Expanded polystyrene with foil	> Expanded polystyrene boards sandwiched between reflective foil > Characteristics as for EPS, plus: higher 'down' R-values due to foil		✓	✓	✓			✓

ADDITIONAL READING

Contact your State / Territory government or local council for further information on insulation considerations for your climate.
www.gov.au

Australian Bureau of Statistics (March 2008), *Environmental Issues: Energy Use and Conversation*, Catalogue no. 4602.0.55.001

BEDP *Environment Design Guide*
GEN 12 Passive Solar Design.

Department of the Environment, Water, Heritage and the Arts (2008), *Energy Use in the Australian Residential Sector: 1986-2020.*
www.energyrating.gov.au/library/details2008-energy-use-aust-res-sector.html

Insulation Council of Australia and New Zealand (2007), *Insulation Handbook Part 1: Thermal Performance Total R-value Calculation for Typical Buildings.*

ReNew: technology for a sustainable future magazine, *Insulation Buyers Guide*, Issue 88
www.renew.org.au

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Last updated:
November 2010

Insulation Installation

Installing insulation or additional insulation in an existing dwelling can make a significant difference to the performance of the home. It is important to install installation correctly. This sheet deals with how to install insulation in various types of construction, providing Installation tips and typical solutions. This sheet should be read in conjunction with 4.7 Insulation.



Please note that total R-values for roofs, ceilings, walls and floors given in this manual provide only one value for total thermal resistance of construction.

Under the Building Code of Australia (BCA), total R-values of the building fabric vary depending on climate zone and the height above the Australian Height Datum at the location where the buildings is to be constructed. Ensure you comply with the BCA requirements for energy efficiency of building fabric.

INSTALLATION TIPS

This section demonstrates how to install insulation without compromising its effectiveness.

Thermal bridges

The building frame can act as a thermal bridge, particularly in cold climates, conducting heat and allowing it to bypass otherwise effective insulation. Metal framing is a particular issue because of its high conductivity. The presence of the frame reduces the overall insulation value, as the frame can constitute up to 15 per cent of the wall, ceiling or floor surface. To help overcome the effect of thermal bridging:

> Foam isolating strips between the metal frame and cladding must be at least 12mm with an R-value of 0.2.

> Fix bulk insulation, such as foam boards, over the external or internal surface of the frame.

Vapour barriers

Vapour barriers include polythene sheet, reflective foil, foil backed plasterboard and well maintained water resistant painted surfaces. Water resistant insulation, such as foam can also act as a vapour barrier. Tape or glue all joints in vapour barriers to keep out moisture.

Use vapour barriers to protect from condensation:

> In high humid (tropical) climates.

> In cool climates where the difference between indoor and outdoor temperature is significant.

> In roof spaces with a low ventilation rate, for example cathedral or raked ceilings.

> In situations where high amounts of vapour are generated and not exhausted.

> On the underside of metal roofing, to minimise the likelihood of condensation and corrosion.

Install vapour barriers on the warm side of the insulation:

> In cold climates place the vapour barrier on the inside of the insulation (directly above the ceiling lining and next to the internal wall lining).

> In warm climates place the vapour barrier on the outside of the insulation.

Roof ventilation

Ventilate the roof space where possible to allow built up heat to dissipate. Even in cooler climates a minimal amount of ventilation is desirable to allow built up moisture to escape. Sufficient ventilation is often achieved through the air gaps along the ridgeline or between tiles. Gable or eaves vents may also be used.

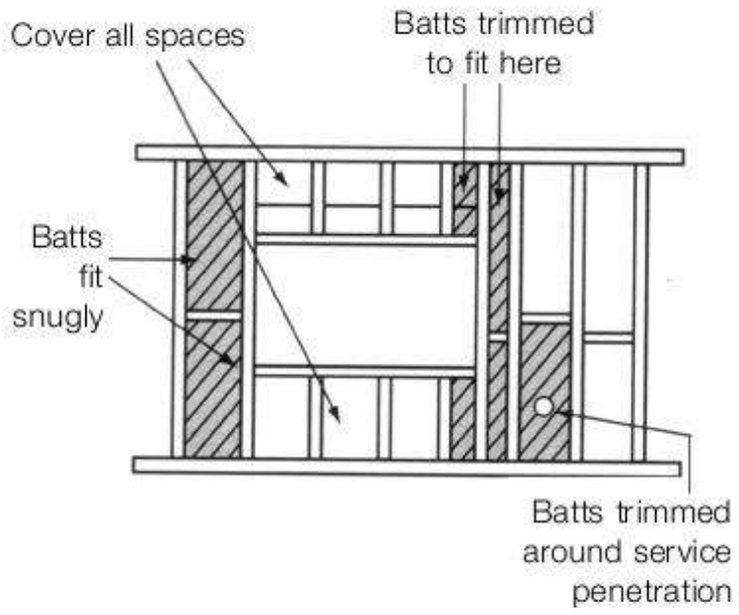
Ventilated roof spaces in high humid (tropical) climates under metal roofing can result in excessive condensation at night. Condensation dripping off the underside of metal roofing onto the ceiling can be avoided by installing reflective foil insulation similar to that used under roof tiles.

In bushfire prone areas cover any openings with fine stainless steel mesh to prevent cinders from entering the roof space. Keep roof spaces weather tight and vermin proof.

Gaps

Avoid gaps in all types of insulation. Even a small gap can greatly reduce the insulating value. Fit batts snugly and don't leave gaps around ducts and pipes. Tape up holes and joins in reflective insulation. Make sure the ends of multi cell and concertina foils are well sealed. Ensure that corners of walls, ceilings and floors are properly insulated as these are areas where heat leaks most often occur.

For safety reasons, minimum clearances must be left around hot objects, such as flues from fires, recessed downlights and their transformers. See 'Health and safety tips' below.



Wall insulation must butt into door and window frames. In cold climates, metal frames around glazing should have thermal breaks to reduce heat loss. [See: 4.10 Glazing]

Insulate internal walls between the house and uninsulated spaces, such as, garages and storerooms.



Bulk insulation

Do not compress bulk insulation as this will reduce its effectiveness. Ensure there is sufficient space for the insulation to retain its normal thickness.

Keep moisture away from bulk insulation, or its performance will be reduced (water resistant types are an exception). Use a vapour barrier where there is a risk of condensation.

Restrain bulk insulation in cavities so it does not come into contact with the porous outer skin of the wall. This can be done with perforated RFL (reflective foil laminate), a non-corrosive wire or nylon fishing line.

Cavity fill insulation (loose fill or injected foam) is particularly useful for insulating existing cavity walls. Check that your local building codes permit the use of cavity fill insulation.

Potential problems to be aware of include overheating of electrical cables, damp problems (if the insulation is absorbent) and moisture transfer across the cavity by capillary action. Injected foams can cause bowing of the walls in some cases.

Loose-fill insulation should not be used in excessively draughty roof spaces or ceilings with a slope of 25° or more. In other applications, keep the density of the insulation consistent to avoid reducing the R-value. Note that loose-fill insulation may settle by as much as 25 per cent over time. Ask your contractor for a guaranteed 'settled R-value'.

Reflective insulation

Maintain an air space of at least 25mm next to the shiny surface of reflective insulation. If this is not done the insulating properties will be reduced.

Dust settling on the reflective surface of insulation will greatly reduce its performance. Face reflective surfaces downwards or keep them vertical.

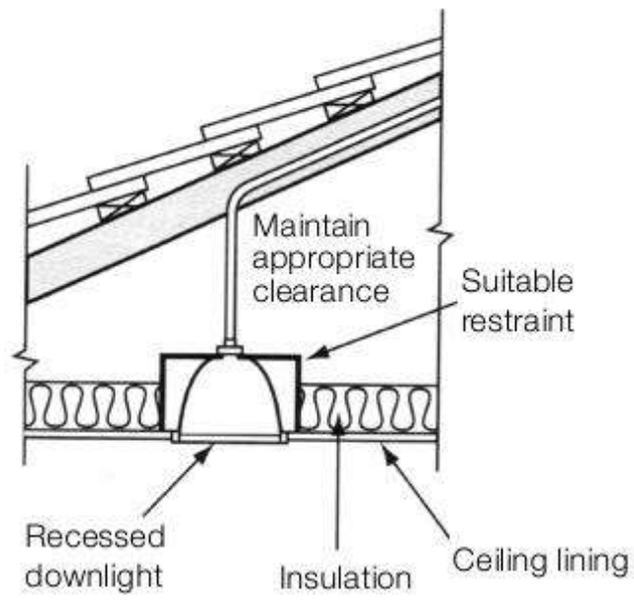
Use perforated reflective foil in walls and under floors when building with porous materials. The perforations prevent water droplets from penetrating but allow vapour through so that the insulation can dry if it does somehow get wet. This prevents rotting behind weatherboards or under timber floors, for example.



HEALTH AND SAFETY TIPS

Electrical wiring must be appropriately sized or it may overheat when covered by insulation. Have it inspected by a licensed electrician to ensure it can be safely covered by insulation.

Allow clearance around hot flues, exhaust fans, appliances and fittings. For light fittings, where the manufacturer's installation instructions do not provide information on required clearances the light fitting can be installed using a suitable Australian Standards approved enclosure for electrical and fire safety. Where barriers are not used, ensure a minimum clearance of 50 mm above the incandescent lights and 100mm side clearance to any structural members and for recessed halogen lights a minimum of 200 mm above and side clearance to any structural member, with a 50 mm gap for lighting transformers. Refer to the Australian/New Zealand Wiring Rules (Australian/New Zealand Standard (AS/NZS) 3000:2007) for more detailed information.



Wear protective clothing, gloves and a face mask when installing glasswool, mineral wool or cellulose fibre insulation. These materials can cause short term irritation to skin, eyes and upper respiratory tract. It is good practice to always wear protective equipment when working in dusty roof spaces.

Ceiling fires have increased significantly with the more common use of downlights that penetrate the ceiling. Care must be taken to ensure minimum clearances around downlights are maintained and that transformers are not underneath the insulation. Wherever possible avoid recessed light fittings as these are a major source of heat loss.

Wear adequate eye protection when installing reflective insulation, as it can cause dangerous glare. Be aware of the increased risk of sunburn.

Insulation materials containing reflective foil must be kept clear of electrical wiring and fittings, and should not be secured using metal staples.

INSTALLATION DETAILS

The following section shows typical solutions for installing insulation in various construction types. It also shows how to estimate total R-values.

Total R-values describe the total resistance to heat flow provided by a roof and ceiling assembly, a wall or a floor. These values are calculated from the resistances of each component, including the insulation.

Total R-values are the best indicator of performance, as they show how insulation performs within the building envelope. Total R-values are used when calculating HERS ratings. [See: 1.5 Rating Tools]

HOW TO ESTIMATE THE TOTAL R-value

> Find the construction type that relates to your situation (e.g. pitched tiled roof with flat ceiling and an unventilated roof space). Calculate the total thermal resistance of the building components of your construction type.

> Add the material or system value of insulation you are installing. This will give you an approximate total R-value.

For example, adding bulk insulation with a material R-value of 2.5 will increase both the up and down total R-values by around 2.5, as long as the material is not compressed.

Adding reflective insulation with a system R-value of 1.7up, 3.0down will increase the total up and down R-values by those amounts, providing the insulation is installed as specified with air gaps.

This method provides a useful estimate, but it must be noted that many factors can reduce the total R-value. These include thermal bridging, compression of bulk insulation, dust settling on reflective insulation, and the lack of a suitable air gap for reflective surfaces.

The total thermal resistance of each construction type has been calculated using information from the Australian Standard.

Total R-values for roofs, ceilings and floors are expressed as up and down values. Thermal resistance to heat flowing up and heat flowing down can vary significantly.

Total R-values for walls are expressed as a single figure, as heat flow in and out through walls does not necessarily correlate to heat flow up and down.

ROOF AND CEILING INSULATION

Installing roof and ceiling insulation can save up to 45 per cent on heating and cooling energy.

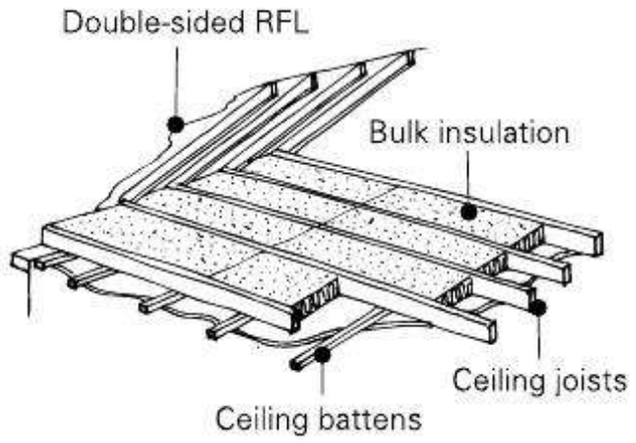
Pitched roofs with flat ceilings

This is the most common type of construction and the easiest to insulate. The BCA specifies different insulation requirements for roofs and ceilings according to the climate zone.

Roof

A second layer of RFL (either sarking or foil batts) beneath the roof will increase resistance to radiant heat. This may be useful in hot climates. Ensure that there is at least a 25mm gap between reflective surfaces.

Place RFL insulation directly under the roofing material between the battens and the rafters with the shiny side facing down.

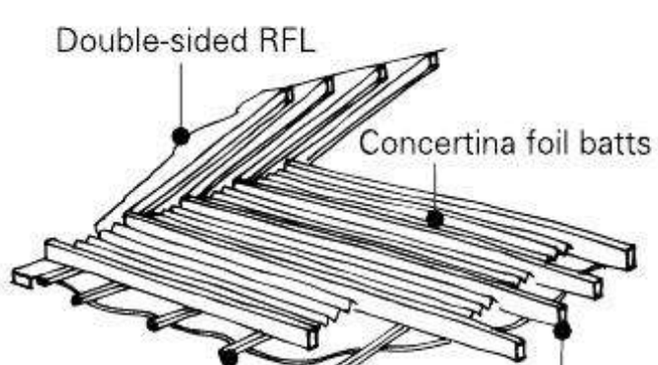


Ceiling

Place ceiling insulation between the joists.

Suitable bulk insulation includes bulk batts, loose fill and foam boards. In alpine climates two layers of bulk insulation may be installed to increase thermal performance, one between the joists and the second on top.

There are cautions related to covering ceiling joists with insulation. Safe places to walk are not identifiable when accessing the roof space. If insulation is removed each time the roof space is accessed it must be reinstalled in accordance with the Australian Standard.



Suitable reflective insulation includes multi cell or concertina style batts. These batts should be placed between ceiling joists. Install insulation strictly in accordance with manufacturers instructions. Failure to do so can significantly reduce insulation values.

Ceilings that follow the roof line

These includes sloping ceilings, cathedral ceilings, vaulted ceilings, and flat or skillion roofs, where there is no accessible roof space.

Design ceilings with enough space to accommodate adequate insulation, including any necessary air gaps.

Ceilings with concealed rafters are easier to insulate and should be considered in preference to ceilings with exposed rafters.

Ceilings with exposed rafters require insulation products with a higher R-value per unit thickness due to space limitations within the ceiling.

Consult the insulation manufacturer about installation clearances. As a rough guide, minimum clearance heights for ceilings that are parallel with the roof are:

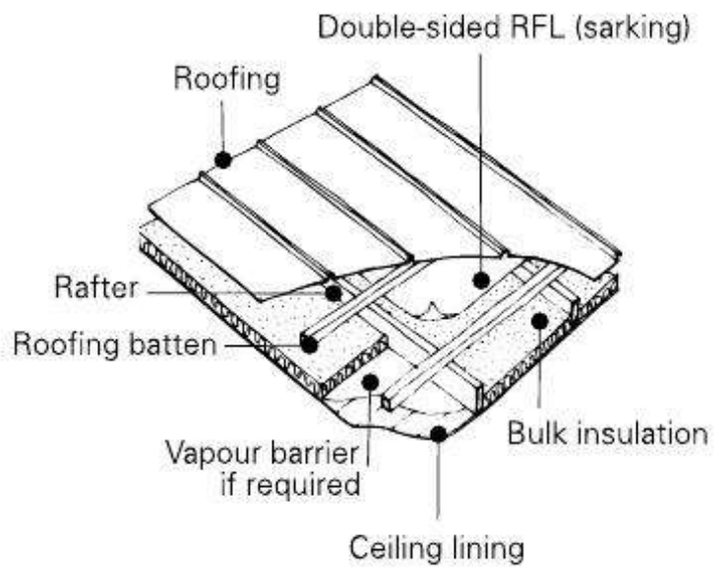
> R3.0 bulk batts: 130mm

> R3.0 foam boards: 85mm

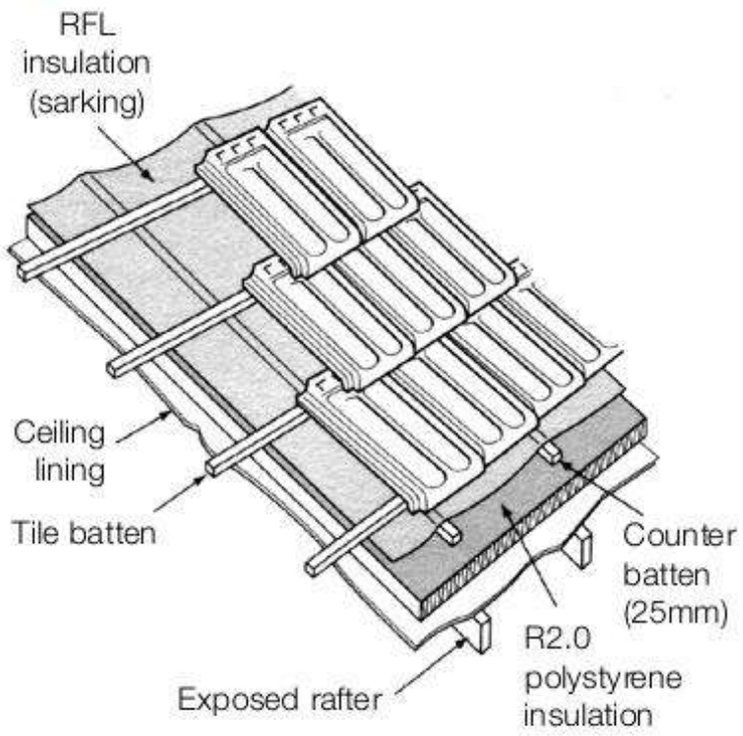
Use sarking or foil backed insulation under metal roofs, making sure that there is at least a 25mm gap below the reflective surface of the insulation.

Similar insulation techniques are used for tile and metal roofs.

Concealed rafters

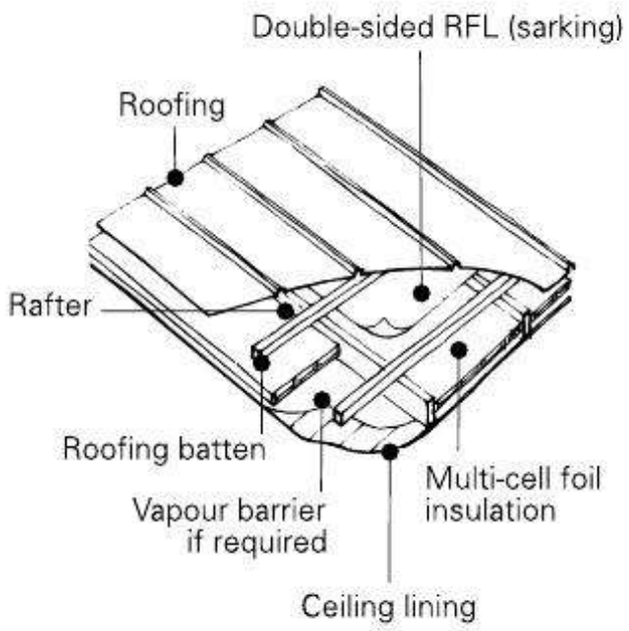


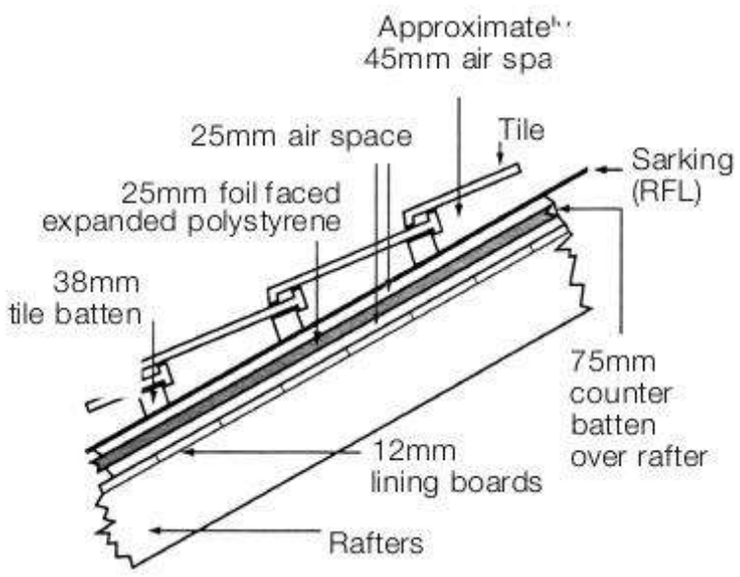
Exposed rafters



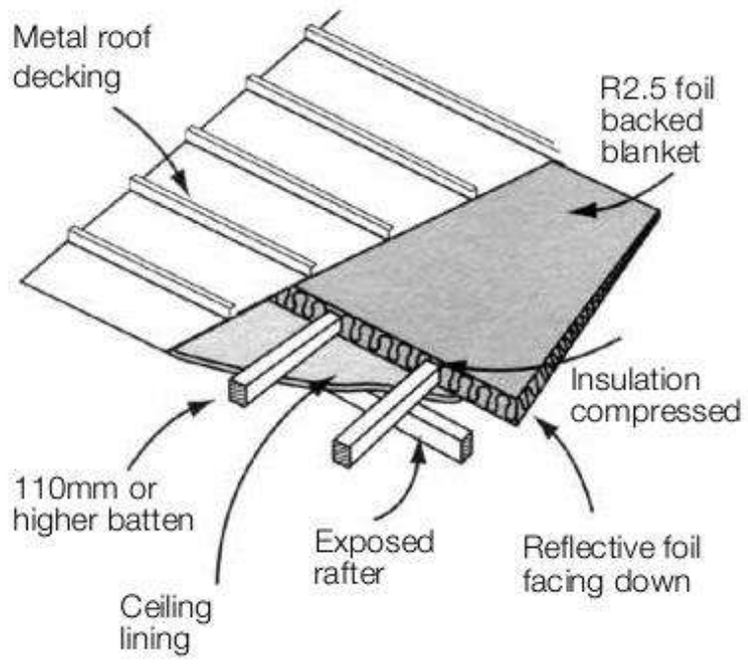
Suitable bulk insulation includes foam boards and bulk batts.

Suitable reflective insulation includes multi cell and concertina-type batts.





Suitable composite insulation includes foil faced foam boards. If rafters are exposed, the minimum batten height is 75mm to allow for two 25mm reflective air spaces either side of the boards. 25mm foil faced foam boards and RFL insulation will give a total R-value of around 1.7up, 2.9down.



Foil backed blankets are mainly used to reduce condensation in the roof space, reduce noise from metal roofing and to provide a vapour barrier, but they are sometimes used as thermal insulation. Compression of the blanket over the battens lowers the total R-value.

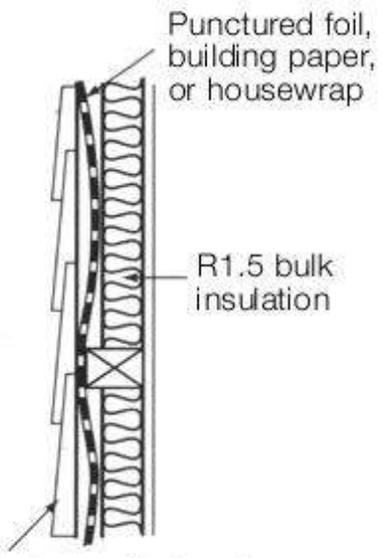
EXTERNAL WALL INSULATION

Insulating your walls will save up to an extra 15 per cent on heating and cooling energy.

Framed walls

Weatherboard walls

The total thermal resistance of typical weatherboard wall construction is approximately R 0.45 and with RFL insulation R 0.9. This is insufficient for most building code compliance or sustainability requirements and needs to be supplemented with additional insulation.



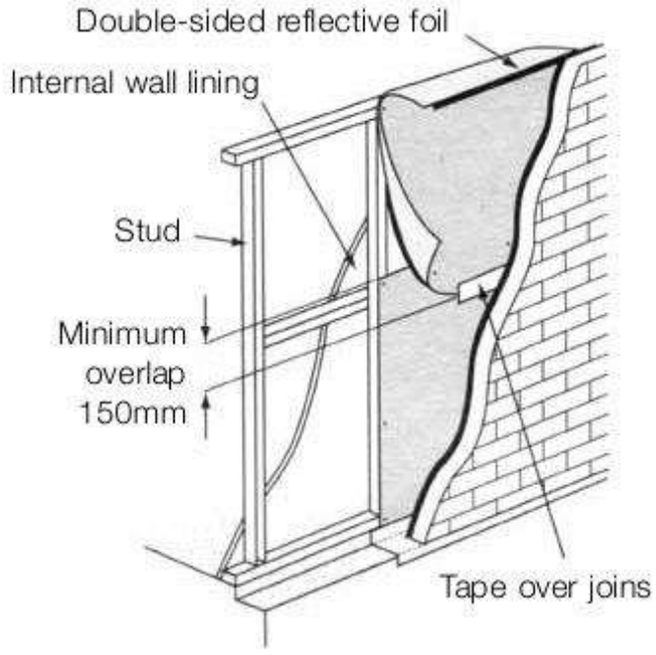
External weatherboards

Use perforated reflective foil over the outside of the frame. For higher insulation levels, add reflective foil batts between the studs. Make sure that the air spaces between reflective surfaces is at least 25mm.

Alternatively, use bulk insulation with perforated building wrap. Ensure batts fit within the cavity without compression, making sure that there is at least a 25mm gap from the reflective surface.

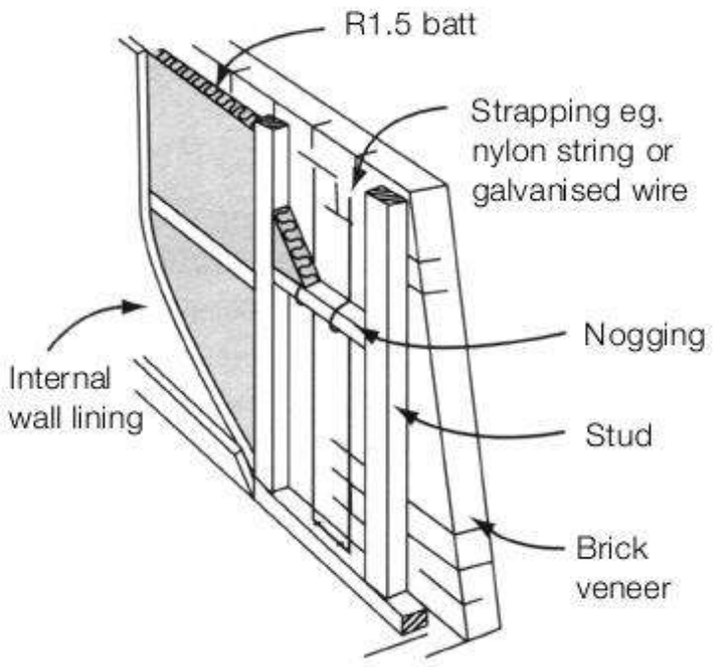
Brick veneer walls

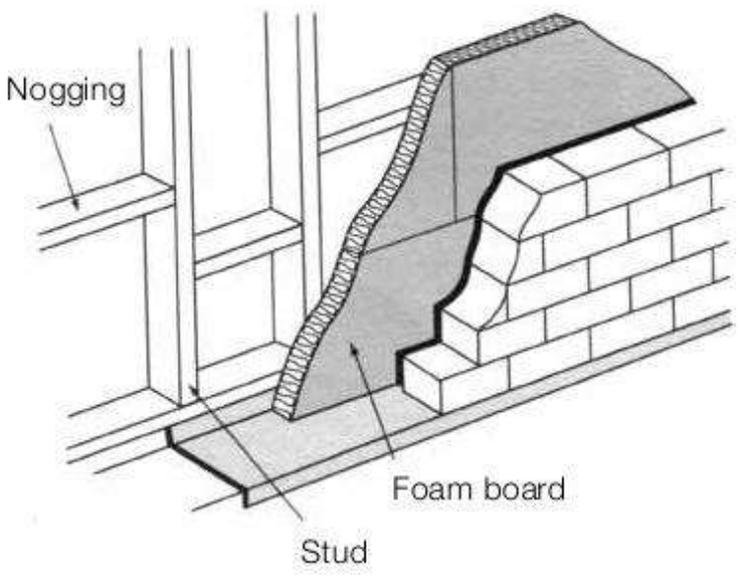
The total thermal resistance of typical brick veneer wall construction is approximately R 0.45 and with RFL insulation R 1.4. This is insufficient for most building code compliance or sustainability requirements and needs to be supplemented with additional insulation.



For higher insulation levels, add reflective batts between the studs, making sure that air spaces between each reflective surface are at least 25mm.

Use bulk insulation with strapping or perforated building wrap over the outside of the frame to prevent batts from touching the porous brick skin.



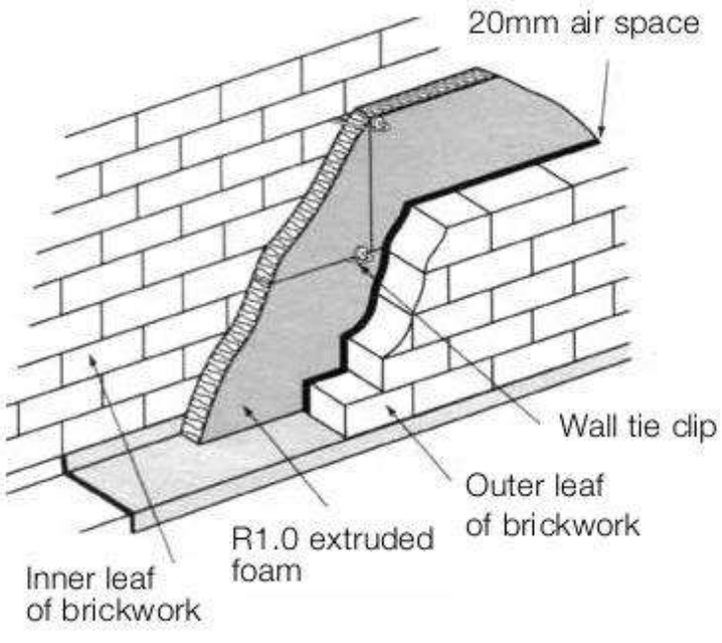


Fixing insulation to the outside of the studs is useful in cold climates to reduce thermal bridging. Placing the insulation on the outside gives a higher total R-value than placing the insulation between the studs.

Suitable materials include foam boards, high density rockwool batts, and foil faced foam boards with a reflective air space of at least 25mm. Leave sufficient space for bricklayers to lay the outside skin (about 35mm).

Cavity brick walls

The total thermal resistance of typical cavity brick wall construction is approximately R 0.5. This is insufficient for most building code compliance or sustainability requirements and needs to be supplemented with additional insulation.



Use foam boards or cavity fill (loose fill or injected foams).

There are various issues associated with the use of cavity fill insulation. This method is mainly used to insulate existing cavity brick walls. Check that local building regulations allow use of cavity fill. Cavity fill must be treated to be water repellent. [See: 4.7 Insulation]

Foam boards with reflective surfaces can have a reduced performance due to insufficient size of air gaps, and the reflective surfaces getting dirty during construction.

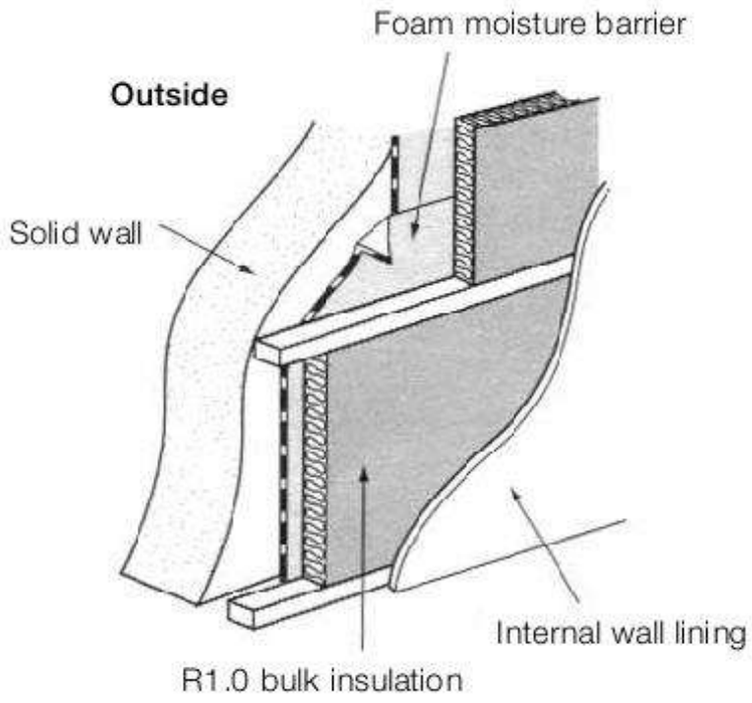
Using cavity fill in double brick walls will provide a total R-value of around R1.3 (dependent on cavity width).

Solid walls

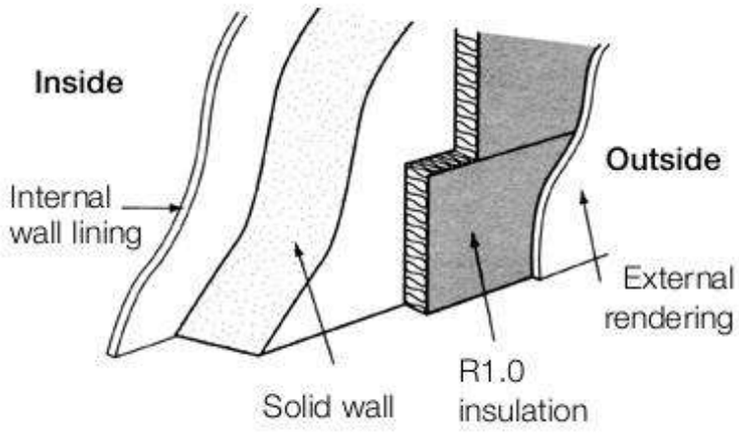
Including concrete block, concrete panel, stone, mud brick, pisé and solid brick construction without a cavity.

The total thermal resistance of solid wall construction without a cavity is approximately between R 0.3 and R 0.4. This is insufficient for most building code compliance or sustainability requirements and needs to be supplemented with additional insulation.

Solid walls can be insulated on the inside or the outside. Do not insulate the inside of walls whose thermal mass is to be utilised. Insulation isolates the thermal mass from the interior, wasting its beneficial passive heating potential.



Suitable materials include foam boards, bulk batts, and foil faced foam boards with a still air layer of at least 25mm each side. For internal walls plasterboard products incorporating foam are also suitable.



On external walls, foam can be clad with an external finish, for example render. No additional waterproofing is required. Fix bulk batts between battens and cover with a waterproof cladding.

FLOOR INSULATION

Suspended floors

The BCA specifies that a suspended floor, other than an intermediate floor in a building with more than one storey must achieve a certain R-value for the downwards direction of heat flow for the relevant climate zone. In addition, such a suspended floor with an in-slab heating or cooling system is required to be insulated around the vertical edge of its perimeter and underneath the slab with insulation having an R-value of not less than 1.0. See 3.12.1.5 Floors in BCA 2010 Volume Two.

In cool climates, some mixed climates, and hot climates where airconditioning is used:

> Enclose the sub floor space if possible [maintain sufficient ventilation to satisfy local building requirements].

> Where appropriate install underlay and carpet, or lay insulation board under floor finishes.

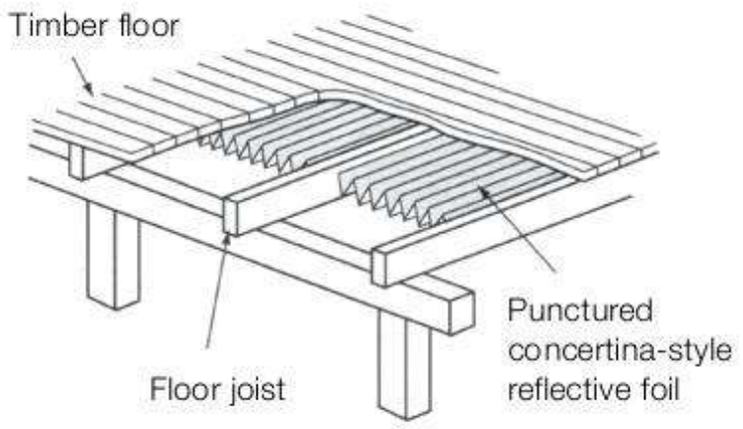
> Insulate the underside of timber floors or suspended slabs exposed to outside air.

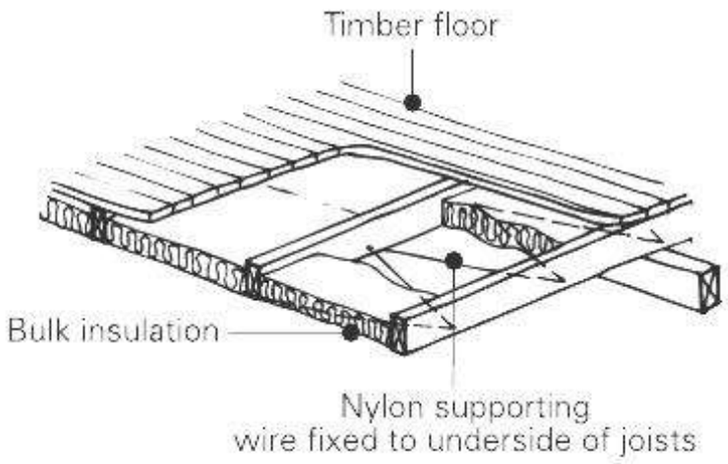
> Insulate the underside of heated suspended slabs.

Timber floors

The total thermal resistance of typical timber floor construction is approximately R 0.3 up and R 0.4 down. With RFL insulation it is approximately R 0.6 up and R 1.0 down. This is insufficient for most building code compliance or sustainability requirements and needs to be supplemented with additional insulation.

Use perforated RFL foil or concertina-type batts, stapled to the joists.

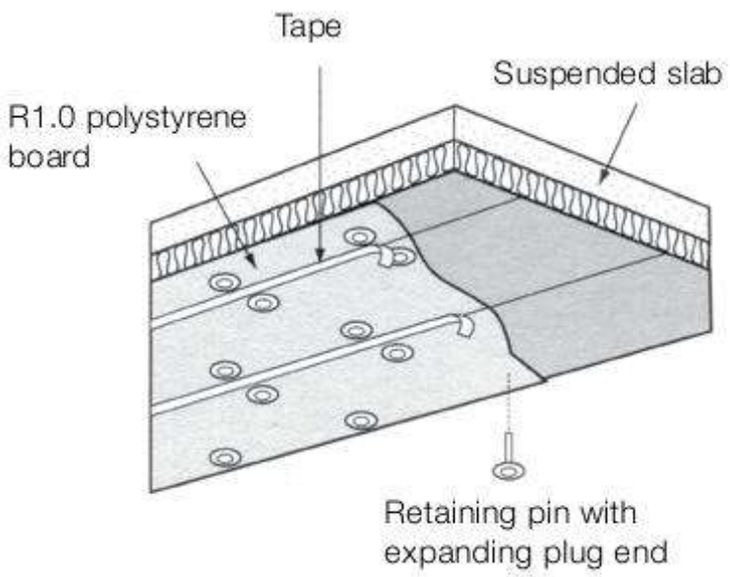




Add bulk insulation under the floor, supported by nylon cord or wire as shown.

Suspended concrete slabs

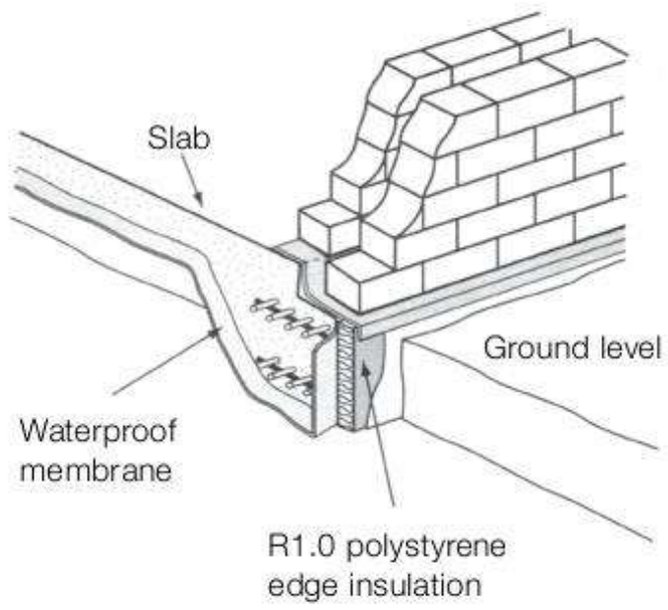
The total thermal resistance of typical suspended concrete floor slab construction is approximately R 0.3 up and R 0.4 down. This is insufficient for most building code compliance or sustainability requirements and needs to be supplemented with additional insulation.



Add foam boards, or foil faced foam boards. Special fixings should be used with foil faced boards to allow a still air layer between the insulation and the slab.

Slabs on ground

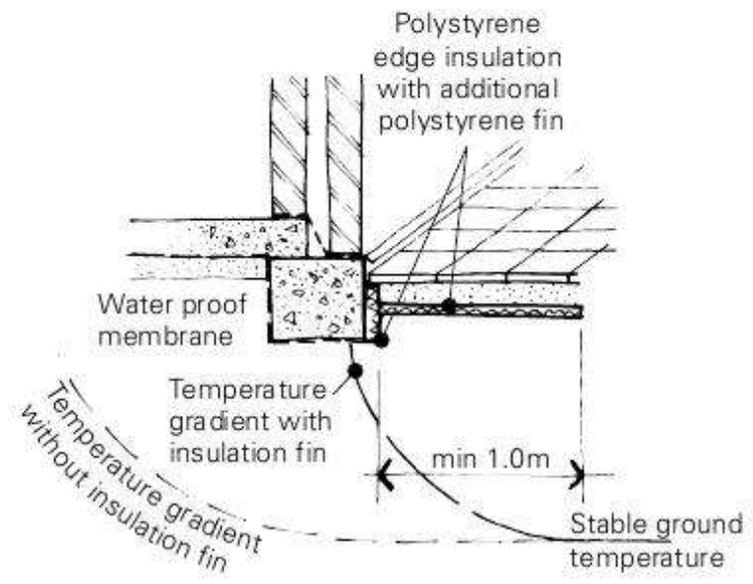
The BCA specifies that vertical edges of slabs on ground are required to be insulated only if located in climate zone 8 (cold climate) or when in-slab heating or cooling in installed within the slab. See 3.12.1.5 Floors in BCA 2010 Volume Two.



Slab edge insulation is usually sufficient, as approximately 80 per cent of the heat loss occurs through the edge. Install edge insulation before the slab is poured. Do not install insulation under concrete edge beams.

Follow the manufacturers directions, particularly regarding the placement of the insulation in relation to the waterproof membrane. In termite prone areas precautions may be needed. Consult your local building information centre.

R1.0 foam boards on the slab edge give a total R-value of at least 2.2 (insulated section only)



For more effective performance, extend an additional fin of foam horizontally from the slab edge as shown.

The fin should extend between 1-1.5m and can be laid under external paving. The presence of the fin affects ground temperature gradients, resulting in more stable ground temperatures below the slab.

The fin is easy to install and can be done as a retrofit to existing slabs. It will not interfere with the load carrying capacity of the footings.

Insulate the underside of ground slabs where groundwater is present. This method can also be used in alpine climates and where slab heating is used, although the 'fin' method above may be just as effective. Insulation under slabs must have a high compressive strength and be resistant to moisture penetration and rotting. If the material is compressed it will no longer act as an insulator and can even lead to structural failure. Some waffle pods can be used for under-slab insulation, as long as they meet the above criteria.

ADDITIONAL READING

Australian Building Codes Board (2010), *BCA 2010 Building Code of Australia, (Volume 1 and Volume 2)*, ABCB, Canberra. www.abcb.gov.au

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SEAV Insulation Guide (images)

Last updated:
November 2010

Thermal Mass

Thermal mass is the ability of a material to absorb heat energy. A lot of heat energy is required to change the temperature of high density materials like concrete, bricks and tiles. They are therefore said to have high thermal mass. Lightweight materials, such as, timber have low thermal mass. Appropriate use of thermal mass throughout your home can make a big difference to comfort and heating and cooling bills. This fact sheet shows you how.



Correct use of thermal mass moderates internal temperatures by averaging day/night (diurnal) extremes. This increases comfort and reduces energy costs.

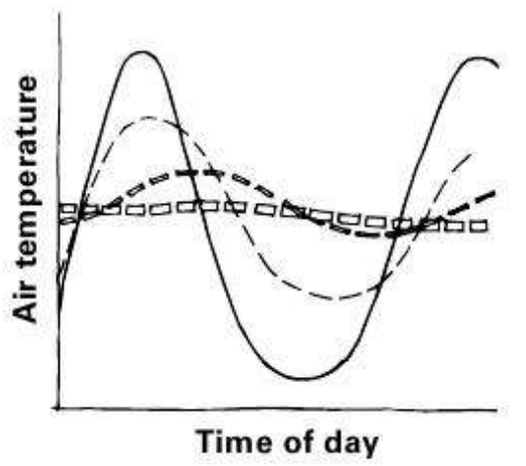
Poor use of thermal mass can exacerbate the worst extremes of the climate and can be a huge energy and comfort liability. It can radiate heat all night during a summer heatwave, or absorb all the heat you produce on a winter night.

To be effective, thermal mass must be integrated with sound passive design techniques. This means having appropriate areas of glazing facing appropriate directions with appropriate levels of shading, insulation and thermal mass. [See: 4.1 Passive Design]

HOW THERMAL MASS WORKS

Thermal mass acts as a thermal battery. During summer it absorbs heat, keeping the house comfortable. In winter the same thermal mass can store the heat from the sun or heaters to release it at night, helping the home stay warm.

Thermal mass is not a substitute for insulation. Thermal mass stores and re-radiates heat. Insulation stops heat flowing into or out of the building. A high thermal mass material is not generally a good thermal insulator.



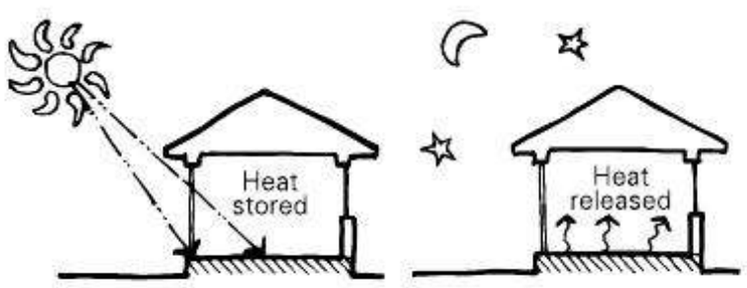
Thermal mass is particularly beneficial where there is a big difference between day and night outdoor temperatures.

Correct use of thermal mass can delay heat flow through the building envelope by as much as 10 to 12 hours producing a warmer house at night in winter and a cooler house during the day in summer.

A high mass building needs to gain or lose a large amount of energy to change its internal temperature, whereas a lightweight building requires only a small energy gain or loss.

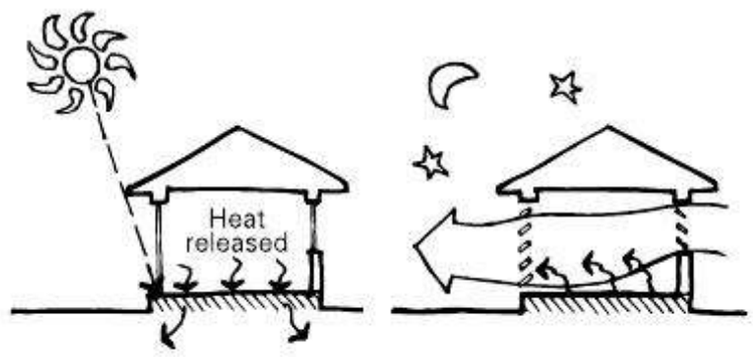
Winter

Allow thermal mass to absorb heat during the day from direct sunlight or from radiant heaters. It will re-radiate this warmth back into the home throughout the night.



Summer

Allow cool night breezes and/or convection currents to pass over the thermal mass, drawing out all the stored energy. During the day protect thermal mass from excess summer sun with shading and insulation if required.



USING THERMAL MASS

Thermal mass is most appropriate in climates with a large diurnal temperature range. As a rule of thumb, diurnal ranges of less than 6°C are insufficient; 7°C to 10°C can be useful depending on climate; where they exceed 10°C, high mass construction is desirable. Exceptions to the rule occur in more extreme climates.

In cool or cold climates where supplementary heating is often used, houses will benefit from high mass construction regardless of diurnal range. (eg. Hobart 8.5°C). In tropical climates with diurnal range of 7-8 (eg. Cairns 8.2°C) high mass construction can cause thermal discomfort unless carefully designed, well shaded and insulated.

Always use thermal mass in conjunction with good passive design.

THERMAL MASS PROPERTIES

High density – The more dense the material (ie the less trapped air) the higher its thermal mass. For example, concrete has high thermal mass, AAC block has low thermal mass, and insulation has almost none.

Good thermal conductivity – The material must allow heat to flow through it. For example, rubber is a poor conductor of heat, brick is good, reinforced concrete is better. But if conductivity is too high (eg. steel) energy is

absorbed and given off too quickly to create the lag effect required for diurnal moderation.

Low reflectivity – Dark, matt or textured surfaces absorb and re-radiate more energy than light, smooth, reflective surfaces. (If there is considerable thermal mass in the walls, a more reflective floor will distribute heat to the walls).

MATERIAL	THERMAL MASS (volumetric heat capacity, KJ/m³.k)
WATER	4186
CONCRETE	2060
SANDSTONE	1800
COMPRESSED EARTH BLOCKS	1740
RAMMED EARTH	1673
FC SHEET (COMPRESSED)	1530
BRICK	1360
EARTH WALL (ADOBE)	1300
AAC	550

Source EDG

The above chart compares the thermal mass properties of some common materials. The volume or quantity of these materials in typical application is also important.

Compressed FC sheet flooring has a higher thermal mass value than brick or earth walls but is usually only present in 20mm thick layers which means it can't store a lot of heat. Brick walls are 110 to 230mm thick and earth walls are usually minimum 300mm, giving them the capacity to store large amounts of heat.

The amount of useful thermal mass is calculated by multiplying the above figure by the total accessible volume of the material, that is the volume of material which has its surface exposed to a heat source. Floor coverings, such as, carpet, which insulate the mass, reduce the accessible volume.

Some thermal mass materials, such as concrete and brick, when used in the quantities required have high embodied energy. Consider the life time energy impact of thermal mass materials.

Will the savings in heating and cooling energy be greater than the embodied energy content over the life of the building? Can lower embodied materials, such as, water or recycled brick be used? In addition, poor design of thermal mass may result in increased heating and cooling energy use on top of the embodied energy content. [See: 5.2 Embodied Energy]

Phase change materials

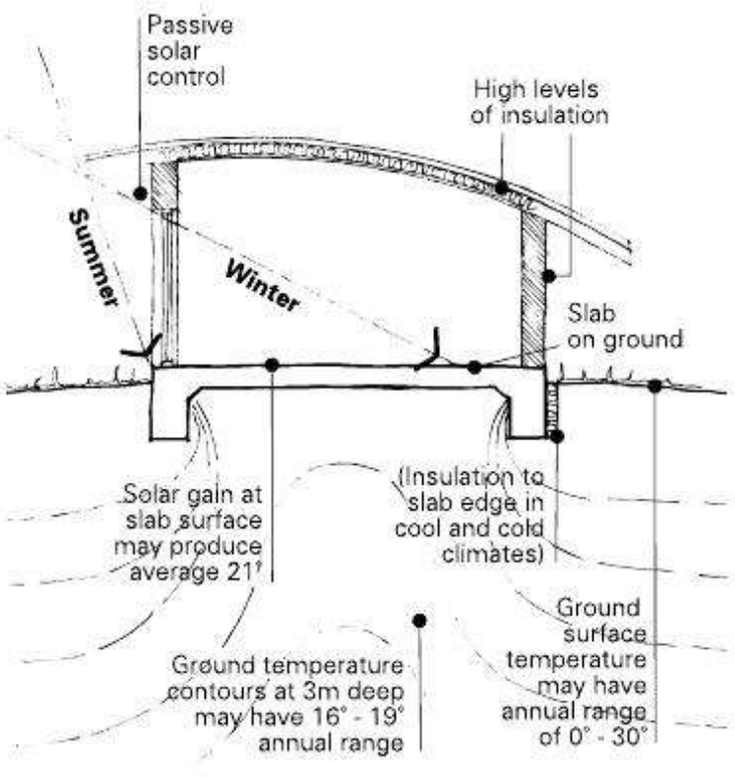
There is growing interest in the use of phase change materials in construction. One development of this technology uses thousands of plastic capsules filled with a wax that absorbs and releases energy by melting and solidifying within the temperature range of human comfort. This increases the effective thermal capacity of the material which contains the capsules and dampens temperature fluctuations, acting like thermal mass.

At least one company manufactures building products that integrate phase-change microcapsules into their structure, including plasterboard and aerated concrete (AAC) blocks. Gypsum plasters, paints and floor screeds have the potential to contain phase change materials and many such applications are likely to appear on the market over the next few years as the technology offers the prospect of lightweight buildings that can behave with characteristics associated with 'traditional' thermal mass – for instance, the thermal capacity of a 13mm thick plaster layer with 30 per cent microcapsule content is claimed to be equivalent to that of a six-inch thick brick wall.

Use of phase change materials can be very helpful on challenging sites where otherwise the provision of thermal mass would be difficult.

TYPICAL APPLICATIONS

In rooms with good winter solar access it is useful to connect the thermal mass to the earth. The most common example is slab on ground construction. A less common example is earth-sheltered housing.

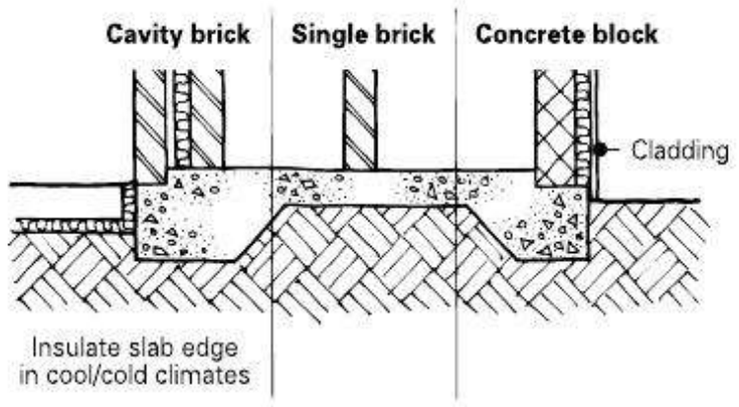


A slab on ground (SOG) is preferable to a suspended slab in most climates because it has greater thermal mass due to direct contact with the ground. The vertical edges of an SOG are required to be insulated in climate zone 8 (cold climate) or when in-slab heating or cooling is installed within the slab. Please refer to Clause 3.12.1.5 (c) and (d) of the BCA Volume Two for more detail.

The whole slab must be insulated from earth contact in cold climates Consider termite proofing when designing slab edge insulation. Care should be taken to ensure that the type of termite management system selected is compatible with the slab edge insulation. Brick or compressed earth floors are also appropriate.

Use surfaces, such as, quarry tiles or simply polish the concrete slab. Do not cover areas of the slab exposed to winter sun with carpet, cork, wood or other insulating materials. Use rugs instead.

Masonry walls also provide good thermal mass. Recycled materials, such as, concrete, gravel or re-used bricks can be used.



Examples of high mass construction.

Insulate masonry walls on the outside, for example reverse brick veneer construction. Masonry walls with cavity insulation and rammed earth walls also provide good thermal mass. (Note: rammed earth has a low insulation value and requires external insulation in cool and cold climates).

Introduce thermal mass within lightweight structures by using isolated masonry walls or lightweight steel-framed concrete floors. Always insulate the underside and exposed edges of suspended thermal mass floors.



Water can be used to provide thermal mass. Walls may be built from water-filled containers.

Internal or enclosed water features, such as, pools can also provide thermal mass but require good ventilation and must be capable of being isolated as evaporation can absorb heat in winter and create condensation problems year round.



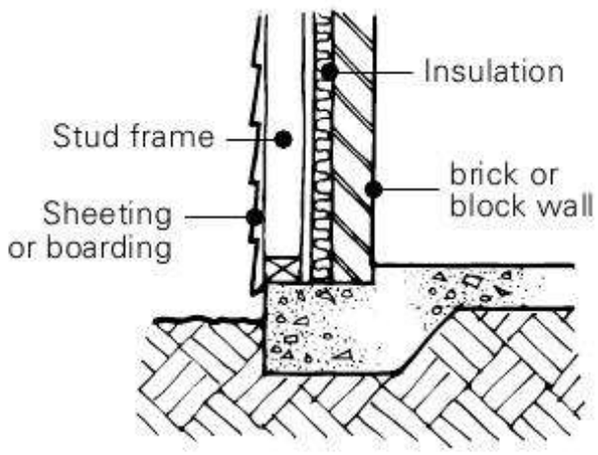
Air enters this building across the pool (thermal mass) via a semi-enclosed courtyard. It is evaporatively cooled before entering the building.

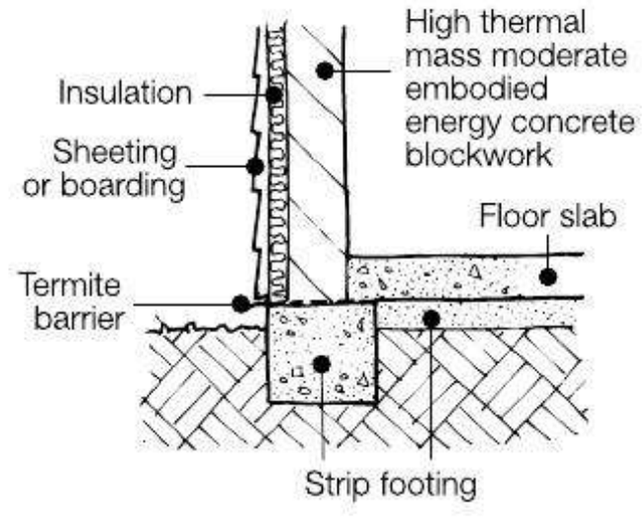
WHERE TO LOCATE THERMAL MASS

The location of thermal mass within the building will have an enormous impact on its year round effectiveness and performance.

As a rule of thumb the best place for thermal mass is inside the insulated building envelope. Insulation levels required will depend on the climate. A better insulated envelope will mean more effective thermal mass. [See: 4.7 Insulation]

Thermal mass should be left exposed internally to allow it to interact with the house interior. It should not be covered with thermally insulating materials, such as, carpet.

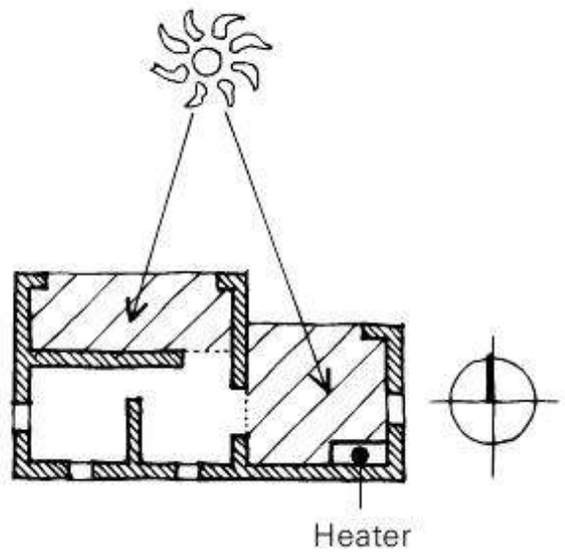




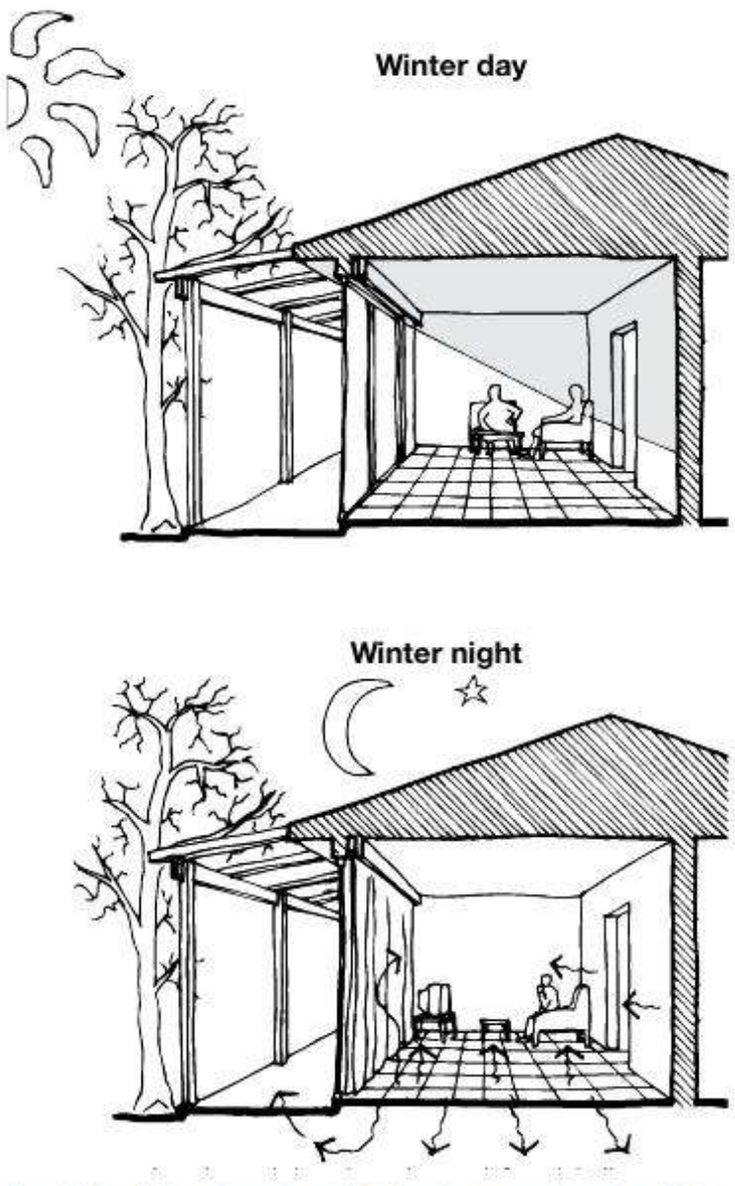
To determine the best location for thermal mass you need to know if your greatest energy consumption is the result of summer cooling or winter heating.

Heating – Locate thermal mass in areas that receive direct sunlight or radiant heat from heaters.

Heating and cooling – Locate thermal mass inside the building on the ground floor for ideal summer and winter efficiency. The floor is usually the most economical place to locate heavy materials and earth coupling can provide additional thermal stabilisation.



Locate thermal mass in north facing rooms which have: good solar access; exposure to cooling night breezes in summer and additional sources of heating or cooling (heaters or evaporative coolers).

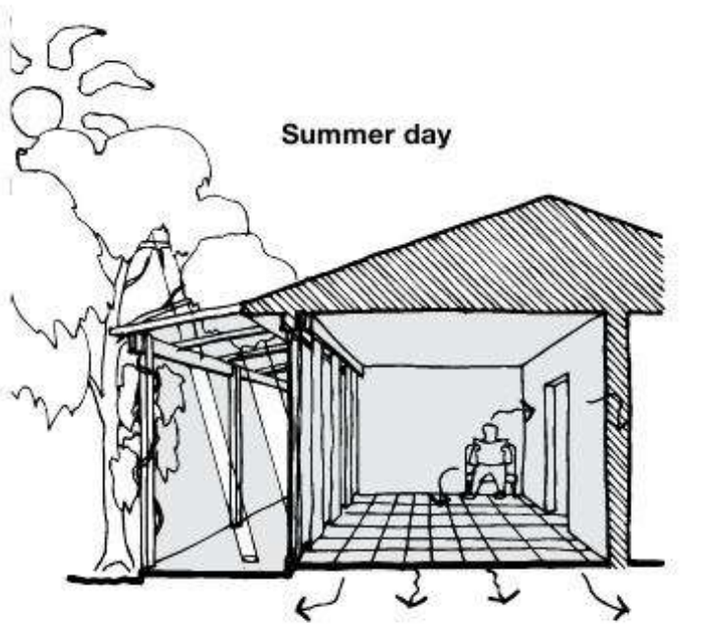


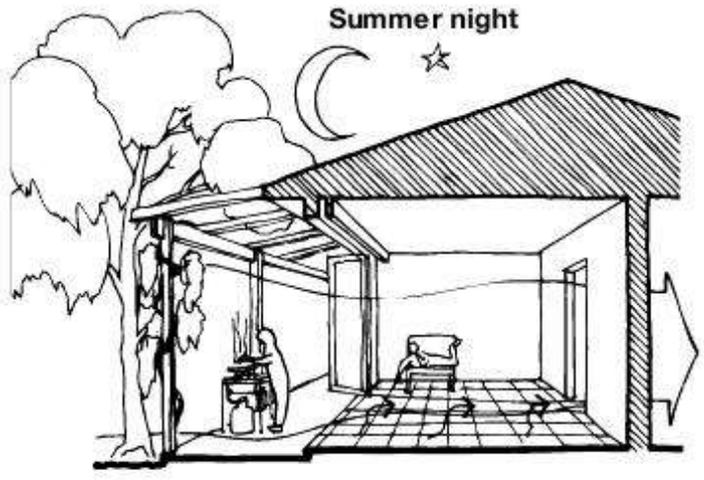
Insulate slab edges in cold climates or when in-slab heating or cooling is installed within the slab.

Locate additional thermal mass near the centre of the building, particularly if a heater or cooler is positioned there. Feature brick walls, slabs, large earth or water filled pots and water features can provide this.

Cooling – Protect thermal mass from summer sun with shading and insulation if required. Allow cool night breezes and air currents to pass over the thermal mass, drawing out all the stored energy.

Roof-mounted solar pool heating is relatively inexpensive and can be used in conjunction with hydronic heating systems or water storage containers to heat thermal mass in winter or (in reverse) to provide radiant cooling to night skies in summer. This method can resolve situations where direct solar access for passive heating is unachievable or where conventional thermal mass is inappropriate (eg. Pole homes). [See: 6.2 Heating and Cooling]





WHERE NOT TO LOCATE THERMAL MASS

In brick veneer houses with tiled roofs the thermal mass materials are on the outside and the insulative materials are on the inside. The value of thermal mass is minimal in this form of construction.

Avoid use in rooms and buildings with poor insulation from external temperature extremes and rooms with minimal exposure to winter sun or cooling summer breezes.

Careful design is required if locating thermal mass wall on the upper levels of multi-storey housing in all but cold climates, especially if these are bedroom areas.

Natural convection creates higher upstairs room temperatures and upper level thermal mass absorbs this energy. On hot nights upper level thermal mass can be slow to cool, causing discomfort. The reverse is true in winter.

SPECIFIC CLIMATE RESPONSES

Climatic consideration is critical in the effective use of thermal mass. It is possible to design a high thermal mass building for almost any climate but the more extreme climates require very careful design.

Adaptation

Think about the impact of predicted changes in climate due to global warming. Will the current use of thermal mass still be appropriate in 20 or 30 years time if temperatures rise and diurnal ranges are reduced? This is a particularly important issue in tropical climates where temperatures are already close to the upper comfort level.

For the main features of these climates see 4.1 Passive Design.

It is important to insulate ground slab edges in cold climates.

High humid (tropical) climates

Use of high mass construction is generally not recommended in high humid climates due to their limited diurnal range. Passive cooling in this climate is generally more effective in low mass buildings.

Thermal comfort during sleeping hours is a primary design consideration in tropical climates. Lightweight construction responds quickly to cooling breezes. High mass can completely negate these benefits by slowly re-releasing heat absorbed during the day.

Whilst low mass is generally the best option, recent research has shown that innovative, well insulated and shaded thermal mass designs have been able to lower night time temperatures by 3 to 4°C in high humid areas with modest diurnal ranges.

Warm humid and warm/mild temperate climates

Maintaining thermal comfort in these benign climates is relatively easy. Well designed houses should require no supplementary heating or cooling.

The predominant requirement for cooling in these climates is often suited to lightweight, low mass construction. High mass construction is also appropriate but requires sound passive design to avoid overheating in summer.

In multi level/story design, high mass construction should ideally be used on lower levels to stabilise temperatures. Low mass on the upper levels will ensure that, as hot air rises (in convective ventilation), it is not stored in upper level mass as it leaves the building.

Cool temperate and alpine climates

Winter heating predominates in these climates although some summer cooling is usually necessary.

High mass construction combined with sound passive solar design and high level insulation is an ideal solution.

Good solar access is required in winter to heat the thermal mass.

Insulate slab edges and the underside of suspended slabs in colder climates. It is advisable to insulate the underside of a slab on ground in extremely cold climates. [See: 4.8 Insulation Installation]

Buildings that receive little or no passive solar gains can still benefit from high mass construction if they are well insulated. However, they respond slowly to heating input and are best suited to homes with high occupation rates.

Auxiliary heating of thermal mass is ideally achieved with efficient or renewable energy sources, such as, solar, gas or geothermal powered hydronic systems. In-slab electric resistance systems cause higher greenhouse gas emissions. [See: 6.2 Heating and Cooling]

Use a solar conservatory in association with thermal mass to increase heat gains. A solar conservatory is a glazed north-facing room that can be closed off from the dwelling at night. Shade the conservatory in summer and provide high level ventilation to minimise overheating. Reflective internal blinds also reduce winter heat loss.

Hot dry climates

Both winter heating and summer cooling are very important in these climates. High mass construction combined with sound passive heating and cooling principles is the most effective and economical means of maintaining thermal comfort.

Diurnal ranges are generally quite significant and can be extreme. High mass construction with high insulation levels is ideal in these conditions. [See: 4.7 Insulation]

Where supplementary heating or cooling is required, locate thermal mass in a position of exposure to radiation from heaters or cool air streams from evaporative coolers. The mass will moderate temperature variations between high/low or on/off and will lower the level and duration of auxiliary requirements whilst increasing thermal comfort.

Underground or earth covered houses give protection from solar radiation and provide additional thermal mass through earth coupling to stabilise internal air temperatures.

RENOVATIONS AND ADDITIONS

Where to locate extra thermal mass

For heating, thermal mass should be added where winter solar access is already available (or made available by 'turning the house around' to place living areas to the north). Thermal mass can also be located near a heater.

For cooling, thermal mass must be protected from summer sun and exposed to cooling night breezes.

Use of thermal mass is generally not recommended in high humid climates, but it has useful applications in all other climates.

Some quick tips

Thermal mass must be used in conjunction with good passive design in order for it to work effectively. [See: 4.5 Passive Solar Heating; 4.6 Passive Cooling]

Add shading to protect thermal mass from summer sun. Its ability to absorb and re-radiate heat over many hours means that in summer or hot climates it can be a source of unwelcome heat long after the sun has set. [See: 4.4 Shading]

Remove carpet or insulative covering from concrete slabs that have exposure to winter sun. The slab surface can be tiled or cut and polished to give a unique and practical finish. [See: 5.12 Concrete Slab Floors]

There are easy opportunities to add useful thermal mass when renovating,, such as, using new slab on ground or suspended concrete floors, or using reverse brick veneer construction.



If the floor of the existing building is suspended timber it is often practical to retro-fit a suspended concrete slab, which replaces the timber floor completely in rooms with winter solar access. The slab can be supported on the original piers or stumps, using steel lintels or beams as bearers.

New slabs can be tiled, polished or burnished (highly steel trowelled when poured, with a post-applied finish, such as, acid reactive staining). These surfaces let the thermal mass of the slab interact with the room to moderate indoor temperatures.

An internal skin of brickwork can be added to timber-framed structures to increase thermal mass. This construction technique is known as Reverse Brick Veneer.

Most houses are conventional Brick Veneer, with a timber wall frame clad in an external non-load bearing brick skin, or veneer. The thermal mass of the bricks is not utilised because they are located on the outside. They are really only doing the same job as weatherboards. For this reason brick veneer is low mass construction (not to be confused with full brick construction, which is high mass).

Reverse Brick Veneer (RBV) is a construction technique which places thermal mass (the brick skin) on the inside of the wall frame. The highly insulated wall frame protects the thermal mass from external temperature extremes. The thermal mass is in contact with the room and helps to regulate indoor temperatures, for the benefit of the occupants.

It is important to note that any high mass material can be used in place of the bricks. Examples include rammed earth, core filled concrete blocks and mud bricks.

RBV is best used in north facing living areas with solar access, especially in climates with a high diurnal temperature range.

If the existing building is slab on ground, the new RBV can be built directly on the concrete slab, after engineering checks are carried out. If the existing building has a raised timber floor it is often practical to combine RBV with a retro-fitted suspended concrete slab.

Roof-mounted solar pool heating is relatively inexpensive and can be used in conjunction with hydronic heating systems or water storage containers to heat thermal mass in winter or (in reverse), to provide cooling to night skies in summer. This method can resolve situations where direct solar access for passive heating is unachievable or where conventional thermal mass is inappropriate (eg. Pole homes).
[See: 6.2 Heating and Cooling]

ADDITIONAL READING

Contact your State / Territory government or local council for further information on passive design considerations for your climate.
www.gov.au

Australian Bureau of Meteorology
www.bom.gov.au/climate/environ/design/design.shtml

BEDP *Environment Design Guide*
DES 4 Thermal Mass in Building Design.

Commonwealth of Australia, *Australian Model Code for Residential Development* (AMCORD) (1995), AGPS Canberra.

Hollo, N. (1997), *Warm House Cool House: Inspirational designs for low-energy housing*, Choice Books, Australia.

Wrigley, Derek (2004), *Making Your Home Sustainable: A Guide to Retrofitting*, Scribe, Carlton North, Victoria.

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Glazing

Glazing has a major impact on the energy efficiency of the building envelope. Poorly designed windows, skylights and glazed surfaces can make your home too hot or too cold. If designed correctly, they'll help maintain year-round comfort, reducing or eliminating the need for artificial heating and cooling.

Windows in a typical insulated home can account for more heat gain or loss than any other element in the building fabric. In summer, heat gain through an unshaded window can be 100 times greater than through the same area of insulated wall. One square metre of ordinary glass can let in as much heat as would be produced by a single bar radiator. In winter, heat lost through a window can be ten times more than through the same area of insulated wall.

Glazing is a key element of your home's design providing, light, ventilation, noise control and security.

It can enhance the appearance and amenity of your home, providing views and connection with outdoor spaces. You can enjoy these benefits and have high thermal performance by selecting the right type of glass and frames and choosing the right size, location and shading of windows.

GLAZING AND THERMAL PERFORMANCE

The impact of glazing on the thermal performance of a building is complex!

There are several aspects to consider:

> Climatic conditions in your location.

> Building design – the form and layout of the building.

> Building materials – the amount of mass and insulation.

> The size and location of windows and shading.

> Thermal properties of glazing units.

The impact of glazing is the result of the interaction of each of these aspects. For example, hot and cold climates benefit from different types of glazing. High mass buildings can benefit from larger areas of glazing than would be optimum for a lightweight building. Double glazing is beneficial for almost all orientations. High performance toned, double or low-e glazing will be more beneficial in specific orientations of the building.

Because of the complex interaction of many variables, the best way to accurately assess the impact of glazing on your home's thermal performance is to model it with one of the sophisticated computer programs now available. AccuRate, BERS Pro and FirstRate calculate a home's heat gains and losses, hour by hour, and the resulting levels of thermal comfort achieved. They consider all aspects of the building's design and construction as well local climatic conditions, such as, temperature, humidity, sunshine and wind. These programs allow options for each window to be compared to ensure that the best performance is achieved without unnecessary expense.

Software assessment of building thermal performance is governed by the Nationwide House Energy Rating Scheme. See 1.5 Rating Tools for more information.

PASSIVE SOLAR DESIGN

There are simple principles that can be followed, at design stage, to optimise the thermal performance of your home. These include:

> Locate and size windows and shading to let sunshine in when the temperature is cold and exclude it when it is its hot.

> Use thermal mass to store the sun's heat and provide night-time warmth in cold conditions.

> Locate window and door openings to allow natural cooling by cross ventilation.

> Provide seals to openings to minimise unwanted draughts.

Incorporating passive solar principles at design stage is the most cost-effective way to achieve good thermal performance. [See: 4.5 Passive Solar Heating; 4.6 Passive Cooling]

Including energy efficient windows in a well designed home can further improve its thermal comfort.

The implementation of passive solar design principles can be made more challenging on some sites. For example, winter sun might be blocked by neighbouring buildings. Or views may be to the south or west, requiring windows with poor orientation. In these instances selecting glazed elements with improved thermal performance is critical in order to compensate for aspects of the building design that are detrimental to its thermal performance.

THERMAL COMFORT

Careful choice of glazing system provides major improvements in thermal comfort for people close to windows – especially large windows. Our sense of comfort is not just determined by air temperature. The temperature of surrounding surfaces has a great impact. The objective should be to achieve an inside glass surface temperature as close as possible to the desired room air temperature. This means glass that is neither cold in winter or hot in summer.

THERMAL PROPERTIES OF WINDOWS & GLAZED SURFACES

There are literally thousands of types of glass and frames to choose from – selecting the right ones is critical to improving energy efficiency of the building.

Specific products have been designed to keep heat in or out and have varying impacts on daylighting, noise control, maintenance & security.

Heat flow

Heat flow through glazed elements, such as, a windows, glass doors or fixed glass panels is determined by the combined effect of the glass, frame and seals.

Heat flows through glazed systems in several ways:

> Conduction.

> Convection.

> Radiation.

Conduction

Conduction is the movement of heat energy through the glass and frame materials from the air on the warmest side to the air on the colder side. The greater the difference in temperatures – the more heat flow. Different frame and glass materials have varying ability to conduct heat, specified by the U-value. The lower the U-value – the less heat is transmitted.

U-values may be for just the frame, just the glass, or the combined glass and frame unit – referred to as the system U-value. The system U-value will depend on the U-values of the frame and glass and the proportions of the area of the glazing unit occupied by each, which are referred to as the frame fraction and vision fraction respectively. The system U-value also accounts for the complex heat flows at the edge region of the glass near where it meets the frame.

The following table shows the difference between element and system U-values.

Indicative value of conducted heat performance.

COMPONENTS	U-VALUE
Aluminium frame	10.0
Timber frame	2.8
3mm clear glass	5.9
Double glazing (uncoated) – 2 x 3mm glass with 6mm air gap	3.1
SYSTEMS	
Aluminium frame with 3mm clear glass	6.9
Aluminium frame with double 3mm clear glass and 6mm gap	3.8
Timber frame with 3mm clear glass	5.5
Timber frame with double 3mm clear glass and 6mm gap	3.0

Note: Values for specific products may be significantly different.

The ability to conduct heat can also be expressed as its opposite – the ability to resist conducted heat flow – represented by R-values. R-values are used to describe insulating properties in many other building materials. The higher the R-value, the less heat is conducted. U-values and R-values can be easily converted:

R-value = 1 / U-value.
U-value = 1 / R-value.

For example, a window with a U-value of 5 will have an R-value of 1/5 i.e. 0.2

Windows in Australia are certified for their energy performance by rating organisations who conform to Australian Fenestration Rating Council (AFRC) standards. In the AFRC system, performance is always certified for the whole system – glazing and frame combined – never the glass or the frame alone.

There is a simple formula that can help you quantify the impact of improved U-value:

> the amount of heat conducted through a glazed unit (in Watts) equals the U-value (U)

> multiplied by the number of degrees difference in air temperature on each side (T)

> multiplied by the area of the glazing unit (A).

U x T x A = watts

If your home has 70m² of windows and glazed doors with aluminium frames with clear glass, on a winter's night when it's 15 degrees colder outside, the heat loss would be about:

6.2 x 15 x 70 = 6,510 watts.

That's equivalent to the total heat output of a large gas heater or a 2hp air conditioner running at full capacity.

If you roughly halve the U-value of the window by selecting double glazing, you can halve the heat loss – in this example saving about 3000 watts of heat loss – equivalent to the energy use of fifty 60 watt incandescent light bulbs.

The U-value is important in both hot and cold climates. Conducted heat flow is relative to the difference between indoor and outdoor temperature. In hot climates it may regularly be 10 or 15 degrees hotter outside than inside, so halving the U-value will halve the conducted heat gain.

Single glazing offers little resistance to conducted heat flow. The small amount of insulation that single glazing does provide is due to thin films of still air adjacent to the surfaces of glass. Increasing the thickness of the glass has negligible impact on its U-value.

Insulating glass units or IGUs (usually in the form of double glazing) provide additional thermal resistance in the sealed space between the panes and a gap which conducts much less heat. Increasingly, argon gas is used to fill the space between the panes instead of air, because it has a lower conductivity than air and is plentiful and cheap.

Conducted heat transfer through the frames can be reduced by choosing materials with a low U-value,, such as, timber. The heat transfer through conductive frame materials,, such as, aluminium, can be reduced by minimising the area of frame through which heat is conducted or by incorporating a thermal break in the frame section.

Convection

Convection is the movement of heat energy by air that passes over the surface of the glazing unit, taking heat away from the glass and frame. Higher air speed causes greater convected heat transfer.

Minimising convective heat transfer can be achieved by reducing air movement adjacent to the surfaces of glazing units through shielding the exterior by walls, screens and plantings and by shielding the interior with curtains and pelmets. It can also be achieved through double glazing which creates a still gas layer between the panes.

Radiation

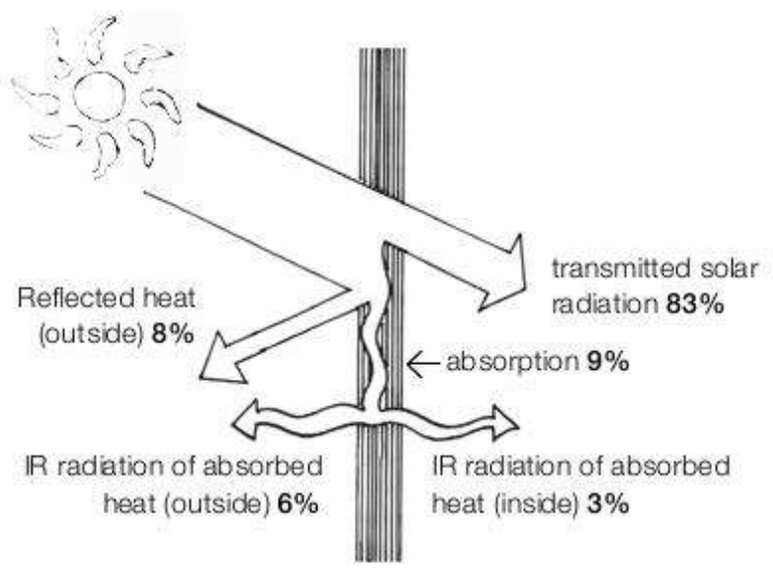
Radiation is heat that is transmitted as electromagnetic waves. They can pass through space, in the same way as visible light moves through space, until reflected or absorbed by materials.

Solar radiation

The sun transmits solar radiation which is comprised of ultraviolet (2% of the total solar energy), visible (47%) and solar near-infrared (IR) (51%). Warm objects like people and buildings, radiate the longer wavelengths of infrared heat.

When sunlight strikes a sheet of glass, some of the solar radiation is transmitted straight through, some is reflected and some is absorbed by the glass. The heat energy absorbed by the glass is then radiated to both the inside and outside as infrared radiation.

The sum of reflected, absorbed and transmitted heat always equals 100%.



For example, 3mm clear glass: 83% of solar radiation is transmitted, 8% reflected and 9% is absorbed. 3% is then radiated inside and 6% outside.

The total amount of solar heat that passes through the glass is the sum of the heat transmitted plus that part of the heat absorbed in the glass which is subsequently re-radiated and convected inside. For the above example this equals 86%. This proportion of solar energy that passes through the window, both directly and indirectly, is called the Solar Heat Gain Coefficient (SHGC). Therefore, 3mm clear glass has a SHGC of 0.86.

The amount of infrared heat energy radiated from the surface of glass depends on its emissivity (also known as emittance). A 'perfect radiator' has an emissivity of 1.0. Untreated (uncoated) glass, whether clear or tinted, has an emissivity of 0.84. It is almost a perfect radiator.

Low emissivity (low-e) glass has a coating on its surface which minimises the amount of heat, absorbed by the glass, being subsequently radiated into the building. It can also be designed to block some of the solar radiation transmitted through glass. Low-e glass is available with an emissivity as low as 0.03 ('soft' coat) or 0.15 ('hard' coat).

Reducing solar heat gain through glass can be achieved by using toned (body tinted) glass which absorbs a greater proportion of solar heat than clear glass. The absorbed heat is then radiated to inside and outside. Including a low emissivity coating on the inside-facing surface reduces the proportion of absorbed heat that is radiated into the building which dramatically increases the effectiveness of the toned glass.

The solar heat gain can also be reduced by reflective glass which increases the proportion of incident solar heat that is reflected away from the glass.

Spectrally selective glazing has a low-e coating which 'filters' solar radiation, allowing maximum visible light transmission while reflecting unwanted UV and solar near-infrared wavelengths. Spectrally selective coatings have very low emissivities – as low as 0.03.

Double glazing is an effective way to reduce U-value, but its impact on solar heat gain depends on the type of glass. One layer of clear glass has a SHGC of 0.86. Two layers have a combined SHGC of about 0.76. This may be reduced much further by using tinted, low-e or spectrally selective low-e coatings. Because low-e coatings also reduce radiative heat transfer compared to uncoated glass, the glazing system U-value may be halved again, especially if the air between the panes is replaced by argon gas.

The SHGC of timber and uPVC frames is negligible. Aluminium frames can account for more than 5% of the total solar heat gain of a complete aluminium-framed window.

Metal frames with high conductivity,, such as, aluminium and steel, absorb solar heat, some of which is conducted through the frame and radiated/convected to the inside. It is common for dark-coloured frames to become too hot to touch on their inside-facing surfaces.

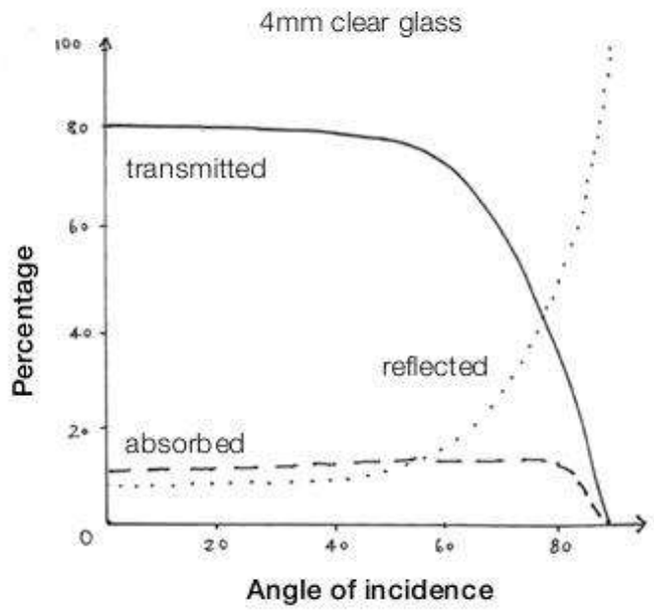
Such heat gain through aluminium frames can be reduced by choosing frames with a light colour, which reflects most of the solar heat. Frames with a thermal break have a low-conductivity polymer separating the inside and outside parts of the frame. Alternatively, some frames use a 'composite' construction with aluminium to the outside and timber to the inside.

Different glazing products offer a wide range of SHGC, enabling you to choose how much solar heat comes into your home.

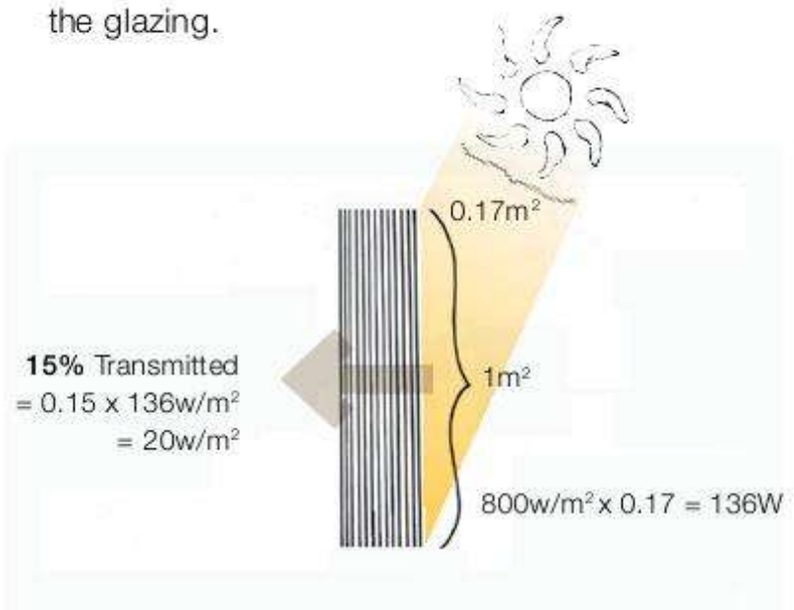
Angle of incidence

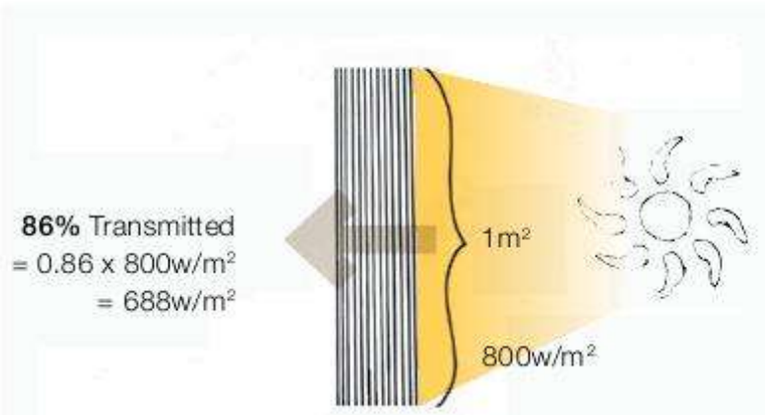
The angle that solar radiation strikes glass has a major impact on the amount of heat transmitted. When the sun is perpendicular to the glass it has an angle of incidence of 0. For standard clear glass 86% of solar heat is transmitted. As the angle increases, more solar radiation is reflected, less is transmitted. It falls sharply once the angle exceeds 55°.

Also, as the angle increases, the effective area of exposure to solar radiation reduces.



So, the same window can have hugely different solar gain, depending on the angle of incidence. The angle of incidence is influenced by the position of the sun according to location, season and time of day and the orientation of the glazing.





A north-facing window in summer, when the sun is high in the sky, may have an angle of incidence of 8° (depending on location). In winter, the angle of incidence at midday would be about 35°and the glass will be exposed to a greater effective area of solar radiation. That window can transmit more solar heat in winter than in summer.

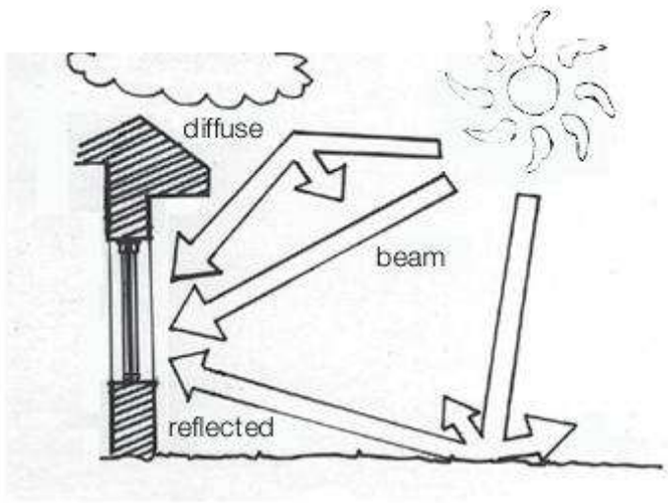
A west-facing window on a summer's afternoon will have an angle of incidence from near-zero up to 30° with a large effective area of solar radiation. A north-facing window, in summer, has a high angle of incidence and low effective area of solar radiation. So, in summer, north facing windows can transmit less heat than west facing ones.

The SHGC declared by glazing manufacturers is always calculated as having a 0° angle of incidence i.e. the maximum solar heat gain.

Indirect solar heat

We normally think of solar radiation as coming in a direct beam from the sun. However, as radiation from the sun hits our atmosphere some is scattered in all directions. Some of this radiation is scattered towards the earth and is called diffuse solar radiation.

The total solar radiation (direct plus diffuse) is called global radiation. Beam radiation may be up to 80Wm². Diffuse radiation varies according to sky conditions and location but may be around 300Wm².



Some solar radiation strikes the earth is reflected by surrounding surfaces. This is called reflected radiation. Light coloured surfaces reflect more than dark ones.

Shading by eaves is generally designed to protect glazing from beam radiation but may leave it exposed to diffuse and reflected radiation. Using glass with a lower SHGC provides protection from all three kinds of solar radiation: beam, diffuse and reflected.

Warm radiant heat

Glazing units transfer heat radiated by the sun. They also transfer radiant heat, in the form of long wave infrared radiation, from warm objects around the glazing. All warm objects radiate infrared heat. In cold climates warm objects and people inside the building radiate heat to outside. In hot climates the warm surfaces surrounding the building radiate heat to inside.

Standard clear glass absorbs about 84% of this long wave infrared radiation then radiates that heat both inside and outside – the amount depends on the temperatures of surrounding objects. The glass effectively blocks a third to a half of the long wave infrared heat transfer.

So, clear glass transmits 86% of solar radiation but only transmits about half of the infrared radiation. This difference in solar versus infrared radiant heat transfer gives us the 'greenhouse' effect: a large amount of solar heat enters through the windows, warms the materials within the building which then radiate lower intensity infrared heat, most of which is trapped inside the building.

The infrared radiant heat transfer can be further reduced by using glass with low emissivity coatings and by double glazing.

Visible light

Reducing the amount of solar radiation transmitted through glazing can reduce the amount of light entering your home. The amount of light transmitted by glazing is specified by the Visible Light Transmittance value or Visible Transmittance (VLT or VT). The ratio of light to heat transmittance varies according to the type of glass and is sometimes called the Light to Solar Gain (LSG) ratio. The bigger the LSG, the more useful light the window admits relative to the overall solar heat gain.



Infiltration and exfiltration

Heat transfer though glazed units is also caused by air that infiltrates and exfiltrates through gaps around operable sashes. This moves warm air from inside to outside or vice versa. Minimising infiltration, or draughts, can be achieved through good seals between moving sashes and their surrounding frames. In general, awning windows, casement windows and French windows, which seal by compression, control air leakage much better than do sliding windows and doors, whose seals tend to lose their shape and wear out gradually from constant friction.

TYPES OF GLAZING

Glass

There is a wide variety of glass products currently available. They can be divided into several categories.

Toned glass has colouring additives included during the melting process of forming glass. It is available in various colours, usually bronze, grey, blue and green. The different colours provide different SHGC and some variation in VT. Body tinting does not change the U-value of the glass because glass conductivity and emissivity are unaffected by the presence of a pigment in the glass. Green and blue tones tend to have a higher ratio of visible light to solar heat transmittance.

Supertoned glass has heavier pigmentation which is tuned to preferentially transmit visible wavelengths while filtering out more invisible solar near-infrared wavelengths. This provides lower SHGC while preserving adequate VT.

Reflective glass has either a vacuum-deposited thin-film metal coating or a pyrolytic coating. Vacuum-deposited coatings are soft and for protection and longevity they must be deployed inside an insulating glass cavity . Pyrolytic coatings are baked onto the surface in the factory while the glass is still hot; they are hard and durable and are normally glazed with the reflective surface to the exterior. To function to specification they must be kept clean and free of condensation. Reflective glazing causes glare which may annoy neighbours. In such instances, reflectivity must be kept below 15 to 20 percent.

High transmission Low emissivity (low-e) glass has a coating that allows daylight from the sun to pass into the house but reduces the amount of the long-wavelength infrared heat that can escape through the window.

Low transmission low-e glass has a coating which reduces the amount of solar heat gain while still maintaining good levels of visible light transmission. Low-e coatings can be 'hard' or 'soft' and can enable a very dramatic improvement in both U-value and SHGC. But they must be employed correctly or they will either deteriorate or fail to perform to specification. The Australian glass industry manufactures a wide range of high-performance, low-e coated glass products, in addition to imported products.

Spectrally selective glass (such as supertoned and low transmission low-e glass) has a surface coating which allows maximum visible light transmission while reflecting unwanted UV and infrared wavelengths. Spectrally selective coatings generally have the lowest emissivities of any type of coated glass – as low as 0.03.

Low-e and spectrally selective coatings can be used in combination with clear, toned or reflective glass. All coating should be protected from abrasion and damage by paints, solvents and harsh cleaning chemicals.

Polymers are used instead of glass in some applications,, such as, translucent glazing and skylights. A plastic glazing layer, called an interlayer, is used in laminated glass to improve impact resistance or within double glazing to improve insulation.

The thickness of glass has negligible impact on its U-value and SHGC. It does though, have a significant impact on noise transmission and the strength and safety of the glazing.

Glazing may be provided as single sheets, or two sheets with a polymer laminate bonded between the glass. The performance of laminated glazing is determined by the type of glass in each layer. The plastic laminate does provide a slight reduction in U-value.

It is often wrongly assumed that double glazing is only for cold climates. In fact, the best performance levels in both U-value and SHGC can only be achieved by double-glazing.

This facilitates higher performance for all climates, especially in heated and air-conditioned homes. Multiple layers of glass can be assembled with sealed cavities between each sheet. This is commonly called double or triple glazing but is now increasingly referred to as an Insulating Glazing Unit (IGU).

Insulating Glazing Unit – The performance of IGUs depends on the properties of each layer of glass and the thickness, sealing and content of the cavities between the glass layers.

Using combinations of standard and low-e glass allows IGU to be tailored to have extremely low U-values ranging from 3.5 to as low as 1. Using clear, toned, reflective or low-e glass can deliver a wide range of SHGC values from 0.2 to 0.7. However in housing, good daylighting is invariably required; in this situation only a double-glazed configuration will simultaneously achieve very low SHGC values coupled with high VT.

The performance of the cavity in IGUs impacts on the U-value and serviceability of the glazing. Cavities must be sealed to minimise convective heat transfer. If the cavity is not properly sealed or contains inadequate dessicant it may contain moisture which, under cold conditions, will condense on the colder glass surface . The spacer (metal or polymer strip) that separates the two glass layers contains a desiccant to absorb any moisture. IGU cavities may also be filled with an inert, low-conductivity gas, such as, argon. Cavity thickness is usually in the range 6 to 18mm. Wider cavities provide lower (better) U-values with 12mm normally accepted as the preferred gap.

Vacuum glazing is just now being commercialised. The cavity is evacuated and the panes are kept mechanically separated by a fraction of a millimetre. The prototype systems were developed in Australia. Because there is no air or other gas to conduct heat across the gap, the separation between the panes need only be sufficient to prevent the two glass layers from 'shorting' on each other. Usually, vacuum glazing units employ a low-e coating on both glass surfaces facing into the cavity. With such a combination of technologies, U-values as low as 1.0 are routinely achieved. If toned glass or spectrally selective low-e coatings are used, vacuum glazing units can also have very low SHGC. Windows with such high-performance glazings are sometimes called 'superwindows'.

Single-glazed windows can also be retrofitted with a thin, flexible, transparent polyethylene membrane attached to the inside of the frame or operable sash using an adhesive tape or magnetic strip. This creates an air space between the glass and the film which reduces the U-value and air infiltration and can be useful for retrofitting to existing windows but does not deliver quite as good performance as a manufactured IGU.

Films

Window films can be an cost effective option for significantly reducing solar heat gain through existing windows.

They consist of a thin polymer film containing an absorbing dye or reflective metal layer, with an adhesive backing. Applied to existing glass, some window films can halve the overall SHGC of the window by means of absorption and/or reflection of solar radiation. They may also cause an equal reduction in visible light transmittance which must be considered when choosing a film.

Window films do not generally have significant impact on the glazing U-value because they do not add thermal resistance nor reduce the emissivity of the glass.

Glass panes exposed to direct sun become hotter than untreated glass and industry guidelines must be followed to avoid thermally induced cracking. For this reason it is generally best to use an accredited installer of window film. The U- and SHGC values of films fixed to specific types of glass will indicate the performance achieved.

Frames

After the glazing, frames have the greatest impact on the thermal performance of glazing units.

Aluminium window frames are light, strong, durable and easily extruded into complex shapes, but aluminium is a good conductor of heat and can decrease the insulating value of a glazing unit by 20 to 30 percent. Aluminium frames, especially dark coloured ones in full sun, absorb a lot of solar heat and conduct it inside. A thermal break is often used to reduce the heat conducted through aluminium frames. It separates the exterior and interior pieces of the frame using a low- conductivity component (typically urethane or other low-conductivity polymer).

A large amount of energy is used to make aluminium but it can be recycled at the end of its use. Some manufacturers may be able to provide aluminium frames made from recycled material which uses far less energy to produce. Powder-coated aluminium never needs painting, which significantly reduces its resource impact.



Timber frames are a good insulator but requires more maintenance than aluminium. Timber frames may require larger tolerances in openings, which can result in gaps that allow air infiltration, unless good draught sealing (weatherstripping) is provided.

Timber absorbs carbon dioxide as it grows and retains that carbon until the wood is burnt or decays. Timber species must have naturally high durability or be treated to prevent decay and deformation. It is important to check that the timber is sourced from a sustainably managed forest. There are currently Australian hardwood window frame manufacturers that use timber certified by the Forestry Stewardship Council (FSC). Plantation-grown hoop or radiata pine can be treated with LOSP (light organic solvent preservative) and painted which provides another option apart from FSC-certified durable hardwood.

Composite frames use thin aluminium profiles on the outer sections with either a timber or uPVC (unplasticised polyvinyl chloride) inner section. These provide the low maintenance and durability of aluminium plus improved thermal performance.

uPVC frames are petroleum derived products which are relatively new in Australia but common in Europe and North America. Their insulating properties are similar to timber and they can be moulded into complex profiles that provide excellent air seals. The colour range is more limited than powder coated aluminium.

Fibre-reinforced polyester (FRP) frames are used overseas and are generally the most thermally efficient high-strength framing materials available.

Styles

Windows come in a range of styles or configurations: fixed, horizontal sliding or vertical sliding (double-hung), hinged, (awning, casement or hopper), louvres or as fixed glazing. Doors come in hinged or sliding configurations. The style of system impacts on its energy performance in several ways.

Different styles of glazing unit have different frame fractions which impacts on the system U-value.

Aluminium frames are more conductive than glass. Therefore, increasing the area of aluminium frame increases the overall (system) U-value. Timber, composite or plastic frames have lower conductivity than a single pane of glass so increasing the area of frame improves the system U-value of a single glazed window.

Small glazing units tend to have a higher frame fraction than larger units, simply because of the different ratios of perimeter to area.

Different styles of doors and windows provide different opening areas, which determines how much cross ventilation can be provided by the glazing unit. Maximum opening area can be achieved by louvres and hinged or pivoting units that open at least 90°. Awning, hopper or casement windows, opened by short winders, provide least opening area.

Window furnishing

The most effective way to control heat flow through windows is selection of systems with appropriate U- and SHGC values. Window furnishings, blinds and curtains, can enhance performance and can be an effective way to overcome problems with existing windows.

Reducing solar heat gain can be achieved by blinds that reflect solar heat that was transmitted through the window, back out through the window. This is not as effective as preventing the solar heat from entering the window in the first place because only a portion of the heat is reflected back to outside.

To reflect solar heat the external surface of blinds should be white or near-white. Some offer a metallic, reflective film on the external surface, with a decorative fabric facing in. The space between the blind and window will trap a lot of heat – a ventilation opening in the window can allow that to escape.

Reducing convective heat transfer through windows can be achieved by snugly-fitted blinds and curtains with pelmets, that trap a layer of still air next to the window. Avoiding air gaps around all perimeters of the curtain and pelmet is key to improving performance.

Heavy fabrics and multiple layers of fabric help increase the insulation provided by curtains by reducing the amount of heat conducted between the air in the room and the air adjacent to the window. This benefit is reduced if air-movement around the curtain is not prevented.

SPECIFYING AND DOCUMENTATION

Because glazing units have a major impact on building thermal performance, and because there are thousands of different types, it is essential and critical that they be clearly specified and documented. Inadequate specification and documentation can lead to products being used that do no meet the intended performance and may fail to satisfy regulatory requirements – leading to potentially expensive errors.

Specification of glazing units must include:

> Dimensions.

> Style.

> System U-value.

> System SHGC value.

The use of system U and SHGC values is much better than using the component values i.e. the U-value of the frame plus the U-value and SHGC value of the glass. The system U- and SHGC values are not the sum of their parts – they are the result of the interaction of the parts. There is a significant difference between component and system values – so be sure to be explicit about the values you specify and require.

If you are using toned glass, it may be worthwhile to check the visible transmittance (VT) if you want to maximise natural daylighting. Be aware that only high-performance IGUs are able to simultaneously combine low U-value with low SHGC (when needed) and high VT (when needed).

The thickness of glass is often included in thermal specifications but be aware that the requirements of Australian Standards for safety and fire protection must take precedence.

The type of glass and frame is not as critical as system U-value and SHGC. It may matter for aesthetic or maintenance reasons – but the thermal performance depends solely on the system U-value and SHGC values. For example, you may require a window with a system U-value of 4 and SHGC of 0.7. That could be achieved by either a standard aluminium frame with clear double glazing or a timber or composite frame with low-e single glazing.

All glazing units for residential use have a rating of their system U-vlue and SHGC values. These include generic and custom ratings.

> Generic (default) ratings use simple descriptors of the type of frame and glazing and apply a system U and SHGC value. The range of descriptors is limited eg. timber, aluminium or uPVC frame and clear, toned, low-e, double or double glazing with low-e.

> Custom (proprietary) ratings have been calculated for products with specific brands, style, glass and frame type so are more detailed and precise.

All glazing units in Australia are rated according to guidelines recognised by the Australian Fenestration Rating Council (AFRC). The testing conditions and documentation procedures recognised by the AFRC are based on the U.S. NFRC (National Fenestration Rating Council) procedures. This is an international scheme applicable to residential and non-residential buildings. NFRC standards were introduced in Australia in 2007 replacing the previous ANAC standard.

All these acronyms might be confusing, but the differences are significant. For a given product, NFRC and ANAC ratings are different! Be absolutely sure, when selecting and specifying products that the declared U- and SHGC values are according to the AFRC requirements or you could end up with products that don't meet performance expectations and may not comply with regulatory requirements. Look for evidence that the ratings are AFRC approved and if you are not sure, question the supplier.

WINDOW ENERGY RATING SCHEME

The Window Energy Rating Scheme (WERS) rates the energy and energy-related performance of residential windows, skylights and glazed doors in accordance with AFRC procedures.

WERS provides the system U- and SHGC values as well as air infiltration, condensation performance rating, fading protection (which quantifies damaging transmission of ultraviolet and short-wave visible wavelengths) and visible transmittance. It also provides a star rating of glazing units according to their heating and cooling performance. It includes thousands of specific products from most manufacturers, listed according to the types of frame and glazing.

WERS-rated windows, skylights and glazed doors carry a sticker and a certificate specifying their performance. It provides manufacturers, designers, consumers and regulatory authorities with certainty that the glazing products meet the required performance specifications.

DESIGN

Passive design considerations

Selection of the right glazing units is a key element of passive design. The range of window performance gives you great flexibility when designing a home.

The starting point is to understand your climate. When do you want inside to be warmer than outside or cooler than outside? How humid is it? What is the position of the sun? What is the frequency and direction of winds?

You can then define the periods of the year and the times of day and night that you want glazing to encourage or avoid heat gain and when you want to encourage or limit air movement.

If you understand the heat flow through glazing you can assess each glazed element and select an appropriate SHGC value to determine how much solar heat comes in.

Its emissivity will determine how much infrared heat (from warm objects) comes in or out.

Its U-value will determine how much conducted heat (resulting from a temperature difference between inside and out) is gained or lost.

The style will determine the opening area and ability to allow cross ventilation.

Your selection of glazing units will also depend on their location in the building and orientation. Without appropriate shading a north facing window will admit winter solar heat gain but allow excessive summer solar heat gain. Without appropriate shading a west facing window will admit some afternoon solar heat in winter, but will admit even more in summer.

Reducing heat loss

Conducted heat loss can be reduced by glazing units with a low U-value. Low emissivity will also reduce heat loss from infrared radiation from warm objects..

Internal coverings, such as, closely fitting heavy curtains with pelmets can reduce conducted and convective heat loss.

External screens can minimise wind speed across the surface of glazing, reducing convective heat loss.

Increasing heat loss

In hot climates there may be times when you need to purge heat from the building. Ventilation through openings in the building replaces indoor air with outdoor air, but the incoming air must be cool in order to be beneficial.

Reducing heat gain

The major part of heat gain is solar radiation. Well designed eaves and overhangs can shade glazing from beam solar radiation and some diffuse solar radiation at specific times of day or months of the year. Blinds and vertical screens can protect glazing from beam and diffuse solar radiation. [See: 4.4 Shading]

Increasing heat gain

In cold climates you generally want to encourage solar gain. Use glazing with a high SHGC.

Orientation of glazing is critical. It will receive most Winter solar heat on the north elevation. It receives less on the east and west though morning sun can be very pleasant. The south sides receives only diffuse and reflected solar radiation in cold climates in winter.

Thermal mass

Thermal mass does not create heat – it just stores it. For thermal mass to provide beneficial evening heat in cool climates it is essential that glazing is used to admit solar radiation during the day to warm the mass. [See: 4.5 Passive Solar Heating; 4.6 Passive Cooling; 4.9 Thermal Mass]

If thermal mass is used in warm and hot climates to absorb heat from the air, solar gain through glazing should be minimised and the mass should not be located where it is exposed to solar heat gain.

Low mass buildings cannot store any heat to make night time warm so choose glazing with a low U-values to minimise heat loss at night and on cloudy days. Low mass buildings can not absorb solar heat during the day, so solar heat gain through windows may cause air temperatures to get too hot during the daytime – even in winter.

Light transmittance

Good window design and location maximises natural lighting. Bright, naturally lit homes promote health and well-being and reduce the need for electric lighting. Natural light provides good colour rendition and skin tones and is preferred by most indoor plants.

Choose glazing with high visible light transmittance to maximise day lighting.

Diffuse lighting (as opposed to direct sunlight) is generally the best for providing good uniform illumination over a room and avoiding glare.

Skylights are an excellent way to provide natural day lighting for a room, particularly in cooling climates where shading and other passive design elements can reduce light transmittance through windows. Conventional skylights can let in too much heat and light, but new designs (such as angular-selective skylights) can be a very efficient way to light a room.

A Skylight Energy Rating Scheme (SERS) has been developed in Australia, similar to WERS and is being used by some manufacturers.

Ventilation

Providing ventilation is an important function of windows. The ventilation depends on physical characteristics, such as, the placement of the windows, the opening size and the frame type.

Cross ventilation is about five times as effective at encouraging air movement through the house as ventilation from a single opening.

It is important to balance the need for ventilation in summer against air leakage and winter heat loss.

Noise control

Sealing cracks and gaps around the window, and elsewhere in the building, is probably the most effective initial way to control noise, though appropriate windows and glass can assist with noise control.

Sealed double glazing reduces transmission of medium to high frequencies, such as, the human voice. To reduce low frequency noise, such as, traffic and aircraft, thicker glass, preferably double-glazed with a large air gap in between the panes (100mm or more) is most effective. Note that such large gaps allow convection to occur between the panes and reduce insulating properties.

Thick laminated glass is also effective in reducing noise transmission but offers little in the way of thermal performance. [See: 2.7 Noise Control]

Fading

Exposure to sunlight causes many modern interior furnishings to fade. The wavelengths most responsible for fading are the ultraviolet, violet and blue wavelengths.

Appropriate glazing will block some of these wavelengths and reduce fading although it will not prevent it completely.

Fabric Fading Transmittance is a measure of the extent to which a window transmits those wavelengths of light that cause fading. It can be found at the bottom of the WERS rating label. The lower this number, the lower the potential for fading.

Condensation

Condensation occurs when moist air is cooled or when it meets cooler objects.

The interior and exterior surfaces of energy efficient glazing are closer to the adjacent air temperature, reducing condensation and the build-up of unsightly and unhealthy mould and fungus on windows.

Less efficient windows create greater differences between room temperature and glass surface temperature, facilitating the formation of condensation.

Properly constructed double glazed units are sealed, filled with inert gas, evacuated or have a desiccant in the cavity to eliminate condensation. IGMA is the National body representing qualified IGU manufacturers and can be contacted for further information on these products.

Lifecycle costing

Glazing is a significant investment in the quality of your home.

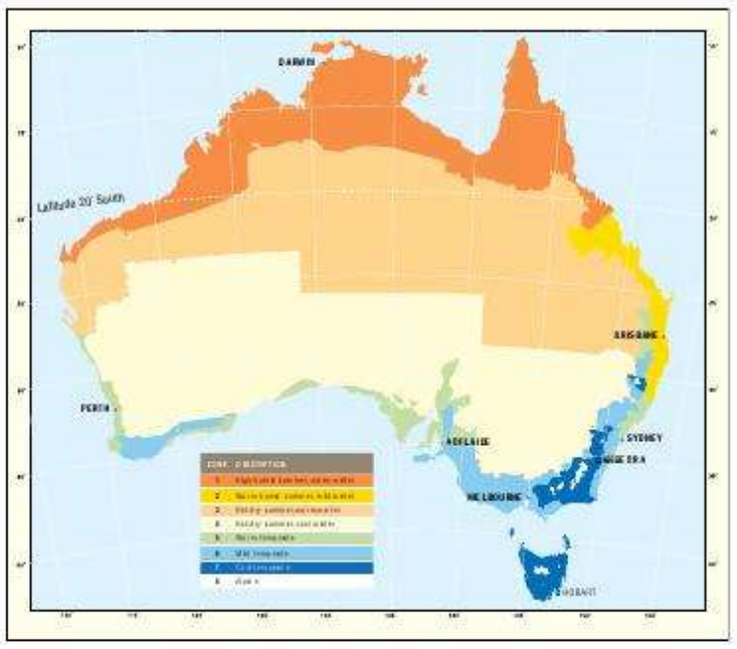
The cost of windows and the cost of heating and cooling your home are closely related. An initial investment in energy-efficient windows can greatly reduce your annual heating and cooling bill. Energy-efficient windows also reduce the peak heating and cooling load, which can reduce the size of an air-conditioning system by 30 percent, leading to further cost savings.

The cost of high performance glazing is coming down significantly as demand and production increases. Money spent on improved glazing is need not be seen as a cost but an investment in the value of your property which should be recouped upon resale.

Improved glazing delivers greater comfort and a healthier home that is kinder to our environment.

CLIMATE CONSIDERATIONS

Australia can be divided into cooling, mixed and heating climates to assist in window selection and design. These guidelines are intended as a simple summary of strategies for glazing. They should be combined with good design of other building elements.



Cooling climates

ZONE 1 High humid summer, warm winter

ZONE 2 Warm humid summer, mild winter

ZONE 3 Hot dry summer, warm winter

ZONE 4 Hot dry summer, cool winter

Cooling climates are warmer climates where most energy is used to cool the home. Geographically, most of Australia has a cooling climate. In these climates windows should be designed to keep the heat outside. These are climates where houses use more than 70 percent of their total space-conditioning energy for cooling.

Climates that are too hot most of the year can present fairly simple design solutions:

> Provide maximum shading of glazing – beam, diffuse and reflective.

> Use light coloured frames.

> Select glass with a low SHGC.

> Consider low U-value to minimise conducted heat gain.

> Choose window styles that provide maximum openable area, located on opposite sides of the building to promote cross ventilation.

Mixed climates

ZONE 5 Warm temperate

ZONE 6 Mild temperate

Mixed climates are warm and mild temperate climates where more than 30 percent of the total space-conditioning energy is used for heating in winter and more than 30 percent is used for cooling in summer. A typical house in Sydney (a mixed climate) may use 57 percent of its total heating and cooling energy for heating and 43 percent for cooling.

Mixed climates present more design challenges. Heat gain is required in winter and it needs to be avoided in summer.

A low U-value will improve both summer and winter performance.

The passive design of the building will mean North facing windows will receive more solar radiation in winter than in summer. These windows may perform best, year round, with a high SHGC.

West and east windows will receive more solar radiation in summer than in winter – the opposite to what is desirable. They may perform best with a low SHGC. The best solution is operable shading that can be drawn in summer and opened in winter or shading screens that block summer sun which sets WSW, but admits winter sun which sets WNW.

Mixed climates can require some compromises between summer and winter performance. Thermal modelling software is useful for determining the exact performance.

Heating climates

ZONE 7 Cool Temperate

ZONE 8 Alpine

Heating climates are those in which a typical house uses more than 70 percent of its total space-conditioning energy for heating in winter and less than 30 percent for cooling in summer. The objective is to maximise solar heat gain most of the year and minimise heat loss. Consider the following:

> Locate most glazing facing north where it receives maximum solar exposure (especially in living areas).

> Avoid shading windows or use adjustable shading for periods when it is too hot or eaves and screens that provide shading only in mid-summer.

> Choose glazing units with low U-values.

> Choose glazing units with high SHGC to maximise solar gain except if specific windows allow unwanted, summer afternoon heat gains.

About 70 percent of Australia's population lives in heating or mixed climates. In such climates, more advanced windows return a net energy benefit over a whole year, regardless of which direction they face. It is possible for an advanced window's energy gains to exceed its losses, even if it faces south.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on passive design considerations for your climate.
www.gov.au

Australian Bureau of Meteorology
www.bom.gov.au/climate/environ/design/design.shtml

Australian Windows Association
www.awa.org.au

BEDP *Environment Design Guide*
PRO 32 Glazing, Windows, Skylights and Atria – Properties and Rating Systems.

Commonwealth of Australia, *Australian Model Code for Residential Development* (AMCORD) (1995), AGPS Canberra.

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www.renew.org.au

Wrigley, Derek (2004), *Making Your Home Sustainable: A Guide to Retrofitting*, Scribe, Carlton North, Victoria.

Windows Energy Rating Scheme
www.wers.net

Window Film Association of Australia and New Zealand
www.wfaanz.org.au

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Skylights

Skylights can make a major contribution to energy efficiency and comfort in new and retrofit low-rise buildings. Daylight is an excellent source of cool light and the right size of skylight admits just enough light and no more. The many available kinds of skylight can use the same energy-efficient technologies used in other window designs.



Skylights can be installed in existing and new homes. Daylight provides cool light, meaning that a given amount of light is accompanied by less heat gain than most types of artificial light. Skylights provide some of the best ways to admit daylight and distribute it evenly, saving energy and improving visual comfort levels. Skylights increase the amenity of internal spaces that might otherwise have no windows and allow additional flexibility in architectural design. They particularly suit one- and two-storey construction.

A skylight can admit more than three times as much light as a vertical window of the same size.

DESIGN PRINCIPLES

A variety of skylight shapes exist for sloping or flat roofs. Some skylight shafts exert nearly as much influence over the energy properties as the actual skylight itself. Skylighting may take the form of general glazed areas, such as, atria, attached conservatories or sunspaces. In this form rooflights are less likely to be factory-manufactured items and more likely to be constructed on-site.

Excellent daylighting is provided by skylights which have the potential to displace much artificial lighting, improving light quality, reducing heat generation and saving on energy costs.

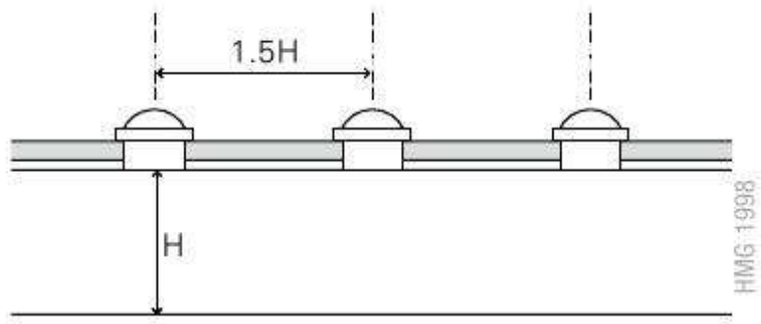
Under an unobstructed, overcast sky the amount of light, or luminance, from directly above (the zenith) is about three times as much as from the horizon.

A skylight can admit more than three times as much light as a vertical window of the same size. While this performance differential may be reduced in reality (eg by a long shaft), in most situations a skylight has the potential to be a very effective daylighting device. Even under overcast conditions use of skylights can result in spaces that can be predominantly daylit with little supplementary artificial lighting required. Additional energy needed for space heating and cooling because of thermal movement through larger window areas will be minimised.



The 'right size' of skylight admits just enough light for the job and no more. Several methods exist for helping to decide on the size and spacing of skylights.

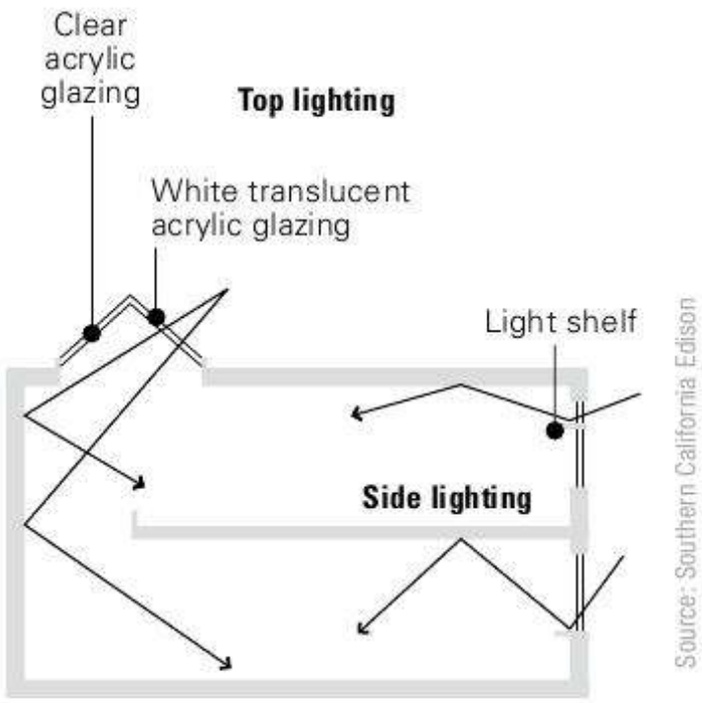
The smaller the skylight, the less its associated solar heat gain and the less its conduction gains and losses.



Rule of thumb for spacing skylights to help achieve uniform illuminance.

Skylight spacing is critical in large spaces. Excellent guidance is provided in several publications. The illustration above shows a rule of thumb example for skylight spacing that promotes even light distribution.

The principles of delivering daylight differ between windows and skylights.
Top lighting increases the potential for uniform light distribution.



Top versus side lighting

SOLAR CONTROL

Provide additional shading or other solar control where necessary. Skylights are more vulnerable to direct sunlight when the sky is clear, rather than overcast.

Energy-efficient technologies used for window design may be applied to skylights. Spectrally selective glazing is discussed elsewhere in *Your Home*. [See: 4.10 Glazing]

Glazing can be designed to block or facilitate light transfer according to sun angles. For example, in summer direct sunlight from above may be rejected while light from nearer the horizon may be admitted. Skylight manufacturers may further reduce their products' solar heat gain coefficient (SHGC) and increase thermal insulation (by reducing the U-value) through the use of shafts, tubes, ceiling diffusers and supplementary blinds or integral shades. These may assist in meeting codes and standards requirements.

Note that the size of the roof light and distance from the ceiling may attract certain Solar Heat Gain Coefficient (SHGC) and the Total U-Values requirements under the BCA.

Also note that maximum allowable aggregate area of the roof lights must not exceed 3 per cent of the total area of the floor or storey served.

Please refer to Clause 3.12.1.3 of the BCA Volume Two for further information.

Excellent daylighting is provided by skylights which have the potential to displace much artificial lighting, improving light quality, reducing heat generation and saving on energy costs.

In temperate Australia, the main limit on skylight size comes from the need to limit unwanted solar heat gain. Skylights should be selected to prevent undue heat loss or heat gain by conduction. The thermal transmittance of sloped glazing is greater (typically by 40 per cent) than that of vertical glazing because the heat loss in winter is in the same direction (up) as the buoyancy effect that drives convection.

The energy burden imposed by a skylight on a house is rarely more than a few per cent of the total energy required for heating and cooling because they are usually only a few per cent of the floor area, compared with 20-30 per cent for typical windows.

Some inbuilt solar control is desirable in warmer climates,, such as, solar-control glazing or blinds.

Skylights come in many combinations of shape, size, glazing, frame and installation details. Skylights can use diffuse (opal) glazing in glass or acrylic to achieve the twin goals of even light distribution and solar control. Diffusely transmitting glazing has a back-scattering effect on incoming solar radiation. This reduces overall visible transmittance slightly but reduces the solar heat load on the space below. At the same time, diffuse transmission scatters light over a wide range of angles. This promotes soft, glare-free lighting.

SKYLIGHT TYPES

Roof windows are popular for attic rooms where there is a cathedral ceiling but no roof space. Almost all roof windows use sealed, double insulating glass (IG) units to reduce heat losses while at the same time minimising condensation. Some are openable which is highly recommended in summer conditions, especially in two-storey houses where heat would otherwise tend to concentrate on the upper level.

Double glazing also allows the use of spectrally selective low-e coatings that reduce solar transmission. The use of a sealed IG allows the option of argon gas in the gap instead of air, which reduces the heat conducted and convected across the space.

Some double glazed units are permanently ventilated to avoid fogging but this may contribute to draughts and heat loss, so they should be used with caution in heating climates.

Roof window frames are typically timber with external, weatherproof aluminium cladding, but may be aluminium or steel. In cool and alpine climates, uninsulated metal frames are not recommended because of the condensation they create.

Roof windows, whether operable or not, are sometimes combined with a shafts in homes that have flat ceilings. Ceiling-level diffusers are rarely used with roof windows.

Plastic dome skylights are typically single-glazed 'opal' (ie. diffuse) moulded units. Specular top glazing may also be employed, either in clear or tinted plastic. Plastic dome skylights typically have long shafts and a diffuser panel fitted at ceiling level.

Tubular skylights reduce absolute heat loss and heat gain because of their small cross-sectional area. Sometimes called tubular daylighting devices (TDDs), their daylighting effect relies on their ability to capture direct-beam sunlight and diffuse it at ceiling level around the room.

They work best in climates with a high incidence of clear, sunny days. On cloudy days the amount of daylight admitted is considerably less than for a large-area, conventional skylight.

A reflecting tube is used to direct sunlight downward. Best results are achieved by a straight tube with a silvered lining. Flexible tubes are effective provided their internal reflectance is high. Tubes should have a visible reflectance of 95 per cent or greater (AS 4285-1995). Silver provides better colour rendition than aluminium as it is a more uniform reflector of the spectrum. Aluminium gives a slightly 'bluer' quality to the light. Diffusers should be fitted to tubular skylights to reduce glare and throw the light over a broad area.



EFFECT OF SKYLIGHT SHAFT ON LIGHT AND HEAT GAIN

Major advances have occurred in the last few years in our understanding of the effect of shafts and reflective tubes on the performance of skylights. The shape and dimensions of the shaft affect both the light transmission and actual solar heat gain obtained from the skylight.

Tests show three quantities tend to be less than predicted from a skylight's theoretical properties. These are:

> Effective Solar Heat Gain Coefficient.

> Overall solar heat gain in watts.

> Useful light that emerges from the bottom of the shaft or tube.

Some incident solar energy is absorbed by the sides of a shaft or tube. Shafts with matt white painted walls scatter some of the incoming solar radiation in all directions, a portion of which is lost to the outside. The fewer reflections experienced by incoming rays and the higher the reflectance of the sides of the shaft, the greater the transfer of light to the room below. The greatest throughput of light occurs in the case of specular tubes in tubular daylighting devices.

Thermal energy is lost to the outside through the skylight glazing and frame at night. Further heat is lost through the tube or shaft walls, to the attic or roof space. During the day buoyant solar-heated air becomes trapped in the shaft (or tube) and there is almost no downward heat transfer.

The longer the shaft or tube, the less light transmitted by the skylight system. Solar heat admitted by the skylight is also less. A skylight with poorly performing top glazing may be improved thermally by using a long shaft, provided adequate overall light transmission is maintained.

MAKING THE MOST OF LOCAL SKY CONDITIONS

Effective delivery of daylight depends on many factors including the:

> Sun's altitude and azimuth.

> Relative occurrence of overcast versus sunny weather.

> Season.

> Levels of air pollution and haze.

In Australia it is possible to predict average sky conditions, including relative amounts of clear and overcast sky, because most populated locations as our cities are less afflicted by heavy air pollution than many overseas locations – except on isolated occasions, such as, during severe bushfires or dust storms.

Locations with a high incidence of cloudy skies are better served by roof windows or conventional skylights with large areas and diffuse glazing systems. In sunny locations tubular skylights deliver very high illumination levels when the sky is clear.

MAINTENANCE AND LONG-TERM PERFORMANCE

Maintenance should ensure that the external (roof) and visible internal (ceiling level) surfaces are cleaned regularly, especially if exposed to a harsh environment. In a harsh environment, skylight exteriors should be cleaned at six-monthly intervals. In benign settings, once every 24 months is adequate. Operable and ventilating skylights (eg openable roof windows and combined skylight/roof ventilators) may require occasional lubrication of moving hardware.

Leaf debris should not be allowed to pile up on skylight materials since rainwater leaches decomposed chemicals out of the leaf litter and causes severe staining.

Skylights are made from a variety of materials including plastics (ABS, acrylic, polycarbonate and others), glass, aluminium (plain and powder-coated), steel and stainless steel. Generally these materials have a long life.

Roof windows often use timber frames but have an exterior, powder-coated aluminium cladding to provide a weather-resistant surface. Mill-finish aluminium is very susceptible to corrosion from salt in outdoor coastal environments.

Some plastics were prone to craze, become yellow or brittle with age and cumulative UV exposure. Modern plastics are far less susceptible to such degradation.

All metals, plastic and glass can be cleaned with warm water and a mild detergent using a sponge or soft brush. Detergent residues should be washed off with clean water. Abrasive products and dry brushing should not be used.

Designers and specifiers should keep maintenance requirements in mind especially if the project is highly dependent on consistent and long-term skylight performance.

Fire safety

Fire safety requirements under the BCA specify that if roof lights are deemed combustible, the aggregate area of the roof lights must not exceed 20 per cent of the roof or part of the roof.

In addition, such roof lights must be distanced minimum 900mm from allotment boundary other than the boundary adjoining a road alignment or other public space; and the vertical projection of a separating wall extended to the underside of the roof covering. Also, combustible roof lights must be distanced minimum 1.8m from any roof light or the like in another building on the allotment other than an appurtenant or a detached part of the same building. Please refer to Clause 3.7.1.10 of the BCA Volume Two.

ADDITIONAL READING

BEDP *Environment Design Guide*
PRO 32 Glazing, Windows, Skylights and Atria – Properties and Rating Systems.

Skylight Industry Association
www.siai.info

Principal author:
Dr Peter Lyons

Apartments and Multi-unit Housing

Apartments are dwellings that are stacked vertically as well as horizontally. Multi-unit housing includes clustered and row, or terrace, housing. Both dwelling types offer additional challenges and opportunities for passive and sustainable design compared with individual dwellings.

Apartments are in a different category from domestic dwellings in the Building Code of Australia with stringent demands placed on fire and noise separation. Issues of privacy and overlooking and consideration of the role of private and common spaces, are inherent in multi-unit and apartment design and it is important to understand their relationship to both passive design and social aspects of sustainability.

SOME DESIGN ADVANTAGES

There are some inherent advantages to building with shared walls and floors as, overall, there will generally be proportionately less building envelope per dwelling and each dwelling may have a smaller external area of wall or roof exposed to heating and cooling loads from the environment. Passive design principles can be applied to these building types to great effect provided the constraints of fire and noise separation are addressed early in the design process.

The same passive principles apply of maximising cooling air movement and excluding sun in the hot months, trapping and storing heat and minimising heat loss to the external environment in cooler months.

A variety of dwelling types encourages diversity in the social mix and offers multiple design opportunities for different sustainable strategies.

SUSTAINABLE COMMUNITIES

Apartments and multi-unit housing are medium or high density buildings that generally fit best in urban environments. There are some examples, mostly overseas, of developing clustered dwellings on peri-urban or semi-rural sites where the strategy is to minimise the buildings' physical footprint and release more land area for vegetation and social amenity.

The density of apartment and multi-unit housing developments make them well suited to urban environments and they should be located close – ideally within walking distance – to shops, playgrounds, parks and other amenities. This improves social amenity for the residents and contributes to minimising motorised transport use, reducing greenhouse gas emissions (and road traffic accidents).

Apartment buildings can include services that support and encourage an active community, such as, gyms, swimming pools and also facilities, such as, laundries and community rooms.

SAFETY AND SECURITY

Alongside 'passive design', 'passive surveillance' should be a watchword in multi-unit dwelling design. A pedestrian dominated environment can be intrinsically safer than one dominated by motor vehicles, but care must be taken to ensure that there are no places that allow hidden loitering.





Unfriendly, fearful, socially alienating.

The individual design of all higher density dwelling units should adopt the principles and recommendations contained in the fact sheets on Safety and Security. [See: 3.4 Safety and Security]

STREETSCAPE

There is nothing more alienating than rows of houses hidden behind two metre high fences blocking passive surveillance of the street from the dwellings whilst giving passers-by no sense of whether the homes are occupied or not. Healthy communities are ones in which positive social interaction is encouraged and this can be facilitated by appropriate design, eg. fences low enough to talk over and placing mailboxes in shared community spaces that are conducive to casual conversation and have seating that feels safe and protected.

Spaces for informal social interaction may be set in common areas that are outside, as well as indoors. As well as being pleasant places to share drinks and chat, attractive garden environments can be places for active participation, managed directly by residents.

SUSTAINABLE LANDSCAPES

The extent of landscaping associated with these dwelling types varies considerably, ranging from environments dominated with hard surfaces with very limited plantings to leafy, substantial vegetation surrounding and dominating the immediate external



Sustainable landscaping can be at the heart of a sustainable community.

environment. There are many opportunities to integrate sustainable landscaping practices into medium and high density developments (particularly as appropriate management can be maintained through strata and community title corporations), including:

> Low water use vegetation.

> Water sensitive design.

> Community produce gardens.

> Green roofs, roof gardens and living walls.

TRANSPORT

It has been said that the quickest way to get from 'A' to 'B' is to build 'A' right next to 'B'; sustainable city advocate Richard Register calls this 'access by proximity'. Higher density dwellings can place more people close to shops, schools and other daily destinations with greater economy than conventional low density sub-divisions and make public transport more economically viable.

ACCESSIBILITY

As with all modern homes, higher density dwellings need to be healthy and adaptable. In the case of apartments and most multi-unit dwellings the need for 'vertical circulation' can be a dominant consideration. Although apartment buildings can be designed as 'walk-ups' this results in access problems for all but the most able people – any of whom may themselves be disabled at any time by a vehicle accident or illness. The provision of lifts addresses the issue of access but they add costs and require additional operational energy. They also have on-going running costs that can be quite high. Lifts should be selected for their energy efficiency.

In multi-storey housing the stairs should be 'future-proofed' by being designed to readily accept 'stair climbers' or similar devices.

Every effort should be made to design lift and stair areas as attractive places and not just as utilitarian spaces. When making landings for walk-up apartments ensure that they are wide enough for people to stop and chat whilst allowing others to pass.

> Regard all common areas as potential social space, including stairs an stairwells.

> Make private balconies and outdoor areas as generous as possible.

> Consider using the roof area for a green roof (for environmental reasons) or accessible roof garden (for both environmental and social benefits).

ORIENTATION

Although it is not always possible to obtain optimum orientation in more urban, higher density environments, the correct positioning of apartments and multi-level dwellings can greatly assist passive design and cooling.



Consider making balconies as generous as possible.

PASSIVE DESIGN

Just as with individual homes, incorporating the principles of passive design in apartment and multi-unit housing:

> Significantly improves comfort.

> Reduces or eliminates heating and cooling bills.

> Reduces greenhouse gas emissions from heating, cooling, mechanical ventilation and lighting.

Whereas the passive design of a single dwelling on its own block usually (but not always) benefits from an uncrowded aspect in all directions, the massing or clustering of multiple dwellings can contribute to improved environmental performance and the comfort of their occupants in a number of ways, including:

> Creation of courtyards that can provide shelter from inclement weather or create suntraps in cooler weather.

> Enabling more dwellings in multilevel buildings to have solar aspect.

> Providing shade to adjacent dwellings that assist in reducing overall energy use.

Passive design is design that does not require mechanical heating or cooling but in apartment buildings this is not always easy to achieve. Homes that are passively designed take advantage of natural energy flows to maintain thermal comfort and multi-unit housing can also do this with good design.

With apartments, various building code requirements can impact on strategies for passive design, for instance, thermal flues for passive cooling can induce fire pathways and be contra-indicated, thus needing particular attention to be paid at the design stage.

When it is necessary to use mechanical ventilation this should be designed to be as energy efficient as possible.

It is always possible and is advisable to provide passive ventilation to habitable rooms – openable windows can be very effective.

SHADING

Shading should be dealt with according to the same principles that apply to detached homes. With multi-level buildings it may be desirable to use shade to protect the whole façade but the practicality of this depends on other aspects of the design. Balconies and shade structures may be used rather than reliance on eaves.



An apartment building where the eaves shade the whole north façade during the middle part of the day.



An apartment building that uses shade structures over otherwise exposed balconies.

PASSIVE SOLAR HEATING

Where it is possible to maintain good solar exposure, passive solar heating of apartments and units should be easily achieved. Where there are difficulties with aspect, as is often the case in tight urban environments, design to first principles, bearing in mind that both east and west sun can be used for solar gain and that in many Australian climates it may be beneficial to have southern aspect during the hottest months.

RENEWABLE ENERGY

Photovoltaic panels are less cost effective on apartment buildings as there are more dwellings per site area compared with the roof area available to carry the panels. Nevertheless, the provision of PVs can be very worthwhile as the energy captured can be used to offset the energy use and other running costs of community or strata corporations for common areas and services.

Incorporating PVs into the fabric of the building as functional cladding helps to amortise the investment in them by giving them multiple functions.



Skylit central stair and liftwell uses integrated semi-transparent PVs as roofing material.

Solar hot water systems can be used for multi-unit and multi-level buildings but consider the use of heat pump systems. A good service engineer can be very helpful when it comes to establishing which kind of hot water system is really the most cost and energy efficient for a given project.

FIRE ISSUES

Fire regulations may determine outcomes that seem to be less than ideal from a sustainability perspective. It may not be possible, for instance, to ensure that all bathrooms and wet areas can have both natural light and ventilation. Given the short occupancy periods of wet areas generally, and the tight constraints on space planning typical of the kind of denser dwelling type represented by apartments, the trade off from resorting to mechanical ventilation may be justifiable.

Lightwells and atriums need careful design consideration if there is to be any attempt to use them as part of a passive design strategy. It is advisable to explore this sort of issue early in the design process and discuss options with both service engineers and building certifiers.

THERMAL INSULATION

The Australian Building Code has only recently begun to demand thermal insulation in apartment buildings. Consider building with insulation in excess of the current code requirements to improve building performance and ensure that the building remains competitive in its thermal performance during its anticipated lifetime.

THERMAL MASS

Multi-storey buildings often require dense concrete cores, particularly for elements like stair and lift wells. Multi-unit dwellings demand good fire separation that is often most economically and effectively provided by using concrete construction whether pre-cast, in-situ or as blockwork. In each case the high density concrete elements can provide excellent thermal mass. Its situation in the core of an apartment or as party walls in well insulated houses is good placement for thermal mass and should be incorporated as such into the overall design strategy.



Dense precast concrete panels provide structural support and appropriately located thermal mass for this five storey apartment building, seen here under construction.

WINDOWS AND GLAZING

Double glazing is advisable for all climate zones. As well as providing thermal insulation it provides additional acoustic insulation that can be a real asset in denser, urban environments.

Openable windows require careful consideration in multi-level buildings and there are often regulatory controls over the extent to which windows may be opened. Consider using vertical sliding sashes for maximum control over ventilation options (the extent of low or high opened area can be adjusted to suit weather conditions and individual comfort requirements).

CONSTRUCTION SYSTEMS

There are many constructions systems available for apartments and multi-unit buildings ranging from frames to load-bearing walls. Having decided on a general approach, whichever construction system it is should be reviewed against the Your Home checklist to ascertain what might be achieved in regard to passive design.

MATERIALS

Materials selection should take into account embodied energy, waste minimisation, indoor air quality and impacts off-site.

APPLIANCES AND LIGHTING

Most apartment and multi-unit housing projects have a main developer who has purchasing powers unavailable to individual home owners. This power can be used to preferentially purchase energy and water efficient appliances and fittings.

STORMWATER

Stormwater can be captured and stored in underground tanks but it will necessarily only be an adjunct to the overall water supply whereas the roof of an individual dwelling in many parts of Australia can shed enough water to provide a significant part of that home's required supply. The amount of water shed by the roof of a single dwelling with a floor area of 260m^2 can be the same as that shed by the roof of a compact apartment building with a dozen or more dwellings within its envelope on the same footprint.

GREYWATER AND BLACKWATER

Capture and treatment of greywater and blackwater may be more economically viable for larger developments on the basis of a collective system. However, there is a threshold at which such systems become economically efficient and this should be clearly established before proceeding with design.

LANDSCAPING

As with individual dwellings, the landscape should be considered as much as possible to be integral with the building. Multi-unit developments often have high car parking demands that may conflict with the provision of a sustainable landscape. A preferred design strategy must be to de-emphasise the car and emphasise the pedestrian domain. If roads and driveways are inescapable, then they should be designed to be multi-user friendly, perhaps with surface treatments and designs that favour pedestrians over wheeled vehicles.

RATING TOOLS

As of early 2008 there are no rating tools for Australia that deal specifically with apartment buildings, although there are some tools under development. In the meantime it is possible to obtain formal ratings for apartments by using tools like AccuRate, as has been done for case studies in this Technical Manual, but they do not take into account the context of each apartment as part of a larger building and therefore may not fully reflect some of the energy benefits of this building type.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on passive design considerations for your climate.
www.gov.au

Australian Bureau of Meteorology
www.bom.gov.au/climate/environ/design/design.shtml

Commonwealth of Australia, *Australian Model Code for Residential Development* (AMCORD) (1995), AGPS Canberra.

Principal author:
Paul Downton

Material Use

The Material Use group of fact sheets examines the economic and environmental cost of various commonly used materials. It identifies and explains various tools available for measuring embodied energy and outlines principles for choosing materials and systems to reduce or eliminate impacts.

Careful analysis and selection of the materials used and the way they are combined can yield significant improvements in the comfort, cost effectiveness and energy efficiency of a home. Consideration should also be given to the lifecycle of materials and the processes adopted to extract, process and transport them to the site.

Informed decisions about materials and construction systems can reduce the environmental impact of a home without adding to the cost.

Quick tips to reduce the total amount of materials consumed and their environmental impact:

> Design and build for de-construction, re-use, adaptation, modification and recycling.

> Make more efficient use of existing materials.

> Use fully recycled materials or materials with recycled content.

> Choose materials with a lifespan equivalent to the projected life of the building.

> Encourage development of new, efficient, low impact materials and applications by creating demand.

> Consider how and where the materials are sourced and the impacts this causes.

> Minimise the energy used to transport materials by using locally produced material. Use of lightweight material where appropriate also reduces transportation energy.

> Minimise the energy used to heat and cool the building by using materials that effectively modify climate extremes.

> Understand how chemicals used in the manufacture of some materials might affect your health.



This well insulated home clad in lightweight fibre cement sheeting has low embodied energy and requires little heating or cooling energy to maintain thermal comfort in a warm, temperate climate.

OVERVIEW OF MATERIAL USE FACT SHEETS

5.2 Embodied energy

Embodied energy is the total energy used to create a product including all the processes involved in harvesting, production, transportation and construction. It can represent a significant proportion of the total energy used during the lifecycle of a home.

Consequences (or impacts) of particular materials and construction systems are often not apparent because they often occur long distances from where the product is used.

This fact sheet outlines some cost effective ways to reduce the embodied energy of materials. These include using construction systems appropriate for climate, substituting materials with high recycled content, and using materials made from new or non-renewable sources.

5.3 Waste minimisation

This fact sheets examines methods for lowering costs and reducing consumption of materials by minimising waste and recycling or re-using materials.

It focuses on the design and construction phases as these are the stages of the lifecycle where the greatest inefficiencies exist and the greatest gains can be made.



5.4 Biodiversity Off-site

Biodiversity is the variety of all life forms – the different plants, animals and micro-organisms, the genes they contain and the ecosystems of which they form a part. Biodiversity is an essential human life support system.

The harvesting of many materials used in building a home may cause many adverse impacts on biodiversity including:

> Extinction of species.

> Destruction of natural systems and habitat.

> Degradation of life support systems.

> Fragmentation of habitat and populations.

These impacts are rarely apparent at the point of purchase or use. As a result, we continue to specify and use materials that destroy our life support systems, even where alternatives exist.

Use this fact sheet to identify significant off-site impacts, guide your design and material choices, and influence your suppliers to provide biodiversity-friendly products.

5.5 Construction Systems

This fact sheet guides the selection of systems with lowest economic and environmental cost. It examines the performance of various roof, wall and floor systems in a range of climates and compares their costs and benefits.

Choosing an appropriate system for climate and location will increase thermal comfort, lower construction and maintenance costs and reduce the overall environmental impact.





More detail on construction systems is provided in the following fact sheets:

5.6 Mud Brick (Adobe)

5.7 Rammed Earth (Pisé)

5.8 Straw Bale

5.9 Lightweight Timber

5.10 Clay Brick

5.11 Autoclaved Areated Concrete (AAC)

5.12 Concrete Slab Floor

5.13 Green Roofs and Walls

EcoSpecifier

EcoSpecifier is a guide to selection of individual materials on an 'environmentally preferred' basis. It was developed by the Centre for Design at RMIT University in conjunction with EcoRecycle Victoria and National Integrated Living P/L.

EcoSpecifier explains how materials are assessed as being environmentally preferred based on lifecycle assessment and a range of other factors. It includes a comprehensive list of environmentally preferred generic materials commonly used in Australia.

Use this tool to either select materials with least environmental cost, or to gain an understanding of the principles of selection in order to identify or develop alternative materials.

www.ecospecifier.org

ADDITIONAL READING

Contact your State / Territory government or local council for further information on building sustainability and energy efficiency.
www.gov.au

BEDP *Environment Design Guide*
PRO 7 The Environmental Impact of Building Materials.
PRO 8 Strategies and Resources for Materials Selection.
PRO 16 Durability of Building Materials – An introduction.
PRO 35 Building Materials Selection – Greenhouse Strategies.

Hyde, R (2000), *Climate Responsive Design: A study of buildings in moderate and hot humid climates*, E and FN Spon, United Kingdom

Lawson, B (1996) *Building Materials, Energy and the Environment: Towards Ecological Sustainable Development*, RAIA, Canberra

Mithraratne, N, Vale, B. and R. Vale (2007) *Sustainable Living: The role of whole life costs and values*, Cambridge: Butterworth-Heinemann

Principal author:
Chris Reardon

Embodied Energy

Embodied energy is the energy consumed by all of the processes associated with the production of a building, from the mining and processing of natural resources to manufacturing, transport and product delivery. Embodied energy does not include the operation and disposal of the building material. This would be considered in a life cycle approach. Embodied energy is the 'upstream' or 'front-end' component of the lifecycle impact of a home.



This fact sheet discusses the relationship between embodied energy and operational energy. It then discusses the embodied energy of common building materials and guidelines to consider when reducing embodied energy impacts.

The single most important factor in reducing the impact of embodied energy is to design long life, durable and adaptable buildings.

Every building is a complex combination of many processed materials, each of which contributes to the building's total embodied energy. Renovation and maintenance also add to the embodied energy over a building's life.

Choices of materials and construction methods can significantly change the amount of energy embodied in the structure of a building. Embodied energy content varies enormously between products and materials. Assessment of the embodied energy of a material, component or whole building is often a complex task.

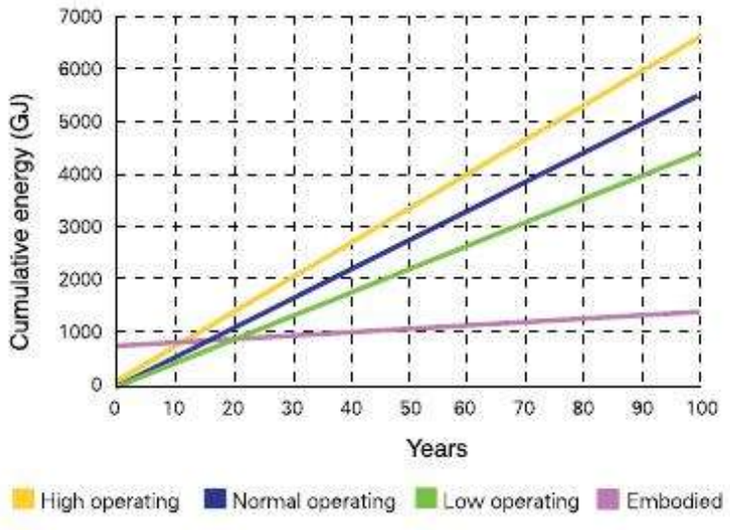
EMBODIED ENERGY AND OPERATIONAL ENERGY

It was thought until recently that the embodied energy content of a building was small compared to the energy used in operating the building over its life. Therefore, most effort was put into reducing operating energy by improving the energy efficiency of the building envelope. Research has shown that this is not always the case.

Embodied energy can be the equivalent of many years of operational energy.

Operational energy consumption dependes on the occupants. Embodied energy is not occupant dependent – the energy is built into the materials. Embodied energy content is incurred once (apart from maintenance and renovation) whereas operational energy accumulates over time and can be influenced throughout the life of the building.

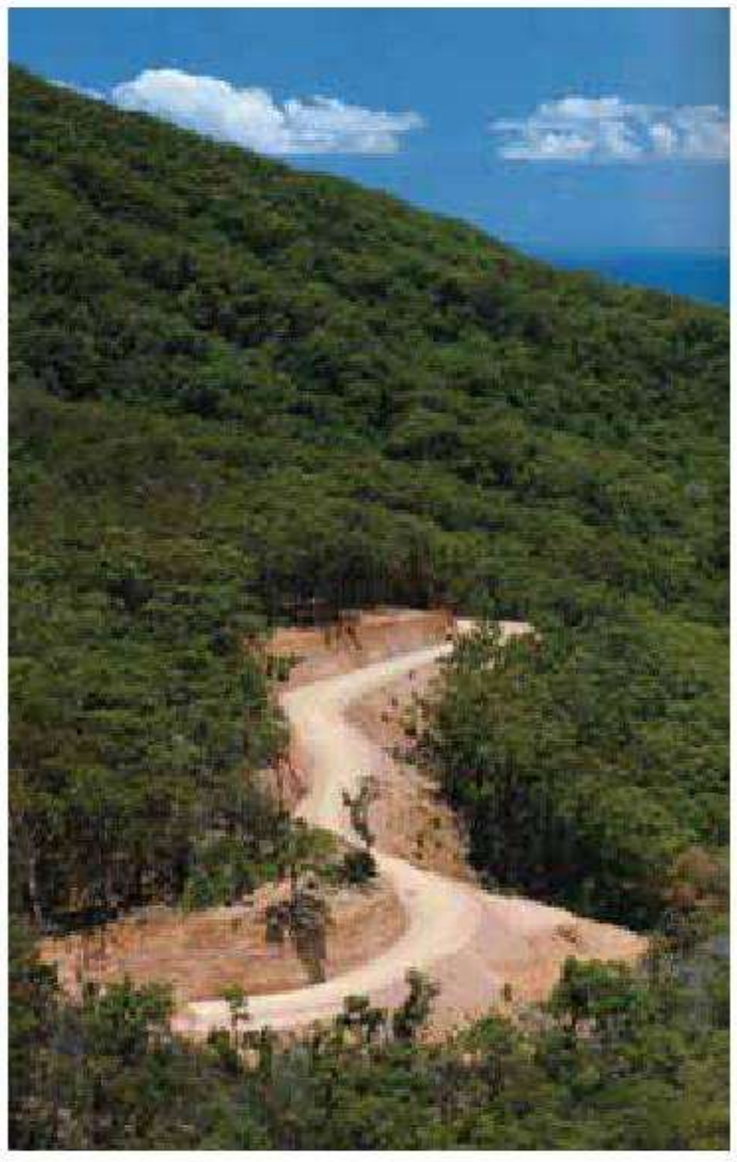
Research by CSIRO has found that the average household contains about 1,000 GJ of energy embodied in the materials used in its construction. This is equivalent to about 15 years of normal operational energy use. For a house that lasts 100 years this is over 10 percent of the energy used in its life.



Embodied energy content varies greatly with different construction types. In many cases a higher embodied energy level can be justified if it contributes to lower operating energy. For example, large amounts of thermal mass, high in embodied energy, can significantly reduce heating and cooling needs in well designed and insulated passive solar houses. [See: 4.5 Passive Solar Heating; 4.6 Passive Cooling; 4.7 Insulation; 4.9 Thermal Mass]

As the energy efficiency of houses and appliances increases, embodied energy will become increasingly important.

The embodied energy levels in materials will be reduced as the energy efficiency of the industries producing them is improved. However, there also needs to be a demonstrated demand for materials low in embodied energy.



ASSESSING EMBODIED ENERGY

Whereas the energy used in operating a building can be readily measured, the embodied energy contained in the structure is difficult to assess. This energy use is often hidden.

It also depends on where boundaries are drawn in the assessment process. For example, whether to include:

> The energy used to transport the materials and workers to the building site.

> Just the materials for the construction of the building shell or all materials used to complete the building such as bathroom and kitchen fittings, driveways and outdoor paving.

> The upstream energy input in making the materials (such as factory/office lighting, the energy used in making and maintaining the machines that make the materials).

> The embodied energy of urban infrastructure (roads, drains, water and energy supply).

Gross Energy Requirement (GER) is a measure of the true embodied energy of a material, which would ideally include all of the above and more. In practice this is usually impractical to measure.

Process Energy Requirement (PER) is a measure of the energy directly related to the manufacture of the material. This is simpler to quantify. Consequently, most figures quoted for embodied energy are based on the PER. This would include the energy used in transporting the raw materials to the factory but not energy used to transport the final product to the building site.

In general, PER accounts for 50-80 per cent of GER. Even within this narrower definition, arriving at a single figure for a material is impractical as it depends on:

> Efficiency of the individual manufacturing process.

> The fuels used in manufacture of the materials.

> The distances materials are transported.

> The amount of recycled product used, etc.

Each of these factors varies according to product, process, manufacturer and application. They also vary depending on how the embodied energy has been assessed.

Estimates of embodied energy can vary by a factor of up to ten. As a result, figures quoted for embodied energy are broad guidelines only and should not be taken as correct. What is important is to consider the relative relationships and try to use materials that have the lower embodied energy.

Precautions when comparing embodied energy analysis results

The same caution about variability in the figures applies to assemblies as much as to individual materials. For example, it may be possible to construct a concrete slab with lower embodied energy than a timber floor if best practice is followed.

Where figures from a specific manufacturer are available, care should be exercised in making comparisons to figures produced by other manufacturers or in tables that follow.

Different calculation methods produce vastly different results (by a factor of up to ten). For best results, compare figures produced by a single source using consistent methodology and base data.

Given this variability it is important not to focus too much on the 'right' numbers, but to follow general guidelines.

Precise figures are not essential to decide which building materials to use to lower the embodied energy in a structure.

EMBODIED ENERGY OF COMMON MATERIALS

Typical figures for some Australian materials are given in the tables that follow. Generally, the more highly processed a material is the higher its embodied energy.

MATERIAL	PER EMBODIED ENERGY MJ/kg
Kiln dried sawn softwood	3.4
Kiln dried sawn hardwood	2.0
Air dried sawn hardwood	0.5
Hardboard	24.2
Particleboard	8.0
MDF	11.3
Plywood	10.4
Glue-laminated timber	11.0
Laminated veneer lumber	11.0
Plastics – general	90
PVC	80.0
Synthetic rubber	110.0
Acrylic paint	61.5
Stabilised earth	0.7
Imported dimension granite	13.9
Local dimension granite	5.9
Gypsum plaster	2.9
Plasterboard	4.4
Fibre cement	4.8*
Cement	5.6
Insitu Concrete	1.9
Precast steam-cured concrete	2.0
Precast tilt-up concrete	1.9
Clay bricks	2.5
Concrete blocks	1.5
AAC	3.6
Glass	12.7
Aluminium	170
Copper	100
Galvanised steel	38

Source: Lawson *Buildings, Materials, Energy and the Environment* (1996); * fibre cement figure updated from earlier version and endorsed by Dr. Lawson.

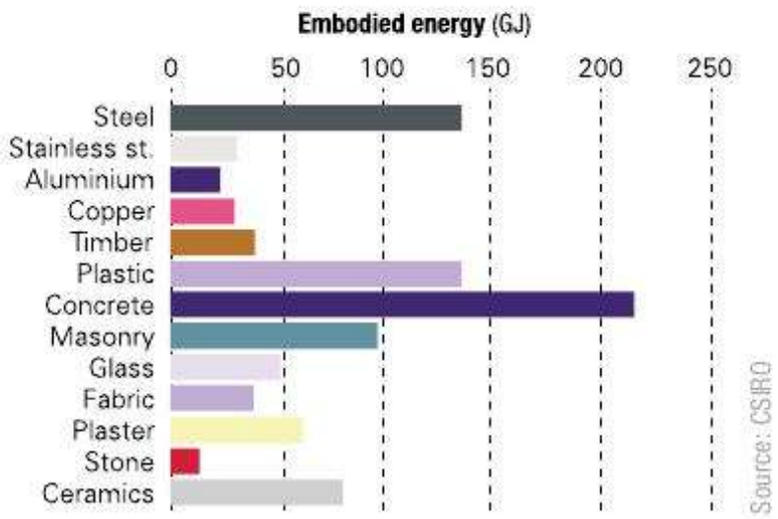
These figures should be used with caution because:

> The actual embodied energy of a material manufactured and used in Melbourne will be very different if the same material is transported by road to Darwin.

> Aluminium from a recycled source will contain less than ten per cent of the embodied energy of aluminium manufactured from raw materials.

> High monetary value, high embodied energy materials, such as stainless steel, will almost certainly be recycled many times, reducing their lifecycle impact.

CSIRO research has found that materials used in the average Australian house contain the following levels of embodied energy:



Materials with the lowest embodied energy intensities, such as concrete, bricks and timber, are usually consumed in large quantities. Materials with high energy content such as stainless steel are often used in much smaller amounts. As a result, the greatest amount of embodied energy in a building can be either from low embodied energy materials such as concrete, or high embodied energy materials such as steel.

ASSEMBLY	PER EMBODIED ENERGY MJ/m²
Floors	
Elevated timber floor	293
110mm concrete slab on ground	645
200mm precast concrete T beam/infill	644
Roofs	
Timber frame, concrete tile, plasterboard ceiling	251
Timber frame, terracotta tile, plasterboard ceiling	271
Timber frame, steel sheet, plasterboard ceiling	330

Source: Lawson *Buildings, Materials, Energy and the Environment* (1996)

For most people it is more useful to think in terms of building components and assemblies rather than individual materials. For example, a brick veneer wall will contain bricks, mortar, ties, timber, plasterboard and insulation.

ASSEMBLY	PER EMBODIED ENERGY MJ/m²
Single Skin AAC Block Wall	440
Single Skin AAC Block Wall gyprock lining	448
Single Skin Stabilised (Rammed) Earth Wall (5% cement)	405
Steel Frame, Compressed Fibre Cement Clad Wall	385
Timber Frame, Reconstituted Timber Weatherboard Wall	377
Timber Frame, Fibre Cement Weatherboard Wall	169
Cavity Clay Brick Wall	860
Cavity Clay Brick Wall with plasterboard internal lining and acrylic paint finish	906
Cavity Concrete Block Wall	465
Strawbale	----

Source: Lawson *Buildings, Materials, Energy and the Environment* (1996)

Comparing the energy content per square metre of construction is easier for designers than looking at the energy content of all the individual materials used. The table above shows some typical figures that have been derived for a range of construction systems.

GUIDELINES FOR REDUCING EMBODIED ENERGY

Lightweight building construction such as timber frame is usually lower in embodied energy than heavyweight construction. This is not necessarily the case if large amounts of light but high energy materials such as steel or aluminium are used.

There are many situations where a lightweight building is the most appropriate and may result in the lowest lifecycle energy use (eg. hot, humid climates, sloping or shaded sites or sensitive landscapes).

In climates with greater heating and cooling requirements and significant day/night temperature variations, embodied energy in a high level of well insulated thermal mass can significantly offset the energy used for heating and cooling.

There is little benefit in building a house with high embodied energy in the thermal mass or other elements of the envelope in areas where heating and cooling requirements are minimal or where other passive design principles are not applied.

Each design should select the best combination for its application based on climate, transport distances, availability of materials and budget, balanced against known embodied energy content.

Guidelines for reducing embodied energy:

> Design for long life and adaptability, using durable low maintenance materials.

> Ensure materials can be easily separated.

> Avoid building a bigger house than you need. This will save materials.

> Modify or refurbish instead of demolishing or adding.

> Ensure materials from demolition of existing buildings, and construction wastes are re-used or recycled.

> Use locally sourced materials (including materials salvaged on site) to reduce transport.

> Select low embodied energy materials (which may include materials with a high recycled content) preferably based on supplier-specific data.

> Avoid wasteful material use.

> Specify standard sizes, don't use energy-intensive materials as fillers.

> Ensure off-cuts are recycled and avoid redundant structure, etc. Some very energy intensive finishes, such as paints, often have high wastage levels.

> Select materials that can be re-used or recycled easily at the end of their lives using existing recycling systems.

> Give preference to materials manufactured using renewable energy sources.

> Use efficient building envelope design and fittings to minimise materials (eg. an energy efficient building envelope can downsize or eliminate the need for heaters and coolers, water-efficient taps allow downsizing of water pipes).

> Ask suppliers for information on their products and share this information.

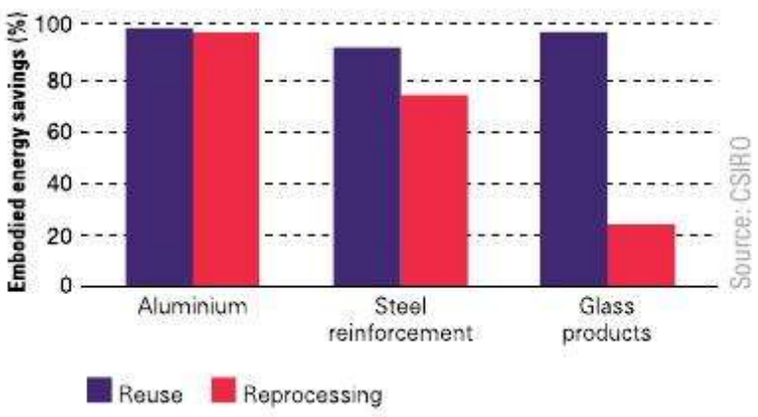
Re-use and recycling

Some materials such as bricks and roof tiles suffer damage losses in re-use.

Re-use of building materials commonly saves about 95 per cent of embodied energy that would otherwise be wasted.

Savings from recycling of materials for reprocessing varies considerably with savings up to 95 per cent for aluminium but only 20 per cent for glass.

Some reprocessing may use more energy, particularly if long transport distances are involved.



Life Cycle Assessment

Life Cycle Assessment (LCA) examines the total environmental impact of a material or product through every step of its life – from obtaining raw materials (for example, through mining or logging) all the way through manufacture, transport to a store, using it in the home and disposal or recycling.

LCA can consider a range of environmental impacts such as resource depletion, energy and water use, greenhouse emissions, waste generation and so on.

LCA can be applied to a whole product (a house or unit) or to an individual element or process included in that product. It is necessarily complex and the details are beyond the scope of this fact sheet. An internationally agreed standard (ISO 14040) defines standard LCA methodologies and protocols.

ADDITIONAL READING

BEDP *Environment Design Guide*
PRO 2 Embodied Energy of Building Materials

EcoSpecifier
www.ecospecifier.org

Lawson, B (1996) *Building Materials, Energy and the Environment: Towards Ecological Sustainable Development*, RAIA, Canberra

Principal author:
Geoff Milne

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Waste Minimisation

Up to 40 per cent of the waste generated by Australians is building waste. Minimising and recycling this waste can have significant social, economic and environmental benefits.

The three R's of waste minimisation: reduce, re-use, recycle.

Reduce consumption of resources by building smaller houses that are better designed for your needs. This is the most effective way to conserve precious resources for use by future generations and reduce waste. It also lowers costs.

Re-use existing buildings and materials and reduce demand for resources, lower waste volumes and save money.

Recycle resources that are left over or have reached the end of their useful life. This will reduce demand for new materials and lower the volume of waste going to landfill.



Don't demolish – deconstruct – give old buildings new lives.

Sending building materials to landfill is like throwing money away.

Use renewable resources like timber from sustainably managed forests. This creates a sustainable economy and helps conserve non-renewable resources.

Use materials with high recycled content to create a market for recycled resources. It will raise the price paid by recyclers for recovered resources and increase the viability of recycling.

LANDFILL

Our traditional means of waste disposal to landfill is uneconomic. Costs to communities for operating and maintaining landfill sites are high and availability of suitable land is limited.

Re-use options for landfill sites are extremely limited due to potential health hazards. Remedial action is often prohibitively expensive.



Emissions and leachate from landfill sites can be highly toxic due to concentrations of heavy metals and toxic chemicals. These toxins find their way into the water table and/or waterways, often with disastrous consequences.

40 per cent of all waste that goes to landfill is building waste.

We must reduce waste volumes going to landfill and remove toxic content from materials before disposal. Support your local council or local waste management's 'reduce, re-use and recycle' initiatives. User pays tipping fees make recycling more profitable.



WHAT IS BUILDING WASTE?

WASTE DESCRIPTION	WASTE QUANTITY WEIGHT % OF TOTAL
Paper / cardboard	1
Garden / vegetation	3
Wood / timber	10
Textiles / rags	1
Hard plastic	1
Ferrous	2
Soil rubble (<150mm)	34
Soil rubble (>150mm)	2
Concrete-based masonry	16
Clay-based [eg. bricks, tiles]	16
Plasterboard	2
Other / unknown	11
Total	100

Extrapolated from NSW EPA Waste Census Data 1997

LIFECYCLE AND WASTE

Life Cycle Assessment of waste streams indicates that significant energy savings can be achieved at little or no cost by considered construction and demolition waste management and planned recycling.

Materials with high embodied energy (eg. metals, especially aluminium) or with high environmental cost in extraction can have their lifecycle impact reduced by end use recycling. The environmental impact of most materials can be substantially reduced with each re-use.

RECYCLING – WHO TO CONTACT

> Local councils.

> Regional Waste Authorities.

> Local waste station or landfill operator.

> Waste recycling contractors.

> Construct Connect Australia facilitates the sale and purchase of salvaged and recycled materials for members. www.armetwork.com.au.

WHAT CAN BE RECYCLED?

Most materials can be recycled. The following list demonstrates some re-use options. There are many more and the list is growing rapidly.

Steel – Electric arc furnaces (EAF) produce reinforcing bar, mesh and sections from 100 per cent steel scrap. Conventional blast furnaces can incorporate up to 30 per cent steel scrap. Recycling steel reduces embodied energy by 72 per cent.

Aluminium – Aluminium is 100 per cent recyclable, recycling aluminium reduces embodied energy by 95 per cent.

Gypsum Plasterboard – CSR recycles plasterboard and other companies are considering doing so. Plasterboard disposed of in landfill produces poisonous hydrogen sulphide and has a foul odour.

Timber can be re-processed into horticultural mulch. A particle board manufacturer in Australia is developing a recycling facility that requires little or no pre-treatment of the waste.



Concrete – Un-set concrete can be 'washed' out at the plant to remove cement. Sand and stone can be re-used. Set concrete can be crushed and recycled as aggregate for new concrete or road base and fill.

Most glass can be recycled. Construction glass must be separated from other glass such as drink bottles. Glass may be cut and re-used or recycled as aggregate for concrete.

Some patterned glass incorporates all types of recycled building glass. Recycling glass reduces embodied energy by 20 per cent.

Carpet in good condition can be sold and re-used. It can also be recycled into secondary carpets. Some carpet can be recycled as weed barrier or a covering and food for worm farms.

Bricks and tiles can be re-used where appropriate or crushed on site for backfill, aggregate and gravel with portable crushing plants.

Plastics – Many plastics can be granulated and re-used to make new plastic products and include:

> High Density Poly Ethylene (HDP): rubbish bins, buckets and traffic cones.

> Low Density Poly Ethylene (LDP): shrink wrap and bubble wrap.

> Polystyrene containers, insulation, PVC pipes, fittings, and vinyl flooring.

MAKING IT HAPPEN

To be cost effective, waste minimisation strategies must be agreed to and implemented by all parties involved in building the home at the design, construction and operation stages.

A team approach by the owner, builder and designer is the most effective way to reduce waste.

Research has shown that opportunities for cost effective inclusion of sustainable features decline exponentially throughout the design process. Up to 90 per cent of critical decisions are made during the design stage. This includes waste minimisation.

There are many good household recycling and waste minimisation guides available. Consult your local Council. This fact sheet focuses on the design and construction stages.

THE DESIGN STAGE

Designers are responsible for introducing and planning waste minimisation strategies from the earliest stages of design through to completion. This includes deciding what to build, whether to demolish, what materials to use and how they might be recycled.

The initial consultation

> Lasting decisions about whether to renovate or demolish are often made at this stage.

> Consider waste streams and life cycle benefits.

A commitment to reducing waste at the initial consultation is more likely to endure throughout the project.

Concept design

> Choose construction to minimise cut and fill.

> Plan for end use and deconstruction.

> Select building systems with low waste rates.

> Identify recycled materials that can be used.

> Source recycled materials.

Early decisions have a major impact on waste stream quantity and quality.

Design development

> Dimension to suit standard modular construction sizes and minimize waste.

> Select materials with known minimum waste rates; manufacturer waste recycling schemes and recycled content or other life cycle benefits.

> Engage like minded design professionals (eg. engineer, interior designer).

> State and agree key waste goals prior to engagement (team building).

Working drawings and detailing

> Design operational waste handling facilities.

> Select efficient appliances.

> Plan for waste separation and sorting on-site during construction.

> Design final dimensions to suit available sheet and materials sizes.

> Prepare accurate shop drawings and nominate waste wise fabricators.

Off-site fabrication can reduce waste, facilitate separation of waste streams and improve recovery rates.

Specification

> Materials with known minimum wastage rates (eg. plywood, finger-jointed timber).

> Materials with known recycled content (eg. paper and polyester insulation.

> Durable materials and finishes.

> Waste handling and recycling contractors.

> Waste streams to be recycled.

Contract documentation

> Prepare a waste management plan so all tenderers factor best practice into their price.

> Agree which party or parties receive financial benefits of recycling.

> Provide economic incentives for recycling.

> Include waste minimisation and recycling performance clauses in the contract.

Tendering period

> Promote economic benefits of waste minimisation and recycling to tenderers.

> Familiarise tenderers with recycling, waste management and minimisation strategies.

> Answer questions and allay concerns (costs).

> Engender a spirit of cooperation to achieve waste minimisation objectives (team building).

Supervision

> Monitor recycling rates and on-site sorting and storage of various waste streams.

> Verify contractor performance or certification.

THE CONSTRUCTION STAGE

Site operations generally

> Plan locations for depositing and stacking of materials prior to delivery.

> Provide recycling skips and ensure waste stream sorting compliance by all trades.

> Form a compound to contain plastic film, cardboard, glue and paint tins.

> Use reputable waste service providers.

> Negotiate recycling paybacks with local resource recovery firms.

> Use waste aware sub-contractors.

> Use written contracts with all trades including clauses requiring waste minimisation practice.

> Require trades to dispose of their own waste.



> Back charge for sorting of waste streams not sorted by each sub-contractor.

> Colour code or label waste skips and protect them from contamination, rain and wind.

> Provide regular waste bins for food scraps and household waste during construction.

> Lock special skips at night and weekends to prevent rubbish dumping in recycling bins.

Materials storage and handling

> Minimise time between delivery and installation and the risk of damage or theft.

> Does packaging adequately protect goods? Is there too much? Can you eliminate some?

> Ask suppliers to collect/recycle packaging.

> Have fragile materials and fixtures delivered and installed close to completion date.

> Use prefabricated framing and trusses to reduce time on site before installation.

> Check quantity, condition and quality on delivery. Report discrepancies immediately.

> Reject inferior goods or materials if their quality will result in additional waste.

> Refuse oversupply as compensation for inferior quality or condition.

> Report careless delivery staff to the supplier.

Concreting

> Use concrete with recycled aggregate in all viable applications.

> Use reinforcement made from recycled steel.

> Form up accurately and fine tune estimating to minimise waste. Up to ten per cent is often wasted.

> Return surplus to the plant for recycling.

> Buy from plants that wash out cement to allow recycling of sand and aggregate.



> Break remnants into small pieces before final set to allow later use as backfill or recycling.

> Always form up a small area of path or low grade slab ready to accept remnants.

Carpentry and joinery

> Use engineered timber products that make efficient use of materials where possible.

> Use sustainably sourced timber.

> Encourage your supplier to find sustainable sources.

> Prepare accurate cutting lists before ordering.

> Give joiners a copy of the cutting list.

> Ensure that carpenters have a complete cutting list to allow efficient timber use.

> Use joinery profiles that can be easily and invisibly joined to reduce off-cuts.

> Use off-cuts wherever possible.

Measure it twice – cut it once.



Bricklaying

> Have bricks dropped around perimeter to save damage in transporting to place of use.

> Use mortar to produce masonry of appropriate strength and durability as required by AS3700. Mortars with lower cement content are usually softer thus helping in recycling as well as saving on cement.



Electrical services

> Use sub-boards and plan wiring to reduce wiring distances, quantities, waste and cost.

> Recycle off-cuts. Strip insulation from copper.

> Consider pulse switching and intelligent controls to reduce cabling and energy use.

> Use cable products that are highly recyclable and contain no or minimal heavy materials.

Plastering

> Buy plasterboard from suppliers who recycle.

> Sort off-cuts and store on site for return to recycler. Keep off-cuts clean and dry.

> Carry useful sized off-cuts to the next job.

Glazing

> Separate construction glass from other glass such as drink bottles.

> Most glass can be melted down and recycled but requires sorting.

> Glass can also be recycled as aggregate.

WASTE MANAGEMENT PLANS

Many local councils require waste management plans prior to granting of development consent.

They usually require the builder or designer to estimate the total waste stream volumes from both demolition and construction and nominate means of disposal including recycling contractor, recycling waste station or landfill site.

The site plan is often required to show waste storage facilities on site during construction and a schedule for delivery or pickup.

Time and cost of waste plan preparation is usually recouped through reductions in waste disposal costs or dividends from sale of salvaged resources. If this is not possible (low tipping fee areas), a fee should be charged for the service to ensure that plans are properly prepared.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on waste minimisation programs.
www.gov.au

BEDP *Environment Design Guide*
GEN 21 Waste Minimisation and Resource Recovery.
GEN 29 Waste Minimisation and Building Design Professionals.
TEC 1 Waste Minimisation – Source Relocation.
PRO 22 Waste Minimisation – Source Relocation.

Building Designers Association of Victoria (1998), *Designing in Waste Minimisation.*

Harkeness T and Prasad D (2001), *Waste Minimisation in Housing: Guidelines for Designers*, UNSW Press, Sydney.

Reddrop A and Ryan C (1997), *Housing Construction Waste*, Department of Industry, Science and Tourism, AGPS, Canberra.

Principal author:
Chris Reardon
Emily Fewster

Contributions by:
Ted Harkeness

The best practice checklist for construction was adapted from: Reddrop and Ryan, 1997.

Biodiversity Off-site

The housing industry in Australia has a substantial impact on biodiversity. This factsheet uses a life cycle approach to help you identify significant off-site impacts, guide your design and material choices, and influence your suppliers to provide biodiversity-friendly products.

Biodiversity is the variety of all life forms – the different plants, animals and micro-organisms, the genes they contain and the ecological systems to which they contribute.

THREATS TO BIODIVERSITY

Clearing native vegetation poses the most serious threat to biodiversity. Once land is cleared it is impossible to restore the full suite of indigenous species, remove pest plants and animals, and repair ecological processes.

Fragmentation of habitat into smaller patches is also a serious problem. Habitat quality is important and its degradation occurs more rapidly in smaller patches. Populations of flora and fauna decline when habitats shrink. When the gene pool shrinks, so does the ability of species to compete, fight disease or adapt to changing conditions.

Find suppliers who can give you information about the biodiversity impacts of the source of their materials.

Habitat degradation can result from many processes including:

> Removal of biomass such as trees, fodder and plants.

> Spread of pest plants and animals.

> Changes to water flow and quality.

> Toxic effects of salinity, pesticides and pollutants.

> Disruptions to ecosystem functions, eg. road/fence barriers to animal movements.

> Changed fire regimes.

> Climate change.



Our demand for the metals, timber, stone, sand, plastics, energy and countless other materials to build, equip and run our homes and cities is high. The combined impacts over a building's life include the clearance and permanent disturbance of ecosystems both near and far. See 'Case Study' next page.

BIODIVERSITY-FRIENDLY BUILDING

> Aim for a net contribution to biodiversity.

> Aim to use 100 per cent recycled materials and recycle those materials at the end of their use.

> Minimise habitat clearing or degrading.

> Minimise greenhouse gas emissions.

> Eliminate the use of toxic substances.

> Minimise the lock-out effect by avoiding the use of areas proposed for habitat restoration in biodiversity plans.

> Maximise land use efficiency by reducing the land required to produce and supply inputs to a building over its life.

> Minimise the use of material, energy and water except where this conflicts with other environmental goals (eg. more insulation is usually better than less).

RULES OF THUMB FOR DESIGN

Unfortunately, most green building and environmental purchasing schemes are unlikely to provide a clear idea of the relative biodiversity impacts of design and product choices. The following rules of thumb for design and material selection should help until more effective decision making aides are available.



Seek to enhance biodiversity through design and material selection. You may also wish to contribute to biodiversity recovery programs and habitat restoration projects elsewhere.

View the entire life cycle of your building development as an opportunity to generate a contribution to biodiversity.

Optimal building design must account for all biodiversity impacts arising from each phase of a building's life, from construction and operation to demolition, disposal or recycling.

Less severe biodiversity impacts can be traded off over a building's entire life. For example, using slightly more material in some stages of a building's construction might be offset by reductions in the operation and demolition, disposal and recycling phases.

Do not trade-off severe impacts likely to be linked with irreversible damage to species and ecological communities in one phase against reduced impacts in another.

Construction phase

Reduce the quantity of materials used where this does not affect the whole-system performance and select for biodiversity friendliness, see 'Rules of thumb for materials selection and guidelines'.

Operation phase

Design to minimise negative and maximise positive impacts of inputs and outputs during the operation of the building where this does not affect the whole-system performance.

You can dramatically reduce impacts on biodiversity by avoiding or reducing:

> Consumption of water from natural systems.

> Use of firewood, the sourcing of which often threatens habitat.

> Use of fossil fuels, which adds to the greenhouse effect and the extraction/processing of which leads to pollution and impacts on ecosystems.

> Disposal of sewage and other waste.

> Use of materials (eg. timber, paints and pesticides) for repairs and maintenance, the extraction/processing of which leads to numerous impacts.

> Use of lights that attract insects, bats and birds.

Demolition/disposal phase

Aim for 100 per cent re-use or reprocessing at the end of a building's life. The building sector is such a large consumer of materials that the industry can not look to any other sector to supply the bulk of its recycled materials.

RULES OF THUMB FOR MATERIAL SELECTION

> Use recycled timber for floorboards, recycled concrete for aggregate in new concrete, and re-used bricks.

Re-used or reprocessed materials are best for biodiversity because their production creates relatively little demand for land or water.

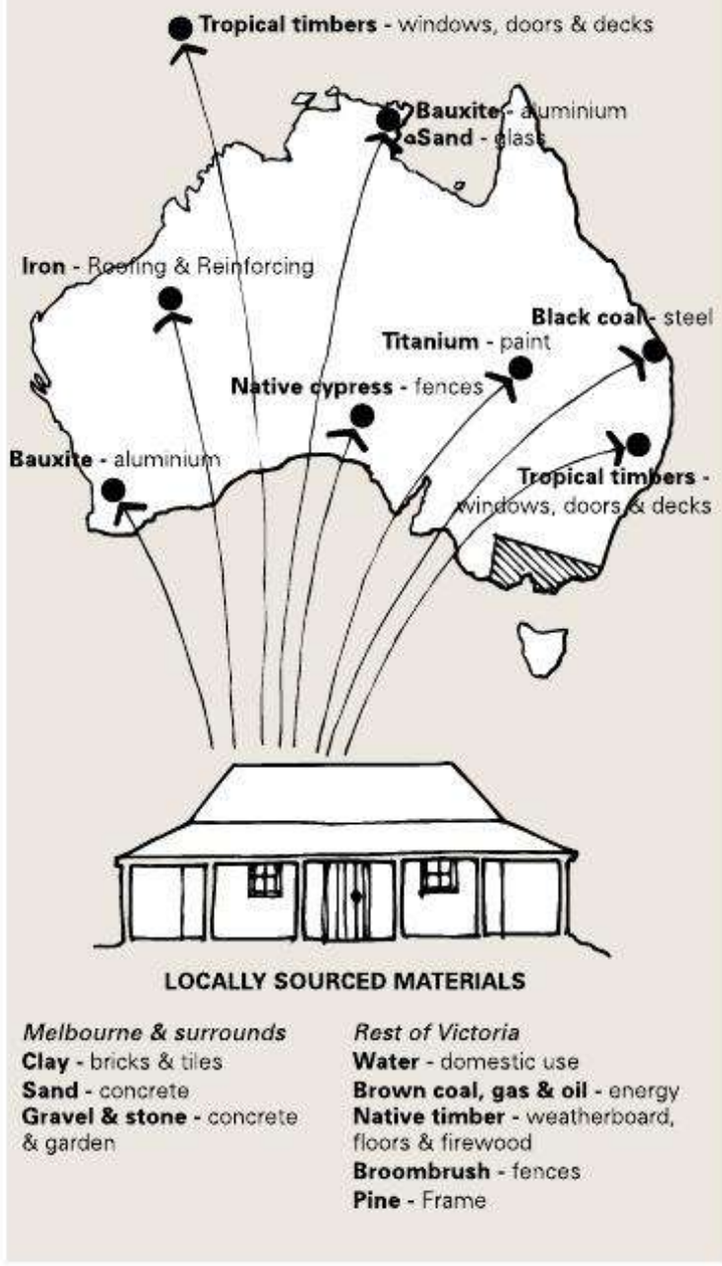
> Use farm or factory-produced resources where the land was cleared long ago and is not needed for habitat rehabilitation (eg. sand from long-cleared land).

> Avoid nature-derived commodities (low-cost high-volume materials) that may lead to clearing or habitat degradation (eg. structural timbers from native forest, sand, gravel and minerals from bushland).

> Do not source materials from threatened ecosystems or natural areas such as rainforests.

CASE STUDY

Your home will affect biodiversity in many places. This example is based in Melbourne but could be anywhere in Australia.



OTHER ACTIONS YOU CAN TAKE

> Seek advice on biodiversity impacts of materials from reliable sources. Organisations with a strong commitment to nature conservation are likely to deal with biodiversity impacts more carefully. Check to see that the criteria used by certification or rating systems explicitly account for biodiversity impacts.

> Find suppliers who can give you information about the biodiversity impacts of the source of their materials. This will encourage the development of material data systems that make it easier to find out about the relative impacts of your options.

> Support initiatives to improve information on building materials' biodiversity impacts and the systems for recording and disseminating that information. For example, subscribe to a green purchasing advisory service or participate in industry programs to improve research, monitoring or reporting of biodiversity impacts.

> Support initiatives to produce and promote biodiversity friendly materials and products.

BUILDING INDUSTRY IMPACTS

Harvesting and extraction

The highest impacts occur where land is cleared for agriculture, quarries, roads, mine sites and factories.

Infrastructure associated with exploration, quarrying and mining activities in natural areas usually involves significant clearing and disturbance to surrounding native vegetation and sometimes waterways. Creation of the roads, camps, dumps and airstrips. that are often involved can cause long term damage. Long-distance transport contributes to the greenhouse effect, which will increasingly cause habitat degradation and biodiversity loss.

Mining and extractive industries

Surface mining and quarrying frequently occur in areas that still support native vegetation, usually because the landform containing the materials has low potential for agricultural development. Extensive mining operations, such as open-cut extraction of coal, bauxite and manganese, and sand mining in coastal heathlands, have caused long-term changes to biodiversity despite attempts at rehabilitation.

The land area occupied by mine sites and petroleum fields is thought to be about the same area as all our cities and towns.

While there is limited information on the extent of mining nationally, the land area occupied by mine sites and petroleum fields is thought to be about the same area as all our cities and towns.

Mining also affects biodiversity when pollutants are released into air or water. For example, when pyrite is brought to the surface during mining it is oxidised to sulfuric acid, which in turn mobilises heavy metals. This acid mine waste can severely pollute rivers and destroy biodiversity.

Processing

The production of some building materials can result in pollution of inland and marine waters. The use of greenhouse-gas-intensive energy sources such as coal also contributes to longer-term pressures on biodiversity.

Landfill

The disposal of building waste can impact on biodiversity in several ways. Using land for dumps increases the pressure to clear habitat. The waste generates greenhouse gases and significant pollution, especially to groundwater. Because the discarded materials are not made available for recycling/re-use, the production of virgin raw materials is much greater than necessary.

GUIDELINES FOR SOURCING MATERIALS

A. BEST OPTIONS

Criteria defining materials for this option:

> The materials are sourced and produced from sustainably managed forests and have negligible impacts on natural hydrological cycles or the atmosphere.

> The level of recycling of the total industry-wide output of the material is very high (eg. over 80 per cent).

> The production process is very efficient in its use of land.

> The materials are durable, non-toxic and recyclable (with low quality loss after being recycled). (1)

> If possible, the production process or the organisations associated with production create a net benefit for biodiversity.

For example:

> Recycled materials produced in ways that have negligible impact on biodiversity.

> Materials from renewable sources that do not involve biodiversity impacts and do not create a major demand for land.

> Habitat restoration or species/ecological community recovery is coupled with the sourcing and/or production of the materials.

Timber – re-used wood, non-toxic reconstituted/ reprocessed timber products (maximum post-consumer waste).

Other biological materials – re-used/recycled materials (maximum post-consumer waste).

Metal, bricks, sand, stone, concrete, etc. – re-used, recycled (maximum post-consumer waste).

Energy – renewable resources (solar, wind, waste-biomass-to-energy) where siting or material sourcing does not involve native species habitats or other significant impacts on native species and does not create a major demand for land.

Water – wastewater; run-off from structures which have a primary purpose unrelated to water capture.

Note: (1) Materials become progressively less desirable as their durability and recyclability falls and their toxicity rises. As their quality falls, they would be located within a progressively lower option class.

B. SECOND-BEST OPTIONS

Criteria defining materials for this option:

> The materials are grown in plantations (2) or on farms using long-cleared land which is not needed for habitat restoration and where the biodiversity-orientated environmental management system is excellent.

> The materials are not commodities and are produced in low volumes from natural systems where the biodiversity-orientated environmental management is excellent. (3)

> Materials have been recycled but the level of recycling of the total industry output of the material is not 'very high'; but the biodiversity-orientated environmental management of the production process is excellent. (3)

Biological materials – produced from farms or plantations (eg. tea-tree/broombrush fencing; native cyprus); non-commodity products in low volume from native habitats.

Metal, bricks, sand, stone, concrete, etc. – recycled materials, or new materials extracted from long-cleared land.

Energy – generated with a very small ecological impact within natural systems; purpose-grown biomass crops on long-cleared land.

Water – sourced from protected bushland catchments with guaranteed generous environmental flows for downstream waterways and wetlands.

Notes: (2) Production from plantations on long-cleared land is in category B rather than category A because of the major demand for land that it creates. Also note that the term 'plantation timber' used by some suppliers does not necessarily indicate a category B source, as 'plantations' are sometimes established on land which has been recently cleared of native forest for the purpose. (3) Claims of excellent biodiversity-orientated environmental management must be verified by an independent, qualified party, especially where materials are sourced from natural systems.

C. SECOND-WORST OPTIONS

Criterion defining materials for this option:

> Commodities (low-cost, high-volume products) from natural systems with good environmental management, involving no glaringly-obvious major impacts and using land which is not of high conservation value and is not needed for habitat restoration.

Biological materials – commodity materials from native habitat; non-commodity materials from areas of native habitat affected by high impact management; high volumes of natural materials where nutrient or micro-habitat removal could cause degradation of the system eg. seagrass harvested from the wild for insulation.

Metal, bricks, sand, stone, concrete, etc. – made from new materials extracted from native habitat where rehabilitation occurs.

Energy – biomass-to-energy using wood from native forest; fossil fuels from long cleared land.

Water – sourced from non-native catchments; only moderate environmental flows for downstream waterways and wetlands guaranteed.

D. WORST OPTIONS

Criterion defining materials for this option:

> Commodities (low-cost high-volume products) from natural systems without any environmental management or with ineffective environmental management.

> Materials sourced from ecological communities that are threatened or from areas of high conservation value for species or ecological communities even where the environmental management is argued to be good.

> Worse still, materials produced in a way that results in the permanent conversion of habitat to land uses with no significant conservation value.

Biological materials – from threatened/high conservation value habitats eg. rainforest; from any area cleared to make farm-style or plantation production possible; from any type of native habitat where environmental management is poor or non-existent.

Metal, bricks, sand, stone, concrete, etc. – made from new materials involving permanent clearing of natural habitat.

Energy – from native habitats with significant habitat disruption/damage; fossil fuels.

Water – from diversions and impoundments that destroy natural habitats; no or low environmental flows guaranteed.



ADDITIONAL READING

Contact your State / Territory government or local council for further information on biodiversity. www.gov.au

Forest Stewardship Council www.fscaustralia.org

Gray A and Hall A (eds) (1999), *Forest Friendly Building Timbers*, Earth Garden Books, Melbourne

Lawson, B (1996) *Building Materials, Energy and the Environment: Towards Ecological Sustainable Development*, RAIA, Canberra

Low, D (eds) (1995), *The Good Wood Guide, Friends of the Earth*, Melbourne

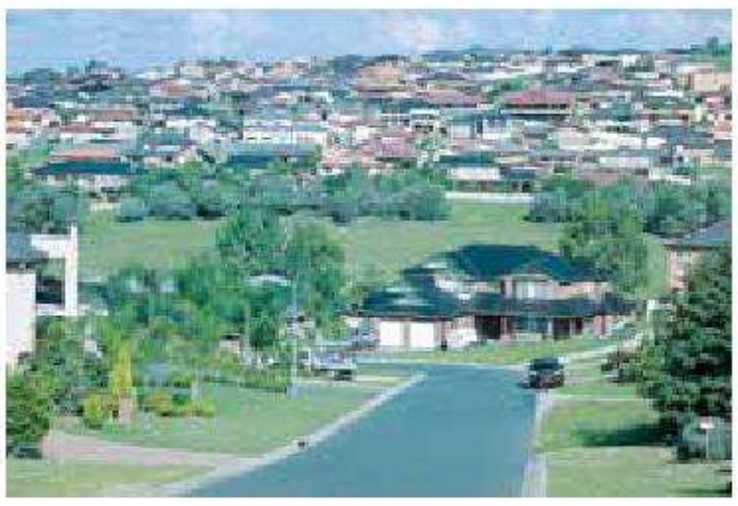
State of the Environment Reporting, Australian Government www.environment.gov.au/soe

Principal author:
Kathy Preece

Construction Systems

The combinations of materials used to build the main elements of our homes: roof, walls and floor are referred to as construction systems. They are many and varied and each has advantages and disadvantages depending on climate, distance from source of supply, budget and desired style and appearance.

This fact sheet analyses the merits of some common construction systems and explains the process of choosing or developing the best combination for your needs in your climate and geographic location.



The majority of new housing stock is built to a common formula that varies only slightly between states and cities. The formula prevails regardless of the enormous range of climates, geographic locations and occupant lifestyles experienced by Australians.

The formula has developed for a variety of reasons including: availability of skills and materials; ease and speed of construction; market perception and familiarity with the final product and individual and community values.

This approach rarely delivers the most appropriate or even the least expensive solutions for Australian housing needs. It contributes to the environmental and economic cost of our homes whilst adding little in the way of improved comfort and lifestyle.

Emphasis is often on 'borrowed style' and greater size – at the expense of comfort, function and performance.

HEAVY AND LIGHTWEIGHT SYSTEMS

A useful point of differentiation between construction systems is their mass content.

Heavyweight construction systems are usually masonry and include brick, concrete, concrete block, tiles, rammed earth and mud brick.

Lightweight construction uses timber or light gauge steel framing as the structural support system for non-structural cladding and linings (eg. fibre cement, plywood and colourbond steel).

Heavyweight and lightweight materials have differing thermal performance and environmental impact depending on:

> Where they are used (internally or externally).

> How they interact with or moderate the climate.

> How far they need to be transported.

> Specific site requirements (eg. slope, thermal performance, noise control and fire resistance)

> Exposure to destructive forces of nature (fire, termites, rain, UV and humidity).

The source of the materials and the way they are processed will determine their environmental impact.

Similar materials can have vastly different environmental impacts depending on where and how they are sourced (eg. A timber frame can be sourced from a sustainably managed forest or an unsustainable managed forest).

[See: 5.4 Biodiversity Off-site]

There is no single best solution. Any combination of materials should be assessed in light of the above factors to arrive at the most appropriate compromise.

See 'Some Composite Systems' for combinations of light and heavy weight systems.

In most situations, a carefully designed combination of lightweight and heavyweight systems will produce the best overall outcome in economic and environmental terms.

Heavyweight construction:

> Generally has higher embodied energy.

> Improves thermal comfort and reduces operational (heating and cooling) energy use, when used in conjunction with passive design and good insulation.

> Is most appropriate in climates with high diurnal (day-night) temperature ranges and significant heating and cooling requirements.

> Requires more substantial footing systems and causes greater site impact and disturbance.

> Should be avoided on remote sites where there is a high transport component (eg. Darwin).

> Is often quarried or processed with high impact.

Lightweight construction:

> Generally has lower embodied energy.

> Can yield lower total life cycle energy use, particularly where the diurnal range is low.

> Responds rapidly to temperature changes and can provide significant benefits in warmer climates by cooling rapidly at night.

> Is preferred on remote sites with high materials transportation component.

> Usually requires more heating and cooling energy in cold to warm climates (where solar access is achievable) when compared to heavyweight construction with similar levels of insulation and passive design.

> Can have low production impact (eg sustainably sourced timber) or high impact (unsustainably sourced timber or metal frame).



High mass lower level (earth bermed pre-cast concrete) and low mass upper levels (insulated timber framed or AAC block) are combined to optimise use of embodied and operational energy.

SELECTING CONSTRUCTION SYSTEMS

Important factors influencing selection of residential construction system/s are:

> Durability compared to intended life span.

> Life cycle cost effectiveness.

> Lifecycle energy consumption.

> Source and environmental impact of all component materials and processes.

> Availability of skills and materials.

> Maintenance requirements.

> Adaptability and/or end use/recycling potential.

> Distances required for transportation of components.

Note to guidelines

The following 'rules of thumb' are a guide only. Every application is unique and should be individually evaluated. Exceptions are the norm – particularly in innovative design solutions.

> Combine high and low mass construction within a building to maximise the benefits of each. See 'Some Composite Systems'.

> Use heavyweight systems internally and lightweight systems externally for lowest lifetime energy use.

> Higher embodied energy content in heavyweight construction can outweigh operational energy savings (particularly in climates where heating and cooling energy requirements are low). [See: 5.2 Embodied Energy]

> Where solar access is unachievable or undesirable (eg. steep south facing or overshadowed sites, tropical locations) insulated lightweight construction is often more efficient as it responds quickly to mechanical heating or cooling.

Maintenance

> Unpainted external brick cladding (brick veneer) has minimal maintenance requirements when compared to many alternative painted claddings.

> Well maintained lightweight systems have durability equivalent to heavyweight systems.

> Poor maintenance can reduce life span by up to 50 per cent, negating embodied energy savings and doubling materials consumption.

> Reliability of maintenance regimes for whole of life span is a critical consideration when selecting external cladding systems.

Source and use of materials

> High renewable or recycled content systems are preferable where their durability and performance is appropriate for lifecycle (eg. fibre cement cladding and sustainably managed forest timber frames).

> Design for de-construction, recycling and re-use to amortise the impact of materials high in embodied energy or non-renewable resources where these materials are the best option.

> Structurally efficient systems minimise overall materials use, transport and processing.

> Specify materials with similar and appropriate life spans (eg. use fixings, flashings or sealants with a similar life span to the material being fixed).

> Use construction systems with known low wastage rates and environmentally sound production processes. [See: 5.3 Waste Minimisation]

Transportation

> Avoid systems with a high on-site labour component in remote projects to reduce travelling.

> Use locally made products where possible to reduce transportation.

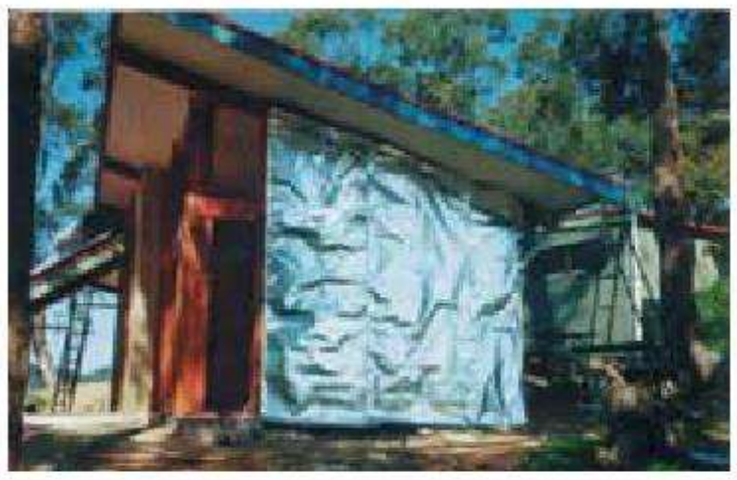
CONSTRUCTION SYSTEMS

The intent of this fact sheet and the details on specific construction systems that are in the following fact sheets, is to enable *Your Home* users to gain a wider, informed perspective of materials use in modern construction. There are many kinds of construction systems listed below. A number of them are dealt with in more detail in the separate fact sheets. They describe wall, roof and floor systems that range from the familiar (lightweight timber) to the relatively new and unfamiliar (green roofs and walls).

The more typical systems are included to draw attention to relevant aspects of their potential for use in sustainable construction – eg. the use of bricks in reverse veneer. Other, less familiar materials, such as straw bale, are included to provide an introduction to both the potential and limitations of their use.

Walls

Double brick – Highest embodied energy, a good source of thermal mass, may require insulation requires added insulation. Low maintenance (if unpainted) and durable but poor re-cycling rates. High cost. [See: 5.10 Clay Brick]



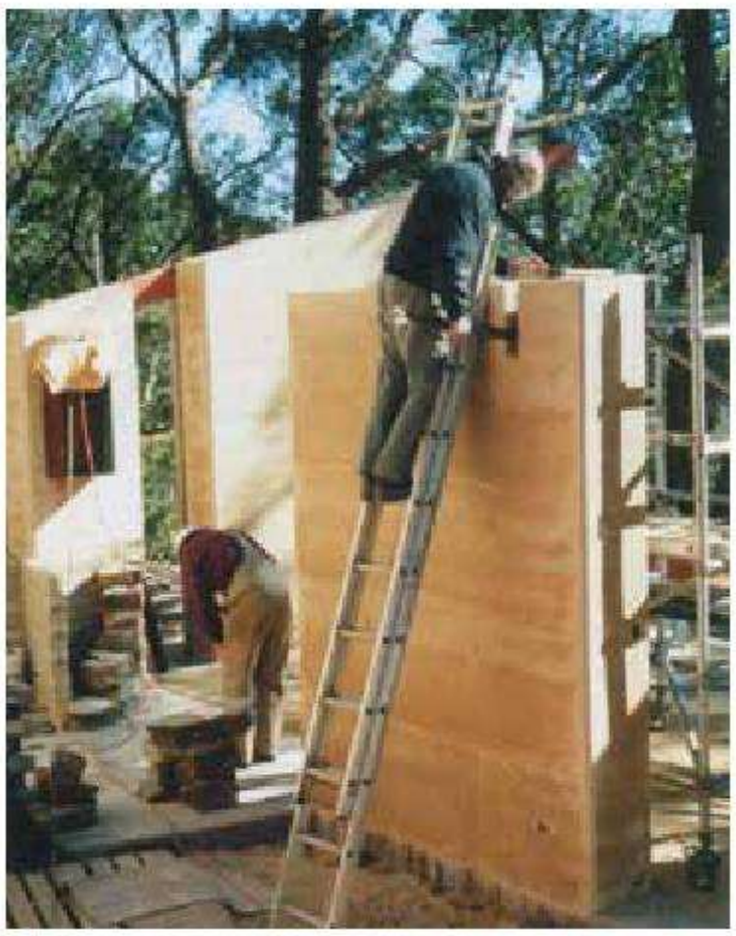
Reverse masonry veneer – High embodied energy with clay bricks, low to medium with concrete block. High thermal mass and high thermal performance with added insulation. Low internal maintenance, external maintenance dependent on finish. Very durable and re-use potential fair. Range of environmentally preferred external cladding includes fibre cement, plywood, sustainably sourced timber or colourbond steel. Cost varies with mass type, which can be any masonry.



Autoclaved aerated concrete block – Average embodied energy, fair thermal mass, fair insulation, average durability (depending on finishes). Maintenance required varies with finish; prone to impact damage; low processing impacts, good transport performance. Medium cost. [See: 5.11 Autoclaved Aerated Concrete (AAC)]

Concrete block – Low embodied energy; good thermal mass; low insulation (which is difficult to add unless lined externally); not easily recycled; low cost. Block walls have lower embodied energy than concrete walls because they are hollow and contain less concrete per square metre.

Insulated concrete (tilt-up or pre-cast) – High embodied energy; high thermal mass; high insulation values; low maintenance internally and externally; extremely durable and can be re-used. Usually, painted finishes give rise to high maintenance component. High cost.



Rammed earth (pisé) – Low-medium embodied energy, depending on cement content. High thermal mass; poor insulation (difficult to add unless lined externally as above); minimal transport energy when used on remote sites, minimal manufacturing process impact, very durable but requires some maintenance (re-application of waterproofing), average to high site impact, depending on footing system. High cost. [See: 5.7 Rammed Earth (Pisé)]

Mud brick (adobe) – Lowest embodied energy, high thermal mass, poor insulation (difficult to add unless lined externally), suited to remote sites; high labour content, no manufacturing impact and low site impact. [See: 5.6 Mud Brick (Adobe)]

Earth bermed – High embodied energy (assuming pre-cast concrete or reinforced block walls are used as the structural support). Highest thermal mass with additional thermal coupling benefits; high site impact during construction; insulation not required in locations where earth temperatures are favorable; extremely durable; significant operational energy savings. High cost.





Straw bale – Low embodied energy (some additional embodied energy and materials in extra width footings and slabs); low-medium thermal mass (depending on render thickness). Extremely high insulation; excellent thermal performance, and high level renewable material content. Long term durability is unproven in Australia and maintenance levels are variable. Bales should be compressed well to minimise settlement and movement. Cost varies from average to high. [See: 5.8 Straw Bale]

Lightweight timber: Low to medium embodied energy. Medium to high insulation values. High maintenance unless protected from weather. Suited to off-site and on-site fabrication. Relatively low transport costs. [See: 5.10 Lightweight Timber]

Panel systems – Sandwich panels have varying embodied energy depending on surface materials and insulation. Those in the photograph above are fibre cement outer linings with expanded polystyrene studs and concrete core fill. The concrete fill adds thermal mass and an outer layer of insulation yields excellent all round thermal performance.

Other lightweight panel systems such as straw board and recycled paper products have low thermal mass, high insulation levels and very low embodied energy. They respond rapidly to heating and cooling and are ideally used with a concrete slab floor. The recycled content of many commonly available products is high. Re-use potential is good and transport costs are low. Construction cost varies from high to average.

Green roofs and walls – Medium to high embodied energy, depending on support structures. Medium to high thermal mass (most growing mediums are lightweight, manufactured material). Insulation medium to very high. Best considered as components in a larger construction system. Medium to low maintenance for intensive roofs to high maintenance for most green wall systems. [See: 5.15 Green Roofs and Walls]

Roofing and Flooring

Tiles – Embodied energy is low for concrete and medium to high for terracotta. They require more structural support than lightweight material and can have an adverse heating effect (external thermal mass). High transport costs. They are inappropriate for remote sites. Medium cost.

Metal sheeting – High embodied energy; very durable; good to ideal for transport to remote sites; available in light colours to reduce heat gain in summer. Low cost.



Earth covered – High embodied energy; high thermal mass with excellent thermal performance from earth-coupling, no insulation required in many regions (dependent on soil temperature at various depths). Capable of zero heating and cooling energy; maintenance free; very durable when waterproofed correctly; high site disturbance during construction, minimal on completion. High cost.

Concrete slab floors – High embodied energy and other attributes as per concrete slab. High thermal mass can be very effective if used correctly in combination with insulation and good passive design. Good fire rating. Low maintenance. Medium to high cost. [See: 5.13 Concrete Slab Floors]

SOME COMPOSITE SYSTEMS

Construction systems such as AAC, straw bale and brick can be 'mixed and matched' according to weight, mass and insulation to produce certain results. Three composite examples are provided below.

1. Lightweight walls with heavyweight floor

Insulated lightweight wall construction on an exposed concrete slab (not covered with insulating materials like carpets) is an efficient and economic combination on level sites in most climates. It is also the most commonly used in most states.

Concrete slabs provide thermal mass to even out diurnal temperature ranges, reducing heating and cooling energy and increasing comfort.

Embodied energy of normal reinforced concrete is high but can be reduced by using recycled steel and aggregate. Cement from an efficient kiln and use of cement extenders can further reduce embodied energy.

Insulated lightweight walls reduce heat loss and have minimal embodied energy content, depending on the cladding material used.

Cladding – Fibre cement sheet, plywood and other sheet cladding systems have low embodied energy and generally low environmental impact. They are very durable – although maintenance is required for any painted surface. [See: 5.2 Embodied Energy]



Brick veneer – is an inefficient, high embodied energy cladding system. The brick has no structural role. The above photograph shows a lightweight timber framed home structurally complete and ready for brick cladding. If this home was clad with lightweight energy materials, its embodied energy would be lowered along with its cost. [See: 4.9 Thermal Mass]

Slab integrated footings – require excavation on all but level sites, increasing impact. They can reduce construction costs where slope is low.

Detached strip footings – with load bearing brickwork to slab level can reduce excavation but increase embodied energy content.

2. Lightweight floor with heavyweight walls

A lightweight insulated floor can reduce site impact and construction costs on sloping sites. Reverse brick/concrete block veneer clad with insulated lightweight cladding (fibre cement or plywood) or internal masonry walls, provide thermal mass for effective passive design.

Embodied energy in the masonry will be offset by operational energy savings during the life span of the building in most climates, providing good insulation levels are included.

Timber framed flooring – has low embodied energy, low thermal mass but requires additional insulation in most climates. It is suitable for flat or sloping sites and durability is good when termite protection and sub-floor ventilation are correctly installed. Sustainably sourced timbers should be specified or biodiversity impact will be high. These floors can be a source of air infiltration if not well sealed. Low cost.

Steel framed flooring – as for timber framed but with slight increase in embodied energy. Durability is high. They can have greater durability advantages in termite prone areas and often have lower transport costs than equivalent timber structures. Usually more expensive than timber.

Lightweight suspended concrete floor systems are now available that are competitive in cost with timber and steel framed floors.

Strip footings and piers add embodied energy and create site disturbance. They are not easily relocated or re-used. Cost is low.

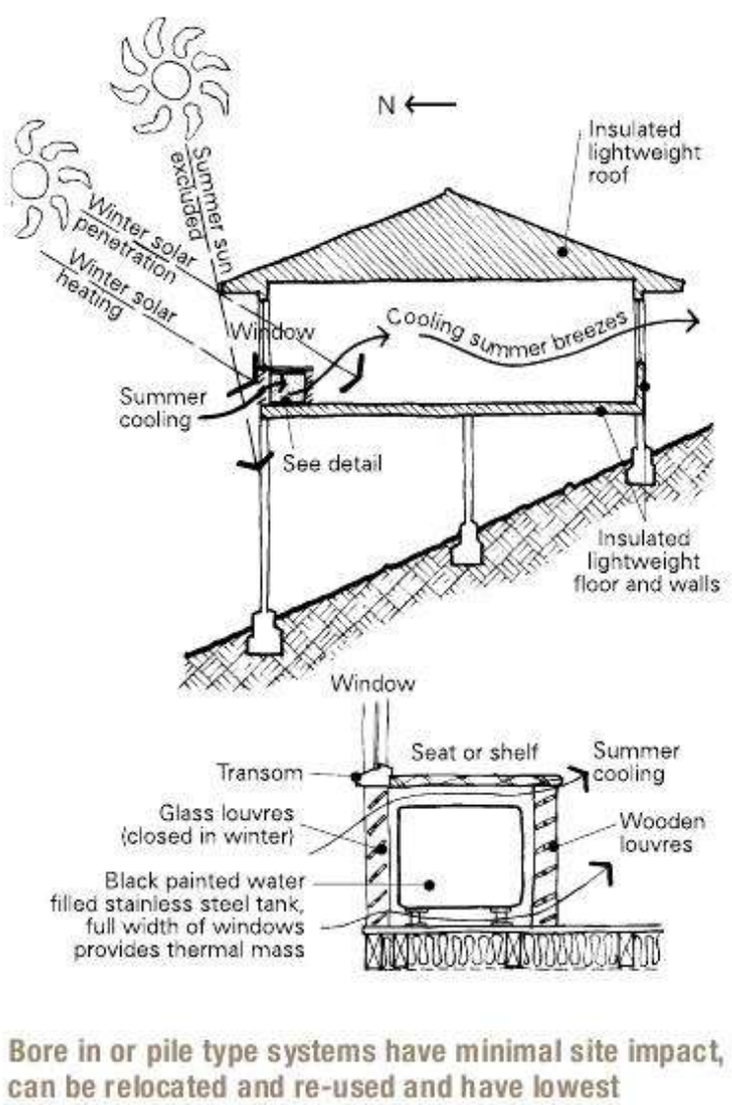
Engineered steel pile systems capable of supporting masonry walls are now available. They reduce excavation and site impact and speed construction. Cost varies with application but is generally more expensive than strip footings.

3. Lightweight walls and floor with water mass

Where slope and/or foundation materials prohibit the use of masonry construction for thermal mass, water filled containers behind passive shaded, north facing windows provide effective mass.

Water has twice the volumetric heat capacity of concrete. A stainless steel tank 600 x 600 x 3,000mm has thermal mass equivalent to a 20m^2 concrete slab and can form a convenient window seat.

The system below is a cost effective solution for achieving high thermal mass passive design with the high insulation levels and low embodied energy of lightweight construction for difficult sites.



Bore in or pile type systems have minimal site impact, can be relocated and re-used and have lowest embodied energy. Cost: medium to high.

Pole frame construction integrates footing and framing, giving benefits on steep sites with high wind exposure. Embodied energy is low for timber and medium for concrete or steel poles. Durability and efficient use of structure are important to maximise efficiency and reduce cost. Cost: medium to high.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on building sustainability and energy efficiency. www.gov.au

BDEP *Environment Design Guide*, RAIA. www.environmentdesignguide.net.au

Lawson, B (1996), *Building Materials and the Environment: Towards Ecological Sustainable Development*, RAIA, Canberra.

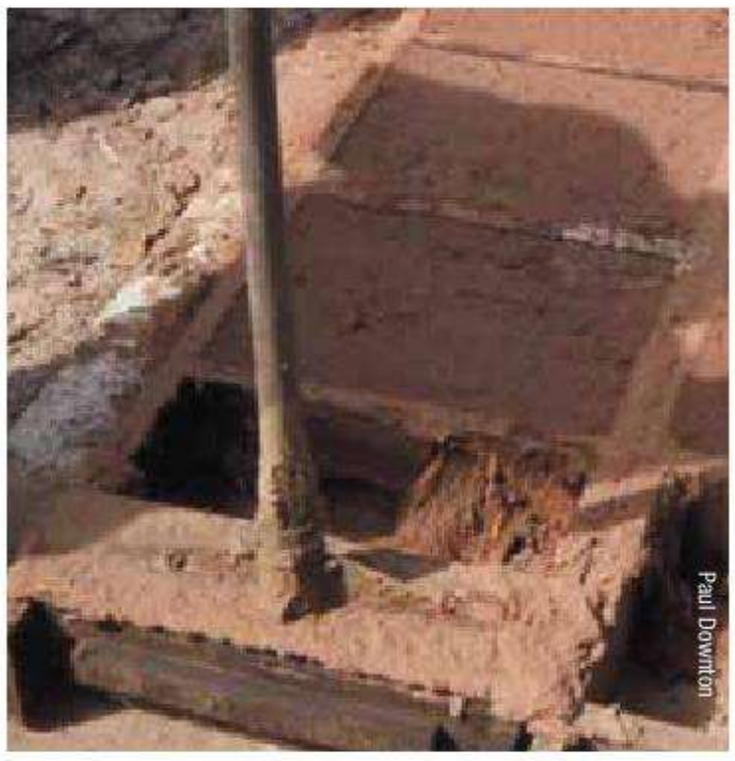
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Mud Brick (Adobe)

The ideal building material would be 'borrowed' from the environment and replaced after use. There would be little or no processing of the raw material and all the energy inputs would be directly, or indirectly, from the sun. This ideal material would also be cheap. Mud bricks can come close to this ideal.

Basic mud bricks are made by mixing earth with water, placing the mixture into moulds and drying the bricks in the open air. Straw or other fibres that are strong in tension are often added to the bricks to help reduce cracking. Mud bricks are joined with a mud mortar and can be used to build walls, vaults and domes.



At its simplest, mud brick making involves placing mud in moulds which, after initial drying, are removed to allow the bricks to dry slowly (not in direct sun). Moulds can be made from timber or metal – anything that can be shaped to provide the desired size for the bricks.

Virtually all the energy input for mud brick construction is human labour (indirectly, fueled by the sun) and after a lifetime of use, the bricks break back down into the earth they came from. The most effective use of mud bricks in building healthy, environmentally responsible housing, comes from understanding their merits and accepting their limitations. Mud brick construction is often referred to as 'adobe' which is an Arabic and Berber word brought by Spaniards to the Americas, where it was adopted into English.

The use of earth construction is well-established in energy efficient housing. There are many aspects to earth construction and despite the fact that most of the world's buildings are made of earth and it is one of the oldest known building materials, there is much about its properties and potential that remains undeveloped and poorly researched.

PERFORMANCE SUMMARY

Appearance

The appearance of mud bricks reflects the material they are made from. They are thus earthy, with colour determined by colour of clays and sands in the mix. Finished walls can express the brick patterns very strongly at one extreme or be made into a smoothly continuous surface.



Structural capability

With thick enough walls, mud brick can create load bearing structures up to several stories high. Vaults and domes enable adobe to be used for many situations other than vertical walls. The mud brick may be used as infill in a timber frame building or for load-bearing walls, although its compressive strength is relatively low. Typically, Australian adobe structures are single or double storey. In the Yemen there are buildings 8 stories high and more that have stood for centuries! [See: 5.5 Construction Systems]



Thermal mass

Adobe walls can provide moderate to high thermal mass, but for most Australian climatic conditions, as a rule of thumb, walls should be a minimum of 300mm thick to provide effective thermal mass. [See: 4.9 Thermal Mass]

Insulation

Contrary to popular belief mud bricks are not good insulators. Since they are extremely dense they lack the ability to trap air within their structure, the attribute of bulk insulation that allows it to resist the transfer of heat. Insulation can be added to adobe walls with linings but is not intrinsic to the material, and, depending on the building design may not be needed in some climate zones. [See: 4.7 Insulation]

Sound insulation

A well-built adobe wall has very good sound insulation properties. In fact, it can be almost equivalent to a monolithic masonry structure in its capacity for sound attenuation. [See: 2.7 Noise Control]

Fire and vermin resistance

Since earth does not burn, and earth walls do not readily provide habitat for vermin, mud brick walls generally have excellent fire and vermin resistance.

Durability and moisture resistance

Adobe walls are capable of providing structural support for centuries but they need protection from extreme weather (eg. with deep eaves) or continuous maintenance (the ancient structures of the Yemen have been repaired continuously for the centuries they have been standing). As a general rule, adobe needs protection from driving rain (although some adobe soils are very resistant to weathering) and should not be exposed to continuous high moisture.

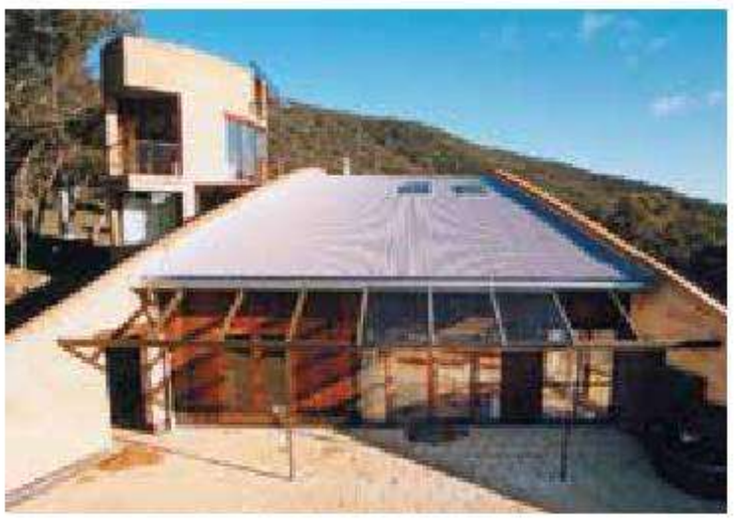
Breathability and toxicity

Mud bricks make 'breathable' walls but some mud brick recipes include bitumen, which potentially results in some outgassing of hydrocarbons. Ideally earth should be used in its natural state or as near it as can be achieved.

Environmental impacts

Mud bricks have the potential to provide the lowest impact of all construction materials. Adobe should not contain any organic matter – the bricks should be made from clays and sands and not include living soil. They require very little generated energy to manufacture, but large amounts of water. The embodied energy content of mud bricks is potentially the lowest of all building materials but additives, excessive transport and other mechanical energy use can increase the 'delivered' embodied energy of all earth construction. [See: 5.2 Embodied Energy]

In a similar way, the greenhouse gas emissions associated with unfired mud bricks can (and should) be very low. To keep emissions to an absolute minimum, the consumption of fossil fuel and other combustion processes have to be avoided. [See: 5.1 Material Use Introduction]



Buildability, availability and cost

Mud bricks provide a forgiving construction medium well suited to owner-builder construction. There are a number of proprietary mud brick makers and builders able to provide good information and a strong owner-builder oriented network. There are good networks in Australia including a broad based national organisation, the Earth Building Association of Australia (EBAA), which is a not for profit organisation "formed to promote the use of Unfired Earth as a building medium throughout Australia."

The materials for making mud bricks are readily available in most areas and may be sourced directly from the site of the building in some cases.

Low costs in construction can only be effectively achieved by self-build, reducing the labour costs associated with manufacture and/or laying of bricks. Commercially produced mud brick construction can be as expensive, or even more expensive, than brick veneer.

TYPICAL DOMESTIC CONSTRUCTION

Construction process

Mud brick wall construction has generally been the province of owner-builders, but a large proportion of mudbrick buildings are now constructed by or with the help of commercial builders. The potential for sourcing the main wall construction material from one's own site, making the bricks, and building the walls, can be very appealing as both an economic and lifestyle choice. As a result, the first stage of construction may involve excavating the mud from the site.



The clay content of adobe can range between 30 and 70 per cent and the overall earth content may also include silt, gravel and stones. There are a number of tests for suitability of the earth and the approval process may require an erosion test. Before excavating for on-site mud, consider the site layout to minimise carrying and transport and ensure there is space to keep any topsoil separate for use on the garden.

Owner builders should recognise that mud brick making is a labour intensive activity. A house may require around 10,000 bricks, but a working couple would be lucky to average a production rate of 200 a week. Mud brick moulds can be made from wood or metal. Bricks must dry evenly to avoid cracking and they should be covered to avoid direct sunlight and overly quick drying out. There are a number of mud brick manufacturers that cater to the market for people who do not have the time or resources to make their own.

A typical standard mud brick is between 300-375mm long, 250-300mm wide and 125mm high and can weigh up to 18kg – as much as a straw bale! Smaller brick sizes are recommended for owner building. Mud bricks can be made in a range of sizes and moulds and can be made in special shapes for fitting around structural elements and accommodating pipes and wires. Stabilised mud bricks may contain materials such as straw, cement or bitumen. [See: 5.8 Straw Bale]

Although adobe can be load bearing, there is also widespread use of frames. The advantages of this are that a roof structure can be erected to provide weather protection for both mud brick making and construction. Disadvantages include the need to connect with and build around frame structures.

After the footings have been placed and the bricks are ready for laying, the building process is similar to that of any other masonry construction.

All structural design should be prepared by a competent person and may require preparation or checking by a qualified engineer. Qualified professionals, architects and designers provide years of experience and access to intellectual property that has the potential to save house builders time and money as well as help ensure environmental performance. All masonry construction has to comply with the Building Code and Australian Standards. For example, all masonry walls are required to have movement/expansion joints at specified intervals.

Footings

It is possible to make footings from rubble, but unconventional construction may make it harder to obtain building approvals and the usual method is to employ strip or raft concrete footings. A raft concrete slab can provide a clean, flat surface for making mud bricks. A damp proof course must be laid between the footings and brick wall to prevent rising damp. A 'splash course' of fired bricks is advisable to prevent erosion of the lower course of mud bricks resulting from heavy rain.

Frames

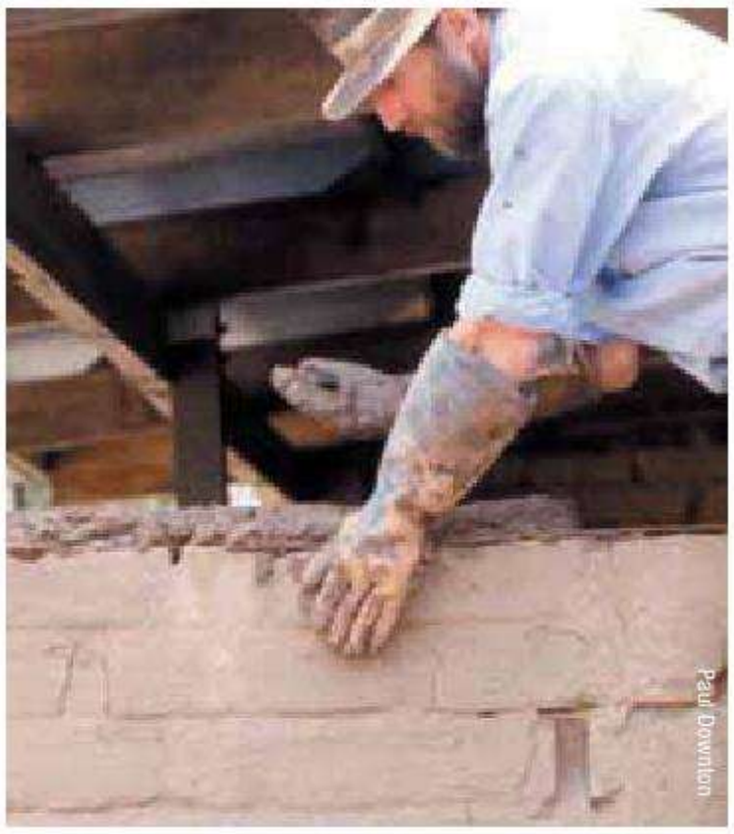
Mud bricks can be load bearing but it is also usual Australian practice to build mud brick walls between timber or steel frames.

Load bearing walls

Load bearing mud brick wall construction requires particular attention to good bonding (avoiding continuous vertical joints) and ensuring stability by having returns on the walls that buttress them against sideways forces. Again, normal, traditional masonry practice applies to the pattern in which bricks should be laid. It is possible to create arches, squinches and domes in mud brick and although these have featured in adobe structure since time immemorial, they are rare in modern building structures of this type.

Joints and connections

Mud bricks are laid on thick mortar beds that are essentially the same mix as the brick, but in its 'muddy' state. It is also common practice in the commercial mudbrick industry to use a sand-cement mortar. Once dried, it can be difficult to distinguish between mortar bed and brick and some adobe aesthetics exploit this 'seamless' appearance to create a monolithic effect. The roof timbers or steel members can spring from the columns (particularly in the case of steel) or bear on wallplates. It is generally recommended that roofs have considerable overhang in order to provide some protection to walls from driving rain. In more sheltered areas this requirement is less vital, but care must be taken to provide a good quality render and waterproofing finish, see 'Finishes'.



Walls are laid in the traditional manner of masonry with string lines to provide a guide to vertical and horizontal alignments.

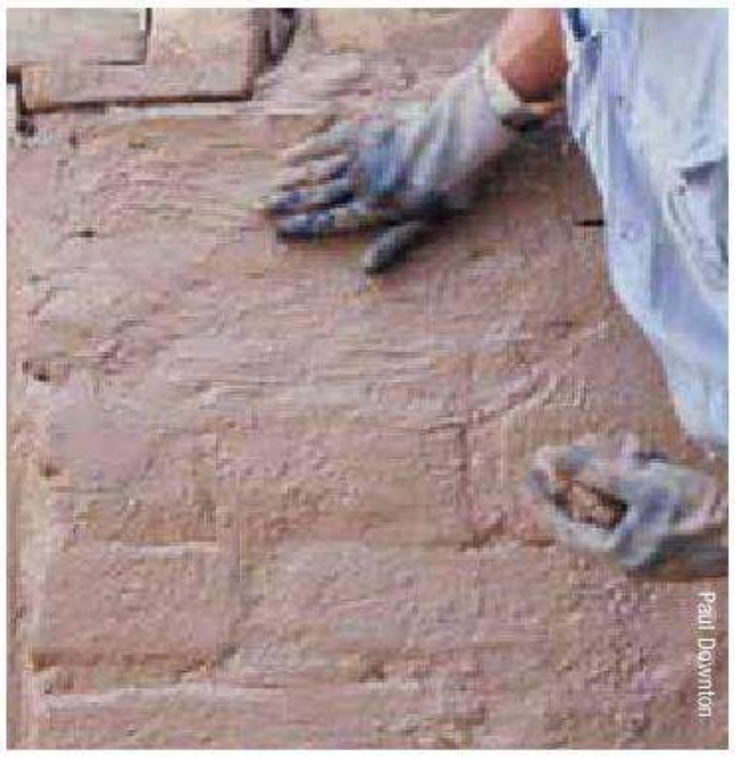
The mud Mortar bed are normally quite thick and needs to provide complete bedding for the bricks. Perpends are similarly thick (about 20 – 30mm). The intention is to produce a wall that is effectively monolithic, ie. as if it were a single piece of material.

Fixings

Fixings to mud brick need to allow for the relatively poor 'pull-out' strength of the material. Strong fixings can be achieved by embedding dowels or plugs into a wall – the depth and type of which should be determined by reference to a skilled builder or engineer if the load carrying capacity of the fixing is critical.

Openings

Lintels can be in any structurally appropriate material, although timber is typically used. Beams and lintels can be formed from quite 'rough and ready' timber and readily blended into the mud brick construction. Mud bricks can be also be laid to form arches, particularly over small spans (less than a metre), and even domes, although this requires high levels of bricklaying skills as well as more stringent demands from engineering and approvals processes.



After brushing to get a fairly even surface, the final finish is a mud slurry, typically finished by hand. This slurry may also be the final waterproofing coat (eg. A mud and cow dung mix) or it may have a further clear coat of proprietary waterproofing material. Linseed oil and turpentine can be used to provide a final finish.

Finishes

Linseed oil and turpentine can be used to provide a final finish. This is also a very effective method of protecting walls susceptible to erosion. There is even the option of using the natural plastic of cellulose, processed by bovine beasts, to create mud and manure slurry, although this is seldom used in Australia. Finishes can range from rustic to smooth with this typical flexibility of approach being one of the material's many appealing qualities.

ADDITIONAL READING

BDEP *Environment Design Guide*, RAIA. www.environmentdesignguide.net.au

Biano A (2002), *The Mud Brick Adventure*, Earth Garden Books, Trentham, Victoria.

CSIRO (1995), *CSIRO Australia Bulletin 5: Earth Wall Construction*, CSIRO, North Ryde, NSW.

Earth Building Association of Australia www.ebaa.asn.au

Lawson, B (1996), *Building Materials and the Environment: Towards Ecological Sustainable Development*, RAIA, Canberra.

Simmons G and Gray T (eds) (1996), *The Earth Builders Handbook*, Earth Garden Books, Trentham Victoria.

Principal Author:
Paul Downton

Rammed Earth (pisé)

Rammed earth walls are constructed by ramming a mixture of selected aggregates, including gravel, sand, silt and a small amount of clay, into place between flat panels called formwork.

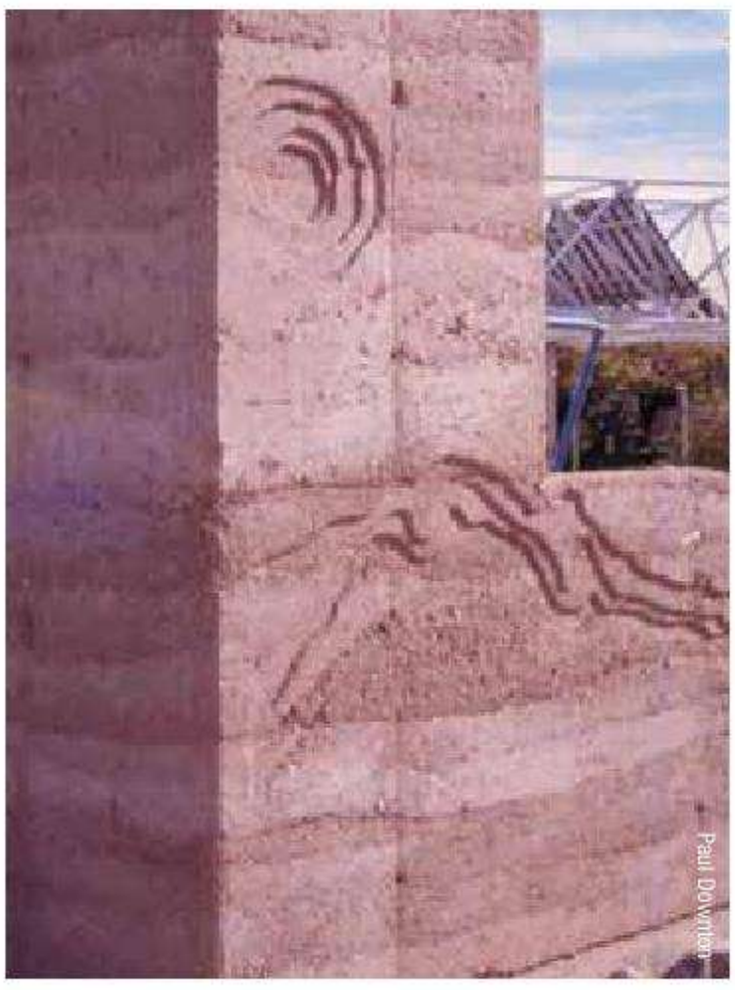
Traditional technology involved repeatedly ramming the end of a wooden pole into the earth mixture to compress it. Modern technology replaces the pole with a mechanical ram. Stabilised rammed earth is a variant of traditional rammed earth that adds a small amount of cement (typically between 5 and 10 per cent) to add strength and durability. Stabilised rammed earth walls need little added protection but are usually coated with a permeable sealer to increase the life of the material – this varies with circumstance and there are thousands of unstabilised rammed earth buildings around the world that have given good service over many centuries. Most of the energy used in the construction of rammed earth is in quarrying the raw material and transporting it to the site. Use of on-site materials can lessen energy consumed in construction. Rammed earth provides some insulation and excellent thermal mass.

The term pisé is of Latin origin from *pisé de terre*. First used in Lyons, France in 1562, the term applied to the principle of constructing walls at least 50cm thick by ramming earth between two parallel frames that are then removed, revealing a completed section of hard earth wall. While 50cm thick walls can still be constructed if desired, with or without cement, most modern rammed earth walls in Australia are built using cement at 30cm thick for external walls and 30cm or 20cm for internal walls.

PERFORMANCE SUMMARY

Appearance

The colour of rammed earth walls is determined by the earth and aggregate used. The ramming process proceeds layer by layer and this can introduce horizontal stratification to the appearance of the walls. The stratification due to ramming can enhance the overall appearance and can be controlled as a feature or eliminated. Aggregates can be exposed and special effects can be created by the addition of different coloured material in some layers and elements such as feature stones, alcoves or relief mouldings can be incorporated into rammed earth walls, at a price. Brushed finishes help reduce formwork marks that can create a concrete-like appearance, but this is only necessary with fine grain size ingredients.



Sample wall at the Environmental Research Laboratories in Tucson, Arizona.

Unusual finishes can be achieved by including shapes in the formwork that can be released after the wall has been rammed. Other possibilities include embedding rocks and other objects in walls for aesthetic effect.



Layers of ramming are visible as are the chamfered corners that are required to allow the walls to be easily released from the formwork.

It is possible to form vertical curves, made by carefully ramming along a drawn guideline on the interior of the formwork. Horizontal curves are also possible but require specialised, and therefore expensive, formwork.

Structural capability

Rammed earth is very strong in compression and can be used for multi-storey load-bearing construction. Research in New Zealand indicates that monolithic earth walls perform better under earthquake conditions than walls made of separate bricks or blocks. There is a five storey hotel in Queensland built of stabilised rammed earth. Rammed earth can be engineered to achieve reasonably high strengths and be reinforced in a similar manner to concrete, although horizontal reinforcement is not recommended and excessive vertical reinforcement can cause cracking problems.

[See: 5.5 Construction Systems]

Interesting structural features, including leaning walls, have been constructed in rammed earth. Any difficulties associated with placing and ramming around reinforcement can be eased by careful management of the construction process and need not add significantly to cost.



Perth rammed earth home.

Thermal mass

Thermal mass absorbs or 'slows down' the passage of heat through a material and then releases that heat when the surrounding ambient temperature goes down. Rammed earth behaves as a heavyweight masonry with a high thermal mass. [See: 4.9 Thermal Mass]

Insulation

Insulation is about stopping heat passing through a material rather than slowly absorbing or releasing it. As a corollary to its high thermal mass, rammed earth has only reasonable thermal insulating qualities. Insulation can be added to rammed earth walls with linings but is not intrinsic to the material and, on its own, it is unlikely to meet building code requirements for wall insulation. However, under certain design criteria (ie. simple rectangle with north facing glass) and in moderate (not temperate) climates it is still possible to meet the NatHERS overall five star performance standard. [See: 4.7 Insulation]

Insulation can also be added within the thickness of a rammed earth wall but this adds to its cost and changes the structural properties of the wall. However it gives the benefit of both excellent thermal mass and good thermal insulation in the one wall whilst retaining the desirable look, texture, feel, acoustics and low maintenance properties of the facing of rammed earth on each side.

Sound insulation

One of the best ways to insulate against sound is have monolithic mass – rammed earth provides this very well. It has excellent sound reverberation characteristics and does not generate the harsh echoes characteristic of many conventional wall materials. [See: 2.7 Noise Control]

Fire and vermin resistance

There are no flammable components in a rammed earth wall and its fire resistance is thus very good. In tests by the CSIRO a 150mm thick Cinva-rammed earth block wall (similar to rammed earth) achieved a near four hour fire resistance rating. There is no cavity to harbour vermin and nothing in the material to attract or support them so, its resistance to vermin attack is very high.

Durability and moisture resistance

The basic technology has been around for thousands of years and there are many rammed earth buildings still standing that are centuries old. Rammed earth possesses a generally high durability but all types of rammed earth walls are porous by nature and need protection from driving rain and long term exposure to moisture. It is essential to maintain water protection to the tops and bottoms of walls. Continued exposure to moisture may degrade the internal structure of the earth by reversing the cement stabilisation and allowing the clays to expand, however, in general, rammed earth has moderate to good moisture resistance and most modern Australian rammed earth walls do not require additional waterproofing. New water repellent additives that waterproof the walls right through may make rammed earth suitable for very exposed conditions, including retaining walls, but may inhibit the breathability of the material.



Rammed earth lends itself to use with timber and natural materials.

Breathability and toxicity

Provided it is not sealed with material that is impervious, rammed earth maintains its breathability. Finished walls are inert, but care should be taken in choice of waterproofing or anti-dust finishes to avoid adding toxicity to the surfaces.

Environmental impacts

Rammed earth has potentially low manufacturing impacts, depending on cement content and degree of local material sourcing. Most rammed earth in Australia uses quarried aggregates, rather than the 'earth' that it is popularly thought to be made from. On-site materials can often be used but materials should be tested for their suitability.

The embodied energy of rammed earth is low to moderate. Composed of selected aggregates bound with cementitious material, rammed earth can be thought of as a kind of 'weak concrete'. It may help to understand cement and earth products as being at different points on an energy continuum with earth at the low, and high strength concrete at the high end. Its cement and aggregate content can be varied to suit engineering and strength requirements.

Although it is a low greenhouse emission product in principle, transport and cement manufacture can add significantly to the overall emissions associated with typical modern rammed earth construction. The most basic kind of traditional rammed earth has very low greenhouse gas emissions but the more highly engineered and processed variant of rammed earth has the potential for significant emissions.

Buildability, availability and cost

Rammed earth is an *in-situ* construction method. Although its buildability is good, formwork for rammed earth demands good site and logistics planning to ensure that other trades are not adversely effected in the building program. Services should be well planned in advance to minimise difficulties. After walls have been rammed in place, conduits for pipes and wires can be provided much as in other masonry construction, but may impact on surface finishes. [See: 5.1 Material Use Introduction]

Basic materials for rammed earth making are readily available across Australia, but cement and formwork may have to be transported long distances, increasing environmental and economic costs. Testing of local aggregates and potential mixes is advisable if not using a proprietary system.

Proprietary approaches to rammed earth help guarantee consistency and predictable performance but come at a cost. The cost of professional rammed earth building is comparable to other more conventional good quality masonry construction, but it can be more than twice as expensive than a rendered 200mm wide AAC block wall.

[See: 5.12 Autoclaved Aerated Concrete (AAC)]

Rammed earth is particularly well established in Western Australia and most states have experienced builders who understand its potential and limitations. Rammed earth construction is relatively high cost. It typically requires high levels of control over material sourcing and batching and expensive formwork. A key element in controlling costs is to design walls as simple panels and to avoid unnecessary complexity. Traditional rammed earth using human power for ramming and simple wooden formwork can be low cost (and low energy) but this is rarely a realistic option.

There are good networks in Australia including a broad based national organisation, the Earth Building Association of Australia (EBAA), which is a not for profit organisation 'formed to promote the use of Unfired Earth as a building medium throughout Australia.'

TYPICAL DOMESTIC CONSTRUCTION

Construction process

Stabilised rammed earth is made by compacting a gravel, sand, silt, clay mixture and cement between formwork in a series of layers approximately 100mm thick.
The traditional rammed earth was just that, and was often dug from the same site as the building it was destined for, but the materials for modern stabilised rammed earth come primarily from quarries.

The modern process of making stabilised rammed earth is both labour intensive and highly mechanical, requiring the use of powered rams.


Paul Downton

Typical details

All structural design should be prepared by a competent person and may require preparation or checking by a qualified engineer. Qualified professionals, architects and designers provide years of experience and access to intellectual property that has the potential to save house builders time and money as well as help ensure environmental performance. All masonry construction has to comply with the Building Code and Australian Standards. For example all masonry walls are required to have movement/expansion joints at specified intervals.

Footings

Conventional concrete slab or strip footings are generally used, subject to soil conditions.

Frames and bond beams

Complex, more elaborately engineered structures may require reinforcement or frames that work in concert with the load bearing capacity of rammed earth. Simple and commonly built rammed earth buildings do not.

Load Bearing Walls

Rammed earth has fair compressive strength and it is common to make rammed earth a load bearing construction.

Formwork

Plywood or steel sheets are both used in making formwork, which is superficially similar to the formwork used for in-situ concrete, but with its own specific requirements.



Propping and temporary stays are required in the construction process and these may impact on other site work operations if the primary structure is more than just rammed earth. Walls are built in sections and the rise of each level of formwork is often visible in the final finish. Walls are built up in layers of approximately 100mm. As the wall rises it is possible to take out the lower portions of formwork provided the wall has set strong enough.

Joints and connections

Walls are built in panels of approximately 3.5m in length. When a wall consists of more than one panel a recess is built into the end of the first wall. The second wall then moulds into this to lock the walls together for lateral stability.

Fixings

Most conventional masonry fixings work with rammed earth walls and they usually need to be set in at about twice the depth normally used for concrete.

Openings

Openings can be made without lintels with spans of up to 1 metre in stabilised walls (subject to strength and engineering requirements). Specialised formwork can be made to make features like pointed arch or circular windows and the formwork can often be re-used.

Finishes

The off-form finish of stabilised rammed earth generally requires no additional finish. A clear water repellent coating may be needed in some instances and unstabilised rammed earth should be protected by eaves, overhangs or render, as they are more prone to erosion. Walls can be wire brushed shortly after being released from the formwork to eliminate the visual impact of the joins between the formwork and achieve an appearance closer to monolithic sandstone. Selection of the ingredients for rammed earth also affects this.

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Straw Bale

Straw has been used as a building material for centuries, for both thatch roofing and also mixed with earth in cob and wattle and daub walls. Straw bales were first used for building over a century ago by settlers in Nebraska, USA, shortly after the invention of baling machines.

Straw is derived from grasses and is regarded as a renewable building material since its primary energy input is solar and it can be grown and harvested.

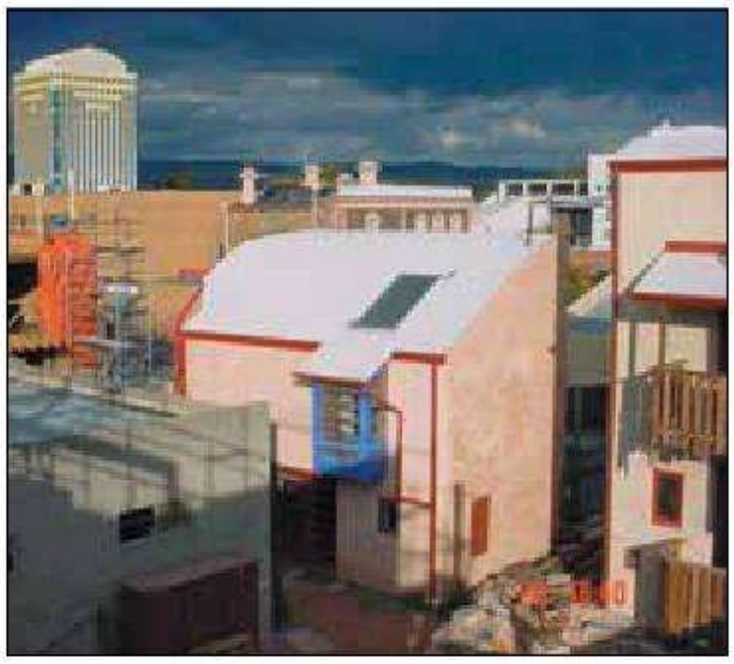
Straw is the springy tubular stalk of grasses like wheat and rice that are high in tensile strength. It is not hay, which is used for feeding livestock and includes the grain head. Straw is composed of cellulose, hemicellulose, lignins, and silica. It breaks down in soil and waste straw can be used as mulch. Different grasses have slightly different qualities, for instance rice straw has a significant amount of silica, which adds density and resistance to decomposition.

Straw bale walls are surprisingly resistant to fire, vermin and decay. Australian straw bales have two strings (American how-to books often show 3-string bales) and are typically 900mm long x 450mm wide and between 350 and 400mm high and weigh 16 to 20 kg.

PERFORMANCE SUMMARY

Appearance

Finished straw bale walls are invariably rendered with cement or earth so that the straw is not visible. The final appearance of rendered straw bale can be very smooth and almost indistinguishable from rendered blockwork, or it can be more expressive and textural. There is a project in London, England, for instance, that made straw bales visible in the completed construction by placing them behind corrugated acrylic cladding.



Straw bales in the city. There is no location that straw bale building cannot adapt to.

Structural capability

The structural capacity of straw bale construction is surprisingly good. In the load-bearing ('Nebraska' style) straw bale method, walls of up to three storeys have been constructed, but straw bale construction commonly uses a frame for the building structure. Most buildings require a frame of timber or steel to comply with current building codes. [See: 5.5 Construction Systems]

There are now several examples of multi-storey buildings in framed straw bale construction, including three houses with two storeys of straw bale wall in the City of Adelaide.

Thermal mass

Straw bales themselves have very low thermal mass, being composed, by volume, mostly of air. However, the cement and earth renders typically used on straw bales results in finished walls having some appreciable thermal mass in the thin masonry 'skins' either side of the insulated straw core. With the use of earthen renders a thick render skin of up to 75mm can be achieved, providing significant thermal mass. [See: 4.9 Thermal Mass]

Insulation

Straw bales demonstrate excellent insulative properties, in fact possibly the most cost effective thermal insulation available. [See: 4.7 Insulation]

Inch for inch, or centimetre for centimetre, straw has a similar insulation value to fibreglass batts. The insulation value of a straw bale wall greatly exceeds that of any conventional construction. All straw bale buildings demonstrate excellent insulation characteristics and the design goal in any structure must be to complement the insulation performance with the performance of the rest of the building. Thus, it is essential to insulate roofs and windows to maintain the overall performance of a straw bale building. [See: 4.10 Glazing]

Sound insulation

Straw bales also provide the most cost-effective sound insulation available. Dollar for dollar, the overall insulation value of a straw bale wall greatly exceeds that of any conventional construction.

The effect of sound insulation contributes to the livability of this kind of construction and can be quite marked. Even walking into the space created by an unfinished straw bale structure, one can appreciate the quietness and hear the difference compared with conventional buildings. [See: 2.7 Noise Control]

Fire resistance

Straw bales are tightly packed and covered with a skin of cement render. Fire can't burn without oxygen, and the dense walls provide a nearly airless environment, so the fire resistance of compacted straw is very good. Conclusive evidence of its good fire resisting performance can be found in laboratory fire tests conducted at the Richmond Field Station in 1997 by students at University of California Berkeley. These rated a straw-bale wall at two hours. Straw bale homes survived Californian bush fires that destroyed conventional structures. [See: 3.5 Bushfires]

A fire that was started in the Whyalla Buddhist's straw bale building did not take hold, as it would have in a conventional structure, and the damage caused was repaired and the cost covered by insurance. Tests undertaken on behalf of AUSBALE and the South Australian fire authority in July 2002 on rendered straw bales (earth, lime and cement) resulted in a two hour fire rating. These tests are likely to be used to establish a formal value of fire resistance for building approval purposes nationwide.

Straw bales can burn but the potential for fire to take hold can be minimized. It is important to try and cap walls by continuing render over the top of the bales and plates so that an inadvertent flue effect does not support combustion by bringing in air to fuel the fire.

Straw bale structures are likely to attract interest. Sometimes that interest is not positive and it is wise to maintain vigilance during construction and to ensure that loose straw and sawdust or other combustibles are not left in or around the structure at any time. Some trades use fire, such as oxy cutters and welders. Special care should be taken to manage activities that are of high fire risk.



A low cost owner built straw bale home in the country.

Vermin resistance

A completed wall has excellent resistance to vermin, but it is important to prevent infestation of mice during construction when the bales are relatively unprotected. In virtually all straw bale construction any exposed straw is coated with plaster or render which is usually adequate to keep animals out, and if they do manage to get inside, densely packed straw makes it hard for them to navigate through the space. During construction, consider using traps and baits to ensure the finished structure is sound and vermin-free.

Durability and moisture resistance

Provided the straw is reasonably well protected and is not allowed to become waterlogged it can last many years with moderate maintenance. Indeed, it is reasonable to expect that straw bale buildings can have a lifetime of 100 years or more.



The most detrimental factor affecting straw bale wall durability is long term or repeated exposure to water. Given enough moisture and two to three weeks, the fungi in bales produce enzymes that break down straw cellulose. But for this to occur the straw moisture content must be high (above 20 per cent by weight). Straw bale walls should not exceed a moisture content of 15 per cent. Reasonable and sensible precautions against water penetration during construction, such as covering otherwise unprotected walls with tarpaulines, make it unlikely that water damage will be a problem in most building programs. The best way to prevent rot in a finished structure is to create a breathable straw bale wall and the success and survival of historic structures in Nebraska and Alabama demonstrate the durability of straw bale structures in climates with variable moisture and temperature.

Toxicity and breathability

The natural materials of straw bale construction are safe and biodegradable, unlike conventional construction, which is replete with artificial materials and toxic fumes. No toxic fumes are released when straw burns and there is no toxic end to the straw bale construction cycle. Straw bale walls have good breathability allowing air to slowly permeate the structure without moisture penetration. Earthen and some earth-lime renders may allow walls to 'breathe' better than cement render, especially compared with renders that have a high cement to sand ratio.

Environmental impacts

Straw is a waste product, it cannot be used for feed, like hay, and much of it is burned at the end of the season. Using straw for building reduces air pollution and stores carbon. The straw left over from building can be used as mulch so that, overall, there is minimal waste from using the material. [See: 5.3 Waste Minimisation]

With grasses able to grow on almost any land, there is a high level of renewable material content in straw bales. They are biodegradable and have a growing cycle of one year. To be truly sustainable in the long term, straw would need to be grown in such a way that it maintained the soil quality and ecological integrity of its provenance. [See: 5.4 Biodiversity Off-site]

The fertilisers and pesticides often used as part of industrial farming practices increase the overall environmental impact of straw, as does the use of twine made from petroleum products.

Straw bales are inherently low in embodied energy but most are produced by fossil-fueled machinery, they are tied together by plastic twine and may end up being transported over hundreds of kilometres. This can add significant amounts of embodied energy to what is a fundamentally low energy material. Straw bale walls are often laid on concrete footings that add further to the intrinsic energy cost of their construction.

Using straw for building stores carbon that would otherwise be released. The greenhouse gas emissions associated with straw bales is very low. One tonne of concrete requires more than 50 times the amount of energy in its manufacture than straw. [See: 5.1 Material Use Introduction]



Buildability, availability and cost

Straw bale construction rates highly for buildability because it can be very straightforward and is well suited to workshop and volunteer based building programs. As a result there have been many volunteer and workshop-based bale-raisings overseas and around Australia. There is a very active and informed international network of straw balers that constantly explores ways to improve and quantify bale building technology. In 2002 a non-profit association Ausbale was formed. Its members can provide excellent access to the best information available in straw bale building techniques and performance.

The general availability of straw bales is good, with many settled parts of Australia being within an hour or so of wheat or rice straw supplies. Straw bale is a low cost material but requires labor-intensive construction techniques. Straw bale construction can be very low cost provided the labour input is also low cost. Projects that can guarantee some volunteer or workshop-based construction can guarantee cost savings. Straw bale cost savings can be used to offset other costs. In South Australia, a large, detached dwelling, with a high standard of fittings and finishes and built entirely via conventional building contractual arrangements, cost the same as if it were in double brick, but had a much better, cost saving thermal performance.



Ladder frame being filled with pea gravel prior to frame and bale placement.

TYPICAL DOMESTIC CONSTRUCTION

Construction process

The various straw bale construction methods are all variations on ways of achieving good compression of the bales to minimise settlement and movement.

Bales should be well compacted and have a moisture content not exceeding 15 per cent and below 10 per cent is preferable. Straw bales should not get wet inside but wetting the sides should not be a problem. Straw does not wick water into itself like concrete. If rain is driven into the sides of bales, the natural movement of air or wind around the bales is able to dry them out and this cycle of wetting and drying does not damage the bale.

Whilst footings are being prepared, work can proceed on other aspects of the building. Construction can be speeded up by making frames and 'bucks' in advance of site works.

The vertical and horizontal stability of straw bale walls generally needs to be guaranteed by tying bales to structural frames or pinning between bales and structural elements, however there is a growing consensus that the extensive use of reinforced steel bars and excessive pinning that characterised early straw bale construction is not necessary and as a result modern straw baling practice is more material and resource efficient.

Bales are laid like giant bricks and, as with bricks, it is preferable to interlock the bales for a stronger and more stable wall, whether or not it is load-bearing.

Typical details

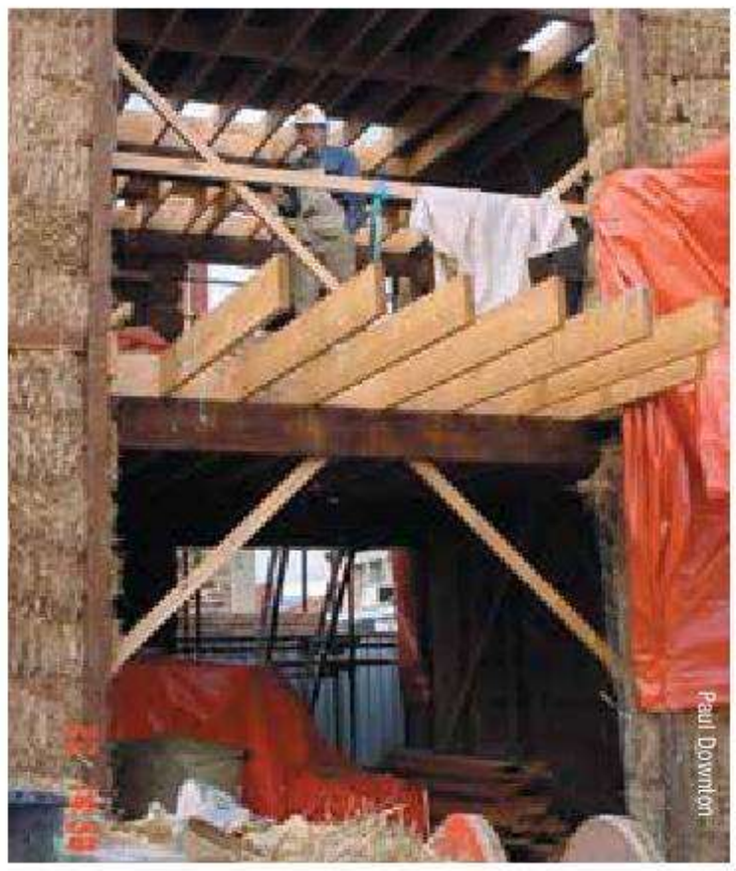
All structural design should be prepared by a competent person and may require preparation or checking by a qualified engineer. Qualified professionals, architects and designers provide years of experience and access to intellectual property that has the potential to save house builders time and money as well as help ensure environmental performance.

Footings

A straw bale wall requires footings with a similar load carrying capacity to that required for a masonry wall, although a straw wall is generally much lighter (one mud brick weighs about the same as a straw bale). The footings used are usually concrete strips or slabs to make compliance with engineering and building codes easier. There have been successful experiments with rubble trench and rubber tyre footings and there are several straw bale buildings in Australia built on piers, bearers and joists. As with mud bricks, the non-load bearing option means a roof structure can be raised in advance of the walls to provide a protected environment for building works. [See: 5.7 Mud Brick]



Ladder frame bottom compression plates being bolted to concrete slab through ant-cap damp course showing recycled irrigation hose for sleeving high tensile wire through pea gravel base.



Framed construction provides more design freedom for wall and opening placement – in the example a large two storey bay structure with a partly cantilevered floor construction can be easily achieved that would not be possible in the same way in a load bearing straw bale structure.

Load bearing walls

The earliest straw bale buildings of over a century ago were load bearing. Australian straw bale experts recommend a maximum wall height of 2.5m when using standard sized bales. Bales for load bearing construction should ideally have tighter strings than normal.

Load-bearing straw bale construction employs relatively simple techniques that are forgiving to novice builders and yet have sufficient flexibility to allow the creation of design features such as curved walls. Its limitations are that openings for windows and doors should not exceed 50 per cent of any given wall surface area and the maximum unbraced wall length is about 6m.

Bales should be laid like bricks in a 'running bond'. Corners should allow for at least a full bale return in each direction to assist in providing strength and stability. After the walls are laid they have to be pre-compressed before taking any structural loads. There are a variety of methods for achieving this but the most popular and practical method is grippling.

Grippling involves running 2.5mm high tensile fencing wire vertically around the bale walls every 450mm. The wires are run through a bottom 'plate' (generally a ladder –frame timber structure secured to the footings) and over a top plate (which may be similar or as simple as a plank of wood). The gripples are proprietary soft metal clamps that hold the wires in tension. They were invented for fencing use and are readily available with the associated specialist tools through fencing suppliers.

Early experiments in bale building involved excessive vertical reinforcement to tie bales to footings and to each other. Good results with better economy in materials can be achieved without reinforced steel bars and the vertical spiking of bales is largely unnecessary when the wire and grippling method is used.

Like giant bricks, straw bales need to be cut to fit into wall lengths, the fewer cuts the better. Walls should be designed in straw bale length modules and heights should be calculated from working out straw bale dimensions and allowing for compression of 50-75mm per single storey height of bales.

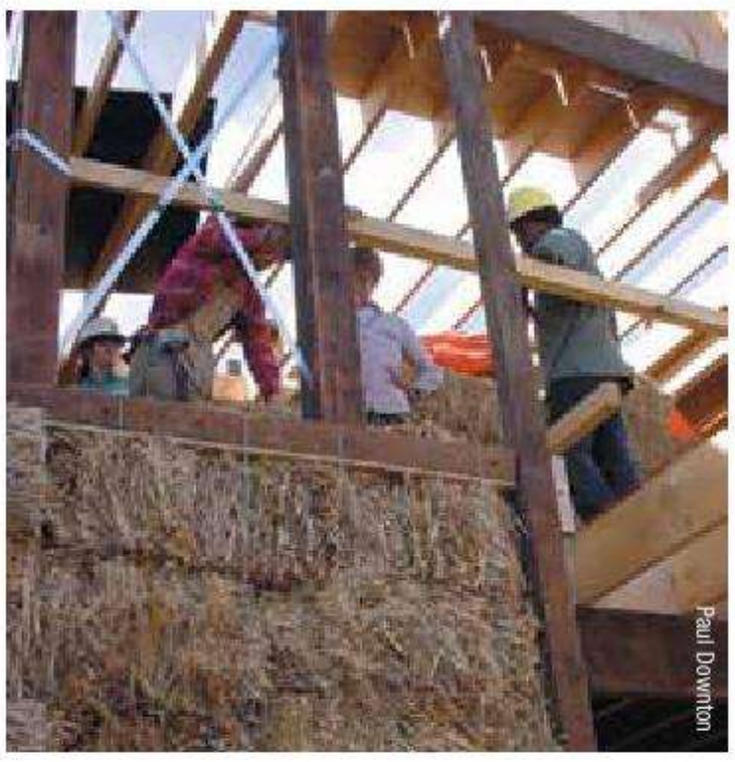
Slicing a bale requires that it is first 'sewn' at the desired finished length, then the original twine is cut. The idea is to produce two short bales with the same compression as the original, held by new sets of twine. The cutting and trimming of bales can be done with hand tools, but the most popular and effective method is to use a chain saw with a blade length of at least 400mm.



Framework and posts can be constructed off-site and the frame can allow a roof to be constructed in advance of the wall raising, providing shelter during the wall construction process.



Bales are trimmed for openings and can be cut to fit structural members.



The middle plate and vertical compression wires can be seen in this detail of a timber framed three storey straw bale townhouse.

Frames

Although it is possible to build strong and effective single storey straw bale structures, it is often easier to ensure Code compliance and predictable engineering outcomes if the straw bale walls are constructed as in-fill elements between load bearing frames. Non-load bearing straw bale walls are very similar to load bearing but are generally more complex and have to be connected to the frames within which they sit. The frames allow more freedom in the design and placement of openings and a running bond is not as essential as it is with load bearing walls. Pre-compression is still necessary to avoid future problems with settling of the bales over time.

Joints and connections

Straw bale walls can be joined to almost any construction provided attention is paid to flashing details. When one material joins another there must always be care taken to ensure that there is no passage for moisture penetration and that any differential movement is accommodated. A competent architect or designer can assist greatly in this regard.

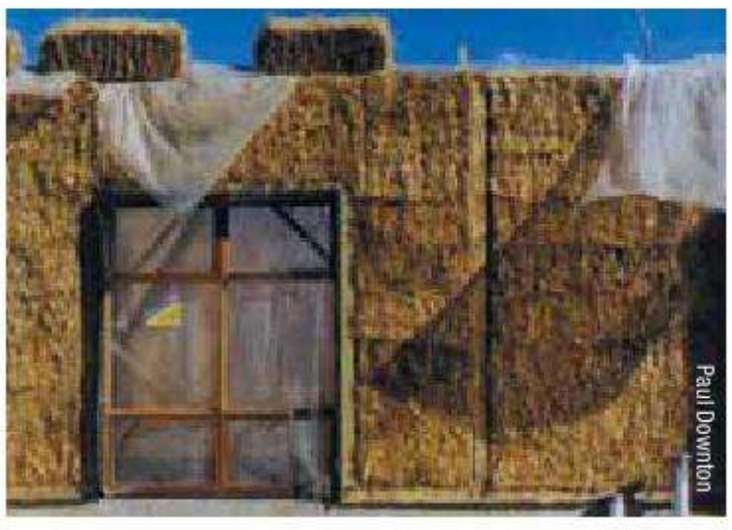
The roof timbers or steel members can spring from the columns (particularly in the case of steel) or bear on wallplates. It is recommended that roofs have considerable overhang in order to provide some protection to walls from driving rain. In more sheltered areas this requirement is less vital, but care must be taken to provide a good quality render and waterproofing finish.

Fixings

It is possible to fix substantial loads to load bearing and non-load bearing straw bale walls by forming clamps made from planks of timber on either side of the bales, tied through the wall with high tensile wire and tensioned by grippling or twisting. Other methods for fixing such things as shelves and kitchen cupboards simply use elements connected to the load bearing frame. With cement rendered interior skins that are a nominal minimum of 30mm thick, it is possible to hang pictures and other items off plugged holes in the thin masonry skin.

Openings

Windows, doors and other openings in straw bale walls generally have to be placed within a frame designed to withstand compression loads, unless the window or door frames are themselves strong enough to do the job. These frames are sometimes called 'bucks'. With bucks to resist distortion, almost any kind of window or door can be set into a straw wall, 'floating' in the bales or tied to frames. Until the walls have undergone final compression, bucks, window and door frames must have adequate temporary cross-bracing.



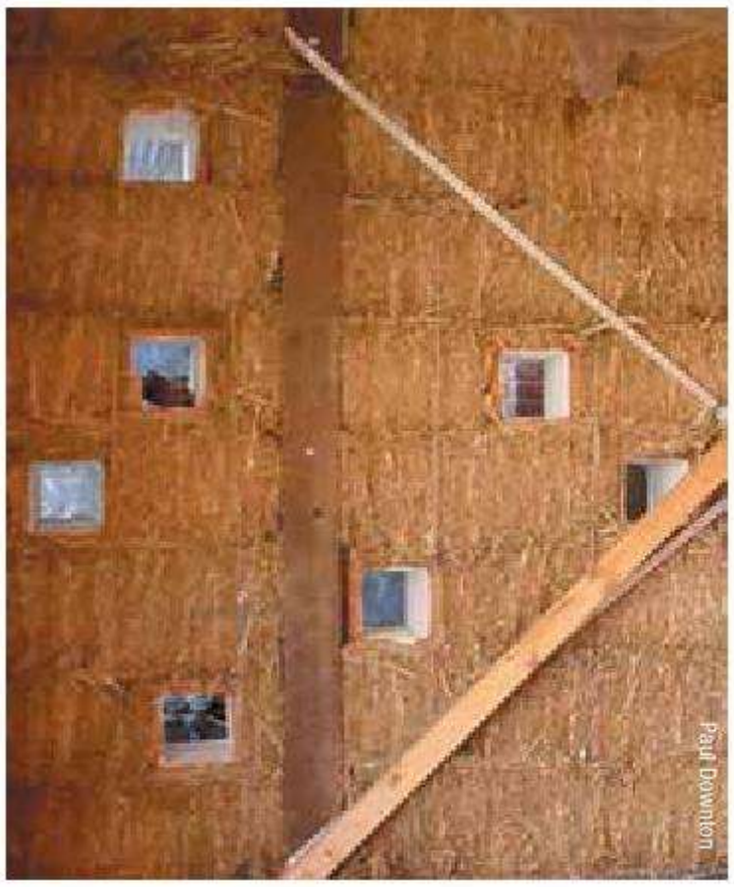
Window set towards outside face of wall.

It is best to set any frames with their faces flush to the outside face of a wall to improve weather protection. This also makes a deeper 'reveal' to the interior, opening up possibilities for deep interior sills, window seats and angled or sculpted surrounds to the openings that can do much to improve overall daylighting qualities.

[See: 6.3 Lighting]

It is very important to weather proof all window openings that are exposed to direct rainfall. This can be done using standard flashing materials and methods.

Niches can be cut into straw bale walls in almost any position or formation provided care is taken not to cut into the twine that binds the bales together.





The final render finish can be applied directly to the face of a straw bale wall, particularly with earth renders. Before any render is applied the final compression of the walls must be achieved. The usual method is to fix chicken wire to the wall surfaces to be rendered by sewing lighter gauge wire (1.5mm) through the walls at approximate 450mm centres and by pinning with staples made from medium gauge wire (2mm).



Finishes

There are three main kinds of render used in Australian straw bale construction: cement and sand, lime putty and sand; and earthen render (sometimes incorporating lime). Final finishes on cement renders can range from clear, acrylic based water repellents to traditional coloured lime wash. Cement renders can be finished with a lime putty render topcoat. The three layers of render should be progressively weaker to reduce the potential for cracking caused by having too brittle an external layer. Earth renders are gaining popularity as concerns about their effectiveness have been addressed. The main advantages of using earthen renders are to do with minimising environmental impact and time spent in preparation and application. Advice should be sought from experienced straw bale builders wherever possible.

Things to watch out for

It is important to keep bales dry during storage and construction and to try and eliminate vermin. It is not unusual to find mice in straw bale deliveries. Straw bales attract mice and the shorter the on-site storage period the better.

During construction, tarpaulins or plastic sheets should be kept ready for covering otherwise unprotected walls. Although it may not be ideal, if bales do get slightly wet they can often be dried out sufficiently to be usable. The moisture content must be below 15 per cent in the finished structure. Renders should be carried over any exposed straw areas to keep out water and vermin and be carried over the tops of walls so that the potential for drawing air through the wall in the event of fire (allowing it to smoulder) is minimised.



Straw bale walls are very resilient and in the event of damage they can be repaired. Wet bales can be taken out and replaced and there is at least one recorded instance in Australia of a straw bale building that suffered fire damage after construction being successfully repaired under insurance.

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The Australian Straw Bale Building Association www.ausbale.org

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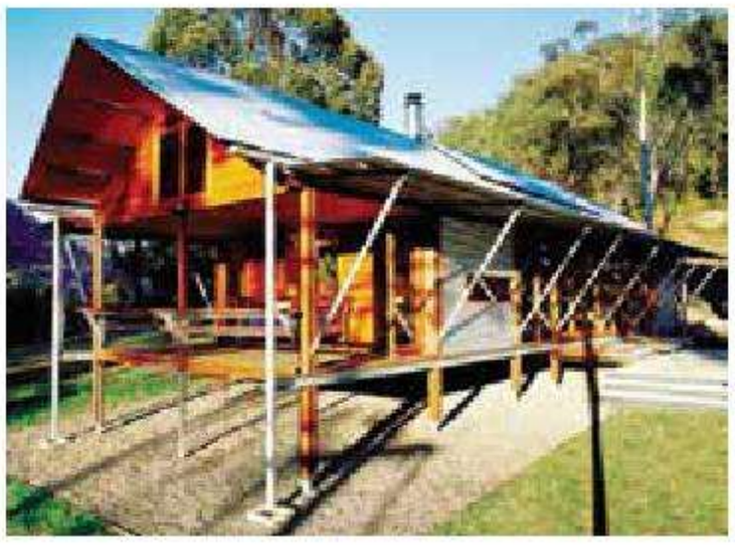
Lightweight Timber

Wooden structures have been used in all kinds of building types for many years. Lightweight timber construction has a long history in Australia where it is the most common house construction type. When it comes from genuinely sustainable sources, timber has the potential to provide a renewable building material that stores carbon in its production.

One of the key advantages of timber is that it provides an adaptive material for use in all climatic zones. This fact sheet deals with lightweight timber constructions that are climatically appropriate for Australia.

The lightweight timber house can provide cost effective and flexible design options. Just as the high mass construction materials are most effectively employed when used as part of appropriate design strategies, so there are many situations where a lightweight building may result in a low lifecycle energy use (eg. hot, humid climates, sloping or shaded sites). [See: 4.2 Design for Climate; 4.9 Thermal Mass; 4.7 Insulation]

Timber frames can support internal and external walls, floors and roofs. A variety of non-structural claddings, linings and finishes can be used such as weatherboards, timber fibre products, or non timber products such as brick veneer, fibre cement sheet or metal.



Lightweight timber houses are well suited to stilt construction and similar design approaches intended to minimise site disruption. Framed structures lend themselves to making houses with diverse openings that provide light and natural ventilation by careful window, door and ventilator placement. Timber provides an adaptive material for use in all climatic zones.

PERFORMANCE SUMMARY

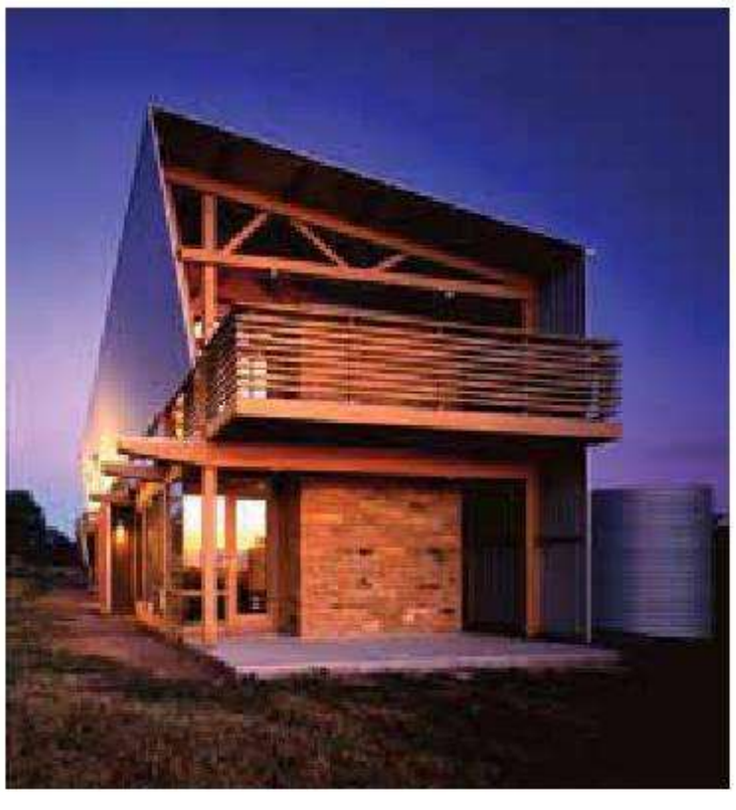
Appearance

Like most natural materials that have not undergone a lot of industrial processing timber possesses an attractiveness that people readily relate to. Its range of colour, grain and texture make it a material with qualities that people generally find visually pleasing and enjoyable to touch.

Timber houses can range in appearance from the ultra modern to the traditional weatherboard house. Depending on the cladding used, the appearance may express the timber construction or disguise it (most timber framed houses in Australia are finished in brick veneer).

Timber construction allows for a range of design solutions to achieve environmentally friendly housing in all climatic zones. Timber framed houses can be found in very cold climates such as Scandinavia and Canada through to the very hot tropical climates of South East Asia, and their appearance will vary according to the climate.

Timber construction allows for a range of design solutions to achieve environmentally friendly housing in all climate zones.

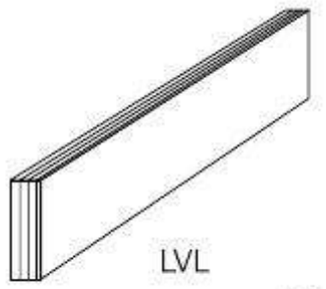


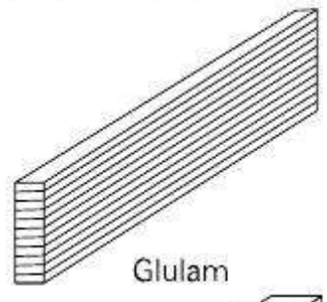
Structural capability

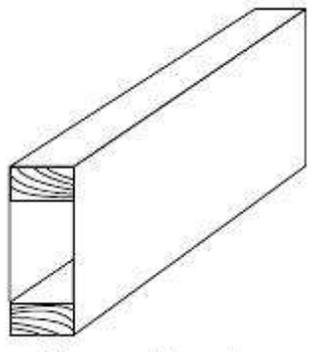
Timber has good compressive strength but is strongest in tension. Structural design techniques exploit this characteristic that can be clearly seen in the design of roof trusses.

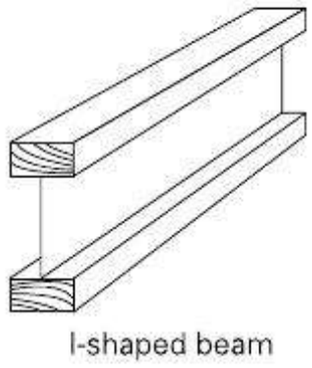
As well as solid timber there are many products that are composites or made of components that can be used in lightweight construction. These include plywood, particle board, fibreboard and engineered products such as glue laminated timber (Glulam) and Laminated Veneer Lumber (LVL). Particularly when used internally, care should be taken to ensure that composite timber products do not contain adhesives that compromise indoor air quality.

There is a timber product to meet most structural requirements, and engineered timber products can be manufactured to meet specified structural requirements.









Thermal mass

In general timber has low thermal mass. There are hardwoods that have similar densities to concrete but these are not common building materials. Thermal mass can be built into lightweight timber constructions if a particular design requires it using elements such as:

> Concrete slabs.

> Masonry features.

> Water tanks integrated into walls or floors.

Insulation

Timber is a natural insulator due to air pockets within its cellular structure. Most timbers are extremely low thermal conductors relative to other building materials. The conductivity of aluminium is typically about 1700 times as great, steel 400, concrete 10, brick and glass 6 times; but bulk insulation materials, such as mineral wool, may have as little as a third of the conductivity of wood.

As most timber buildings in Australia are stick built stud construction, the spaces between noggings and joists can accept bulk insulation readily. Lightweight timber constructions can be designed to incorporate as much or as little insulation as the construction requires. Reflective materials can also be readily incorporated into lightweight timber constructions.

The low thermal conductivity of timber minimises the occurrence of thermal bridging that can reduce the overall R-value of a structure. [See: 4.8 Insulation Installation]

Sound insulation

The sound insulation of walls is usually obtained by providing a barrier of sufficient mass to absorb the sound energy. In lightweight timber constructions the wall cavities provide a cushion of air that absorbs some of the sound energy, and as long as here are no rigid bridgings to transmit the energy this can be a reasonably effective barrier. Acoustic barriers can be supplemented by placing insulation materials in the wall cavity and this also helps to reduce the drumming effect of large sheets of lining material.

Fire resistance

Where timber is used extensively in exterior application and around the house, Australian Standard AS 3959 must be consulted to ascertain if any special constructions are required. Each category of fire risk – from low to extreme – has a level of required construction that defines where timber can be used, and what detailing is required. [See: 3.5 Bushfires]

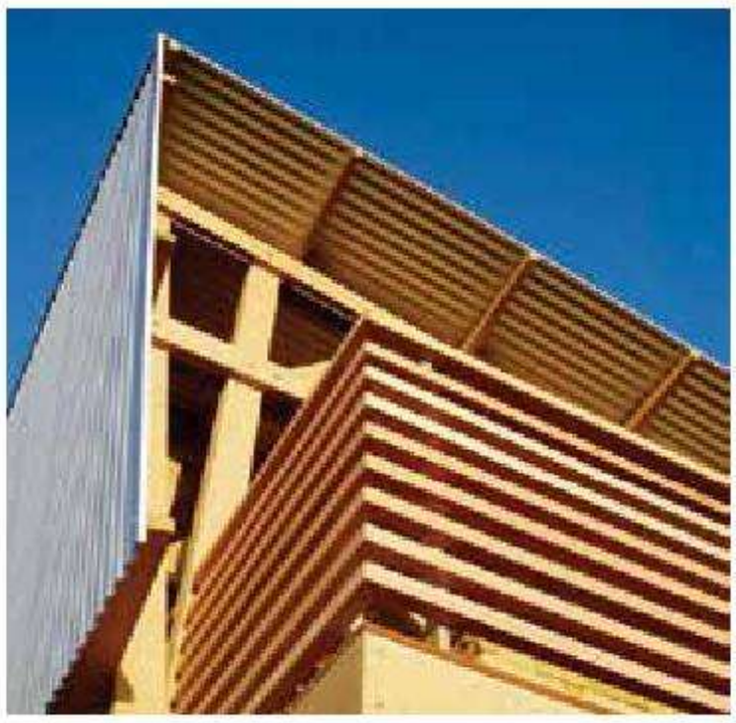
Vermin resistance

Termites are a main concern for lightweight timber constructions. The two main methods of dealing with the threat of termites are chemical and physical. Current building regulations emphasise managing termites through physical barrier systems and inspections rather than the environmentally harmful methods of the past.

Physical barriers prevent hidden entry. They are inspection systems rather than prevention systems. Termites attack from underground and the best risk management strategy is to design the house for easy inspection, ie. leave an accessible space to inspect for termite activity.

Lightweight timber constructions, especially those with elevated floors or pole framing, lend themselves to easy inspection for termite activity.

Other vermin such as mice can be controlled by ensuring that all cavities are sealed.



Durability and moisture resistance

Timber is an organic material and deteriorates due to weathering. The main way of preventing weathering is protection of the timber surface. This may be achieved by appropriate design detailing, so that the timber remains dry or sheds water quickly. It may be achieved by treatment with an appropriate surface coating of oil, varnish or paint. Such coatings on external timber components of buildings generally need replacing every 5-7 years.

Weathering can be reduced by the selection of durable timber species in the first instance. Over a forty year life a fully maintained timber clad building will require less embodied energy than common alternatives, see table below.

A lightweight timber construction can have a very long life, making the dwelling more valuable both from an economic and environmental perspective. This can be achieved using appropriate design, building practices and detailing.

Toxicity and breathability

Timber is generally non-toxic. Provided it is not sealed with material that is impervious to air it maintains its breathability. The durability of the timbers used in the lightweight construction can be improved by treatments. Very low VOC treatments are readily available nowadays and most are water rather than solvent based.

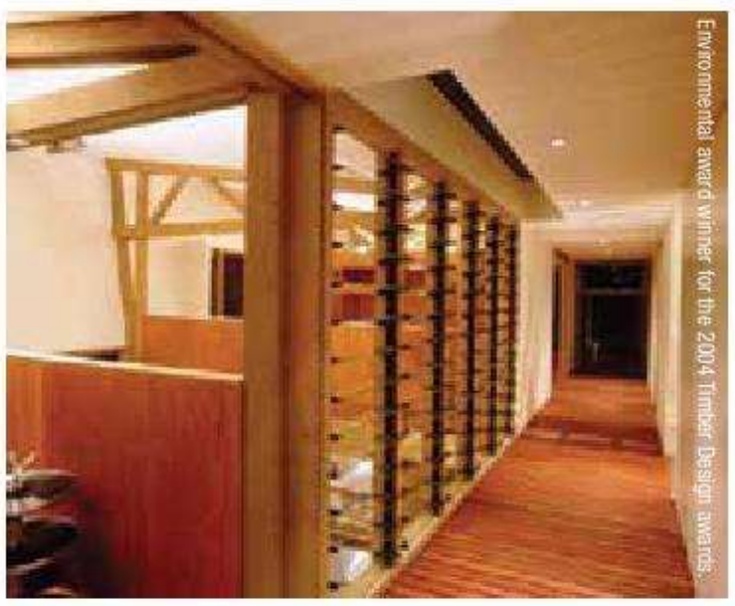
	EMBODIED ENERGY PER UNIT AREA OF ASSEMBLY MJ/M²	INITIAL EMBODIED ENERGY OF WALLS OF BUILDING MJ	EMBODIED ENERGY IN EXPANDED MAINTENANCE OVER 40 YEAR LIFE MJ	TOTAL EMBODIED ENERGY MJ
Timber frame, timber clad, painted	188	31,020	24,750	55,770
Timber frame, brick veneer, unpainted	561	92,565		92,565
Double brick, unpainted	860	141,900		141,900
AAC painted	464	76,560	24,750	101,310
Steel frame, fibre cement clad, painted	460	75,900	24,750	100,650

[See: 5.2 Embodied Energy]

Environmental impacts

Timber is a renewable building resource that absorbs carbon it its production. A lightweight timber construction can be built for deconstruction or easy dismantling, and timbers from the construction re-used or recycled at the end of its use in the building.
[See: 5.3 Waste Minimisation]

Timber is completely biodegradable and can even be composted if no re-use application can be found. Timber building products offer an opportunity to sequester carbon in the built environment, complementing efforts to mitigate global warming with carbon abatement schemes using timber plantations (typically, pine) to absorb carbon from the atmosphere.
[See: 1.4 Carbon Neutral]


Environmental award winner for the 2004 Timber Design awards.

Although it is a low greenhouse emission product in principle, transport and manufacturing processes can add significantly to the overall emissions associated with typical modern timber construction. Fundamentally, timber construction has very low greenhouse gas emissions but the more highly engineered and processed it is the more there is potential for significant emissions. Nevertheless, lightweight timber construction is often a sustainable option for housing.

Buildability, availability and cost

Lightweight timber construction is relatively simple to build. The typical Australian interpretation of lightweight construction mostly encompasses the use of stud frames. Contractors are familiar with timber in this context and are comfortable using it. They find it easy to handle, easy to nail and easy to adjust. This contributes to affordable labour costs, and means that construction is quicker.

Less typical uses of timber for lightweight construction may carry a cost premium but on the whole timber structures are affordable to build in the short-term and with good design can provide a dwelling with low operational costs in the long run. Plantation pine is currently readily available and care should be taken to ensure that timbers are sourced sustainably.
[See: 5.4 Biodiversity Off-site]

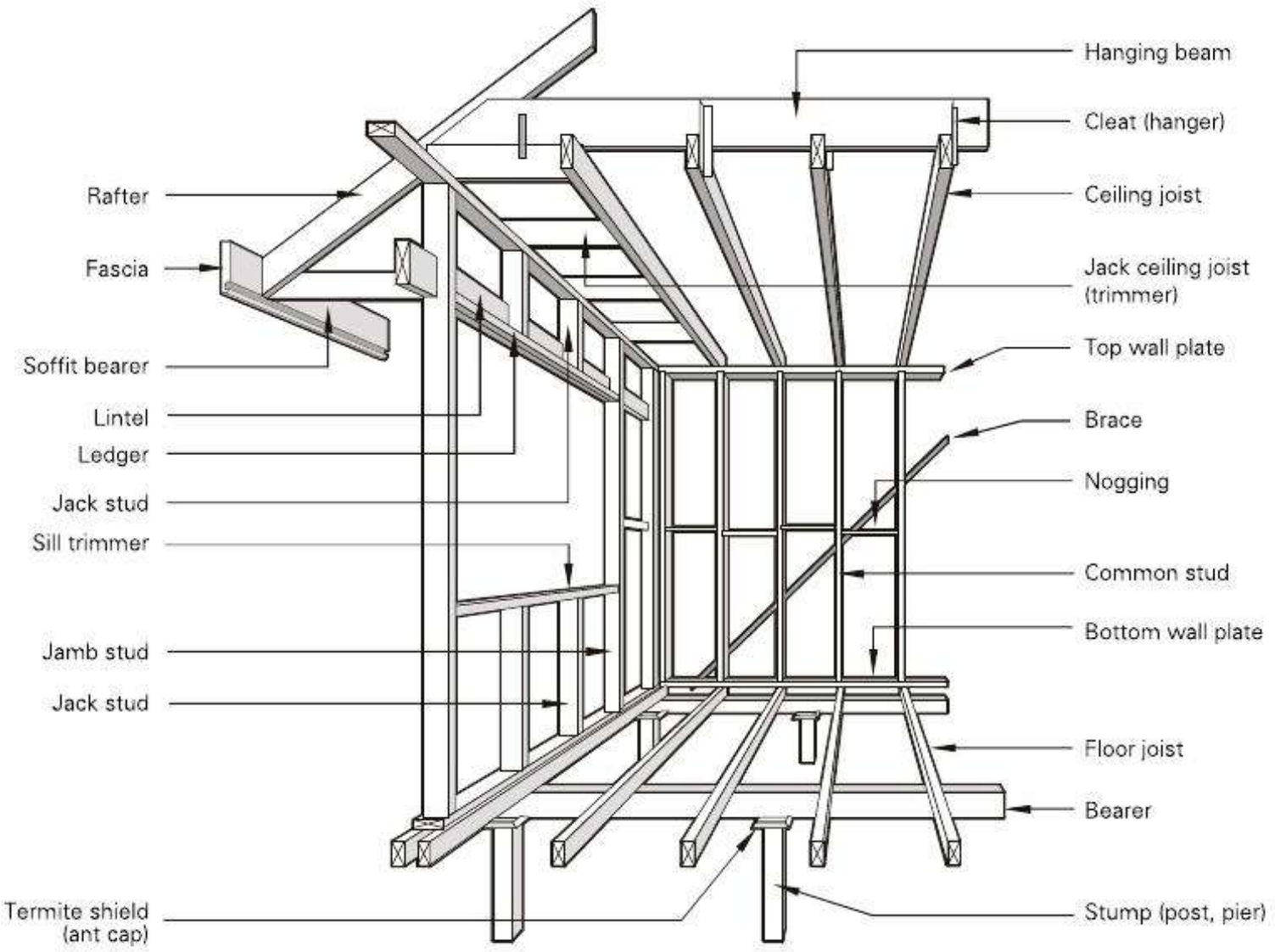
TYPICAL DOMESTIC CONSTRUCTION

Construction process

Typical lightweight timber construction consists of framed and braced structures with applied claddings. The type of framing can range from large, widely spaced timbers to the closely spaced light timbers commonly seen in stud frame construction. The process of construction may begin with a concrete slab onto which continuous frames are fixed, or placement of piers or pad footings to carry posts or bearers.

Some terms that apply to timber framing

Timber components may be fabricated off or on-site. Modern construction techniques in Australia generally favour off-site fabrication of items like trusses with the extent of on-site fabrication of elements like stud frames being dependent on individual designs.



Some terms that apply to timber framing.

Typical details

The timber framing construction is regulated under the BCA and typical details are provided in AS 1684:2006 *Residential Timber Framed Construction*. All structural design should be prepared by a competent person and may require preparation or checking by a qualified engineer. Qualified professionals, architects and designers provide years of experience and access to intellectual property that has the potential to save house builders time and money as well as help ensure environmental performance.

Footings

A sub structure of piers, piles, stumps, posts, dwarf brick walls or perimeter masonry walls support the building frame.

The sub structure carries the load to the footings, which depending on local practice may be sole plates of durable or treated timber or commonly, a concrete pad or a rectangular section reinforced concrete-filled trench.

The use of piers and posts can greatly reduce the need for cut-and-fill on sloping blocks.
[See: 2.5 Biodiversity On-site]



Environmental award winner for the 2004 Timber Design awards.

Frames

For a conventional house, a timber frame can be described as a skeleton of timber components to which is attached exterior wall claddings, internal linings, flooring, roofing, windows and doors.

The timber frames that are designed and built to Australian Standard 1684:2006 – *Residential Timber Framed Construction* will comply with the BCA requirements, except when designed and built in areas subject to seismic activity, for which the BCA provides additional fixing and construction requirements.

For unconventional timber framed housing the approving authority will accept that Australian Standard AS1720 The Timber Structures Code can be utilised in design but will need some professional expertise to verify that the proposed design meets statutory requirements.

Joints and connections

There are many types of traditional joints and a professional joiner or carpenter will use the most appropriate for a specific construction.

Timber frames and trusses can also be purchased ready fabricated. A common joining system is a nail plate that is a metal plate with integral nail shapes, or holes for nails, designed to join the timbers together.

Finishes

Finishes can be applied to increase timber's resilience: to make it more durable in external applications, to protect it from the elements, or to increase wear resistance for internal applications (such as varnish on floors). There are a wide range of finishing products on the market with a number of environmentally friendly water based finishes emerging that make timber more durable whilst complementing its aesthetic beauty.

Things to watch out for

Builders, consumers and designers should be alert to the emergence of new systems, new building codes or regulations and innovation such as the engineered timber products identified in the image above.

ADDITIONAL READING

Forsythe P (2005), *A Review of Termite Risk Management in Housing Construction*, Forest and Wood Products and Research Development Corporation.

Gray A and Hall A (eds) (1999), *Forest Friendly Building Timbers*, Earth Garden Books, Melbourne.

Low, D (eds) (1995), The Good Wood Guide, Friends of the Earth, Melbourne.

National Timber Association publications
Environmentally Friendly Housing Using Timber – Principles (2001).
Environmental Benefits of Building with Timber (2004).
Australian Hardwood and Cyprus Manual (2003).
www.timber.org.au

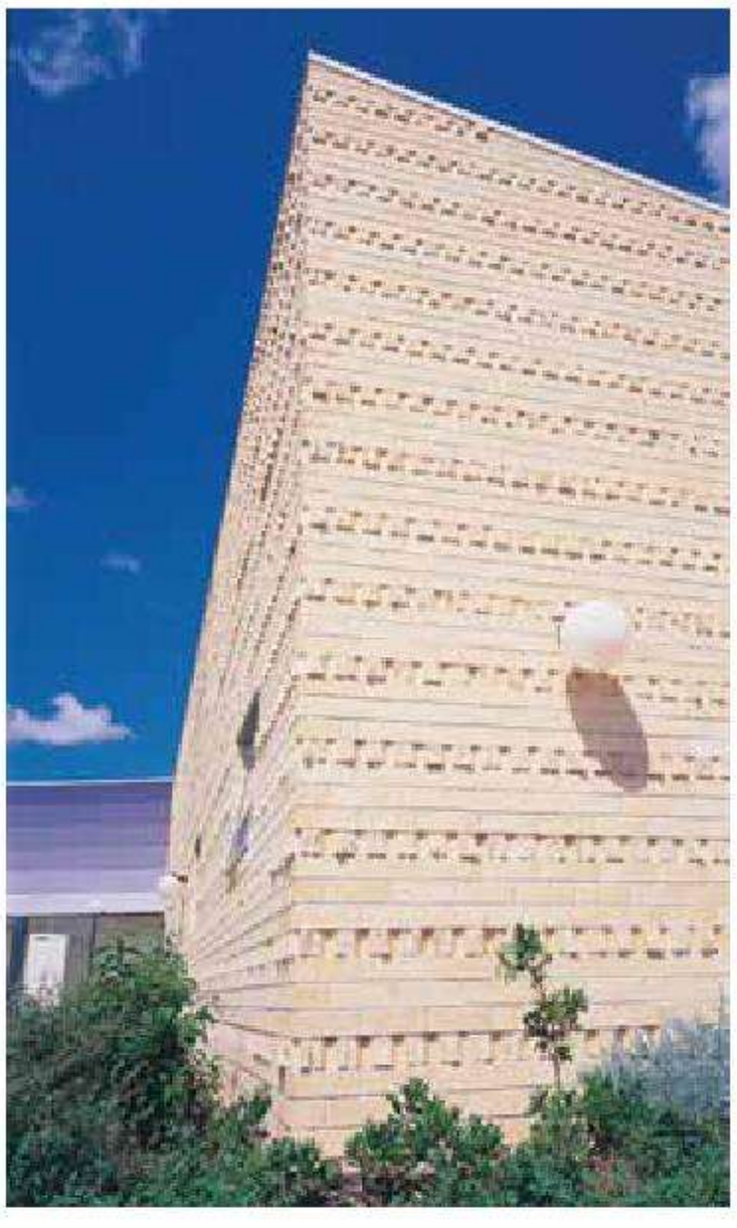
Principal author:
Tom Davis

Contributing author:
Paul Downton

Clay Brick

Clay brickwork is made from selected clays that are moulded or cut into shape and fired in ovens. The firing process transforms the clay into a building component with high compressive strength and excellent weathering qualities, attributes that have been exploited for millennia to build structures ranging from single-storey huts to enormous viaducts. Clay brickwork is Australia's most widely used external cladding and loadbearing wall medium.

Clay bricks are readily available, mass-produced, thoroughly tested modular building components. Their most desirable acoustic and thermal properties derive from their relatively high mass. Clay bricks are generally affordable, require little or no maintenance and possess high durability and load bearing capacity. The use of clay brickwork is informed by extensive Australian research, manufacturing and construction experience.



PERFORMANCE SUMMARY

Appearance

Clay brickwork is available in a wide variety of natural colours and textures derived from fired clay used in combination with cement mortar joints of various colours and finishes. Bricks remain stable and colour-fast and do not need to be rendered or painted. Clay brickwork is most commonly used uncoated to display the richness and texture of the material.

Structural capability

The high compressive strength of fired clay bricks has been exploited for millennia to build structures ranging from single-storey huts to massive public buildings and enormous bridges and viaducts.

Clay brickwork walls can support relatively high loads such as suspended concrete slabs. Clay brickwork is commonly used in four storey construction and with suitable detailing can be used for load bearing walls in much higher buildings. Clay bricks are manufactured under close controls to the requirements of AS/NZS 4455 Masonry units and segmental pavers and AS 3700 provides the means of determining the strength of clay brickwork walls when subjected to horizontal loads resulting from wind, earthquake or fire. [See: 5.5 Construction Systems]

Thermal mass

Clay brickwork has high thermal mass. If a building with internal clay brickwork walls and concrete floors is subjected to a heating and cooling cycle that crosses the comfort zone, the brickwork and concrete will maintain a relatively stable level of heat energy for an extended period. In summer, they will remain relatively cool and in winter, the same building will remain relatively warm. [See: 4.9 Thermal Mass]





Reverse brick veneer

Conventional brick veneer construction places the high mass of brickwork on the outside of the building, where it contributes little to the thermal performance of the building and fails to take maximum advantage of the inherent properties of brick other than its capacity for long life and low maintenance.

Despite its popularity in the mainstream marketplace, conventional brick veneer is not an ideal construction system for climate responsive design.

On the other hand, reverse brick veneer, in which the brickwork is the inside skin of an otherwise conventional stud framed construction, takes advantage of the thermal mass properties of clay brickwork and can result in high performing buildings with lower than average energy demands for both heating and cooling.

Insulation

Clay brickwork, combined with internal and external air films and a cavity, has moderate thermal resistance. Typical R-values are shown below.

The thermal resistance of clay brick veneer or cavity walls can be greatly enhanced by adding foil or bulk insulation. Wall insulation should be accompanied by appropriate detailing to avoid thermal transfers by bridging through window and door frames, by radiation through window openings or by convection through leakage. [See: 4.7 Insulation]

Sound insulation

Due to their mass, clay bricks provide excellent sound insulation, particularly for low frequency noise.

The Building Code of Australia has specific requirements for sound attenuation for multi-unit dwellings which can be satisfied by two leaves of 110mm clay brick masonry with cavity of 50mm between leaves and 13mm cement render on each outside surface. [See: 2.7 Noise Control]

Toxicity and breathability

Clay bricks are inert and are not prone to off-gassing of volatile materials. Clay brickwork and its constituents are non-toxic, however when handling cement (used in the mortar) or cutting brickwork with a masonry saw, manufacturersí safety procedures must be observed to minimise the risk of skin irritation and lung damage.

Fire resistance

Clay bricks are an excellent medium for achieving fire resistance, with their design for fire covered by Australian Standard, AS 3700.

Clay brickwork does not burn when exposed to bushfire and can help protect the more combustible items inside a house.

DESIGN OF CLAY BRICKWORK FOR FIRE

Fire resistance period (minutes)	Required material thickness for insulation (mm)	Maximum slenderness for structural adequacy (mm)
30	60	25.0
60	90	22.5
90	110	21.0
120	130	20.0
180	160	18.0
240	180	17.0

THERMAL RESISTANCE, R, OF CAVITY BRICKWORK

Description of cavity brick wall				
Brick width / cavity / brick width (mm)	90 /50/90	110/50/110		
Description of bricks				
Bulk density of bricks (kg/m^3)	1690	1950	1690	1430
Thermal conductivity of bricks, k (W/m.K)	0.653	0.547	0.653	0.778
Thermal resistance, R (m^{2}K/W)				
External air-film	0.03	0.03	0.03	0.03
External leaf of brickwork	0.14	0.14	0.17	0.20
Cavity	0.16	0.16	0.16	0.16
Internal leaf of brickwork	0.14	0.14	0.17	0.20
Internal air-film	0.12	0.12	0.12	0.12
Total thermal resistance of wall, R (m^{2}K/W)	0.59	0.59	0.65	0.71

Adapted from AS3700.



Paul Downton

Vermin resistance

Clay brickwork consists of dense inorganic materials that do not harbour vermin. Termite resistance may be achieved in a variety of ways, including proprietary termite barriers developed for use with clay brickwork.

Durability and moisture resistance

Clay brickwork is extremely durable. AS 3700 masonry structures tables provide the prescriptive requirements for bricks, mortar, built-in components and reinforcement to achieve various levels of durability.

Clay brickwork walls resist the penetration of rainwater, including wind-driven rain, although they are not completely waterproof. Some moisture may eventually soak through the mortar joints. For this reason external clay brickwork is generally constructed as either cavity walling (two leaves of brickwork separated by ties) or brick veneer (one leaf of brickwork separated from, but tied to a structural frame – may be reversed).

Detailing for clay brickwork needs to incorporate:

> Damp-proof courses.

> Flashings.

> Weep holes.

Environmental impacts

Clay brick manufacture uses energy but the investment of embodied energy is repaid by the longevity of the material. Clay brick homes have a long life, low maintenance requirements and are highly recyclable making them a potentially sustainable form of construction.

Clay bricks can often be reclaimed for re-use when a building is demolished. After cleaning they can either be directly re-used as bricks again, or they can be crushed for making path and road surfaces. Because of their inert, inorganic nature, another use for crushed clay

bricks is as part of the mix for the growing medium of extensive green roofs. [See: 5.13 Green Roofs and Walls]



Buildability, availability and cost

As a result of the long history of cavity brick and brick veneer construction in Australia, there is a huge body of knowledge and experience on construction standards and techniques.

Clay bricks are manufactured throughout Australia and are available at competitive prices throughout the whole of Australia. Even in remote areas, clay bricks can be supplied at moderate prices due to the wide availability of truck transport and back-loading opportunities. Consideration should be given to transport energy costs for any long-distance movement of heavy material. [See:5.2 Embodied Energy]

TYPICAL DOMESTIC CONSTRUCTION

Typical details

AS 3700 Masonry structures and the BCA Volumes 1 and 2 provide the regulatory framework for the design and construction of clay brickwork. Think Brick Australia (formally Clay Brick and Paver Institute) and many of the brick manufacturing companies publish design manuals and standard details.

Footings

For clay brickwork houses, concrete footings and concrete raft slabs should comply with AS 2870 Residential slabs and footings. This standard has been based largely on the behaviour of clay brickwork houses. Footings for brick veneer buildings are generally smaller than the corresponding footings for cavity brickwork.

For other clay brickwork buildings, concrete footings and concrete slabs should be designed and constructed in accordance with AS 3600 Concrete structures.

Frames

For brick veneer and reverse brick veneer houses, frames provide the required strength and stability. Timber frames should comply with AS 1684 Residential timber framed construction and steel frames should comply with AS 3623 Domestic metal framing.



In architecturally designed homes the use of frames and clay brick walls may more freely exploit the qualities of bricks to achieve particular design outcomes.

Loadbearing walls

Critical to the function of any building is the ability of the walls to support suspended floors in addition to the roof and walls in the storeys above. In most cases, the inclusion of concrete floor slabs dictates the use of loadbearing masonry. Think Brick Australia provides comprehensive manuals with charts and tables for the design of loadbearing clay brickwork walls.

Fixings

Major anchorages (such as roof tie-down anchorages) should be built into brickwork during construction. For high wind uplift, anchorages should pass down the brickwork cavity and be tied into supporting concrete slabs or footings. Windows and doors may be built into brickwork by setting the attached ties in the mortar joints.

Minor anchorages (such as hanging light loads from walls) may employ any of the wide range of commercially available proprietary mechanical or chemical anchors. These are set in holes drilled using a hammer drill of the appropriate size. If set into brick rather than mortar, higher anchorage strength can be achieved.

OPENINGS

Most commercially available doors and windows are manufactured to be compatible with clay brickwork, either in veneer or cavity construction. CAD and hard copy details that provide information on the required sizes of openings and fixing information are available from window manufacturers and on the internet.

Finishes

External face clay brickwork capitalises on the broad variety of colours, textures and finishes of Australian bricks, mixed and matched with coloured or plain mortars in struck, ironed, pointed or raked joints.

Clay brickwork is often used for internal feature walls – a particularly appropriate approach for reverse brick veneer construction. Internal brickwork, loadbearing walls, firewalls and acoustic partitions may also be painted, rendered or sheeted with plasterboard.

ADDITIONAL READING

Think Brick Australia publications
www.thinkbrick.com.au

Energy Smart Housing Manual, Victorian Government
www.sustainability.vic.gov.au/resources/documents/ESHousingManualCh061.pdf

Principal Author:
Cathy Inglis

Contributing Author:
Paul Downton

Autoclaved Aerated Concrete (AAC)

Autoclaved Aerated Concrete (often shortened to 'AAC') is effectively concrete with lots of closed air pockets in it. It is lightweight and energy efficient, and is produced by adding a foaming agent to concrete in a mould, then wire cutting blocks or panels from the resulting 'cake', and 'cooking' it with steam (autoclaving).

The use of AAC in Australia is not yet widespread but autoclaved aerated concrete blocks have been used in Europe for more than 50 years. AAC has a moderate embodied energy content and performs very well as thermal and sound insulation, due to the aerated structure of the material and the unique combination of thermal insulation and thermal mass properties. AAC is light, does not burn, is an excellent fire barrier, and is able to support quite large loads. It is relatively easy to work with and can be cut and shaped with hand tools. Blocks are made to very exacting dimensions and are usually laid in thin-bed mortar that is applied with a toothed trowel, although more conventional thick-bed mortar can be used. AAC has a long life and does not produce toxic gases after it has been put in place.

PERFORMANCE SUMMARY

Appearance

Autoclaved Aerated Concrete is very light coloured. It contains many small voids (similar to those in aerated chocolate bars) that can be clearly seen when looked at closely. The closed air pockets contribute to the material's insulating properties and also its aerated nature. Although there is no direct path for water to pass through the material, an appropriate coating is required to prevent water penetrating into the AAC material.

AAC can be sculpted with wood working tools, but its softness means that it is rarely used as an exposed finish owing to its need for surface protection.



Veneer construction.

Structural Capability

The compressive strength of AAC is very good and load-bearing structures up to three storeys high can be safely erected. Entire building structures can be made in AAC from walls to floors and roofing with reinforced lintels, blocks and floor, wall and roofing panels available from the manufacturers. The Masonry Structures code AS 3700—2001 now includes provisions for AAC block design. AAC panels and lintels contain integral steel reinforcement to ensure structural adequacy during installation and design life. [See: 5.5 Construction Systems]



Block construction showing two storey house.

Thermal mass

The thermal performance of AAC, as for other high-mass materials, is dependent on the climate in which it is used. With its mixture of lightweight concrete and air pockets, AAC has a moderate overall level of thermal mass performance. The temperature moderating thermal mass is most useful in climates with high cooling needs. [See: 4.9 Thermal Mass]

Insulation

AAC has reasonably good insulation qualities. In most Australian climates the need for supplementary insulation can be avoided. A 200mm thick AAC wall gives an R-value rating of 1.43 for AAC with 5 per cent moisture content by weight. The Building Code of Australia provides an AAC masonry Deemed to Comply building solution consisting of a 200mm thick AAC wall and finishes, which requires no additional R-value insulation in most Climatic Zones around Australia. Although the R-value is lower than a well insulated, timber-framed structure, the combination of thermal mass and thermal insulation properties can deliver savings in heating and cooling costs through the life of a home. [See: 4.7 Insulation]



Load-bearing, insulating and capable of being sculpted, AAC has enormous potential as an environmentally responsible building material choice.

Sound insulation

With its closed air pockets, AAC can provide very good sound insulation. As with all masonry construction, care must be taken to avoid gaps and unfilled joints that can allow unwanted sound transmission. Combining the AAC wall with an insulated asymmetric cavity system will provide a wall with excellent sound insulation properties. [See: 2.7 Noise Control]

Fire and vermin resistance

AAC is inorganic and incombustible and is thus especially suited for fire-rated applications. Depending on the application and the thickness of the blocks or panels, fire ratings up to four hours can be achieved. AAC does not harbour or encourage vermin.

Durability and moisture resistance

The purposely lightweight nature of AAC makes it prone to impact damage. With the surface protected to resist moisture penetration it is not affected by harsh climatic conditions and will not degrade under normal atmospheric conditions. The level of maintenance required by the material varies with type of finish applied.

The porous nature of the material can allow moisture to penetrate the material to a depth but appropriate design (damp proof coarse layers and appropriate coating systems) prevents this happening. AAC will not easily degrade structurally when exposed to moisture, but its thermal performance may suffer.

There are a number of proprietary finishes available (acrylic polymer based) which when applied over a sand and cement render provide a very durable and water resistant coating system to AAC blockwork. They need to be treated in a similar fashion with acrylic polymer based coatings prior to tiling in areas such as showers. The manufacturer can advise on the appropriate coating system, surface preparation and installation instructions to give good water repellent properties prior to tiling in wet areas.

Plasticised, thin coat finishes are common, but here a non-plasticised thick coat (10mm approximately) render was used for environmental reasons. Some variation in the amount of show-through of the blockwork pattern can be seen in this example that also illustrates the use of glass blocks, as well as more conventional windows. The external plumbing was a choice made to reduce loss of internal space, avoid potential problems with wall cavities, and express the decision to adopt the use of HDPE plastic in the construction.



External plumbing was chosen to reduce loss of internal space and avoid potential problems with wall cavities, and adopt the use of HDPE plastic in the construction.

Toxicity and Breathability

The aerated nature of the material facilitates breathability. There are no toxic substances and no odour in the final product. However, AAC is a concrete product, and similar precautions should be taken as when handling and cutting concrete products. Personal protective equipment (such as gloves, eye wear, respiratory masks) is required during cutting due to the fine dust that is produced by concrete products. If low-toxic, vapour permeable coatings are used on the walls and care is taken not to trap moisture where it can condense, AAC may be an ideal material for homes for the chemically sensitive.



Autoclaved Aerated Concrete is about one-fifth the density of normal concrete blocks.

Environmental impacts

Weight for weight, AAC has manufacturing, embodied energy and GH emission impacts similar to those of concrete, but can be up to one quarter to one fifth that of concrete based on volume. AAC products or building solutions may have lower embodied energy per m^2 than a concrete alternative. Its much higher insulation value reduces heating and cooling energy consumption. AAC has some significant environmental advantages over conventional construction materials addressing longevity, insulation and structural demands in one material. As an energy and material investment it can often be justified for buildings intended to have a long life. [See: 5.1 Material Use Introduction]

Off-cuts from construction can be returned to the manufacturer for recycling, or be sent out as concrete waste for re-use in aggregates, or the odd pieces can be used directly for making other walling, eg. Garden walls or landscape features. In this illustration there is a clear difference between the lower course and higher course of blockwork in the AAC apartment building under construction – this shows the kind of difference in quality that can be derived from the same material by differently skilled tradespeople.



Buildability, availability and cost

Blocks are one-fifth of the weight of concrete and are produced in a variety of sizes, but although AAC is relatively easy to work, is light and easily carved, cut and sculpted, it generally requires careful and accurate placement so that skilled trades and good supervision are essential. Competent bricklayers or carpenters can work successfully with AAC. Very large block sizes may require two-handed lifting and be awkward to handle but can result in fewer joints and more rapid construction.

The construction process with AAC products results in a low waste component, as the offcuts can be re-used in the construction of the wall.

The cost of AAC is moderate to high. In Australia, AAC is competitive with other masonry construction but more expensive than timber frame. Lack of competition in the marketplace makes consumers highly dependent on one manufacturer.

TYPICAL DOMESTIC CONSTRUCTION

Construction process

All structural design should be prepared by a competent person, and may require preparation and approval of a qualified engineer. Qualified professionals, architects and designers provide years of experience and access to intellectual property that has the potential to save house builders time and money as well as help ensure environmental performance. All masonry construction has to comply with the Building Code of Australia and relevant Australian Standards, eg. all masonry walls are required to have movement/expansion joints at specified intervals.

The standard block size is 200mm high by 600mm long. Block thickness can range from 50mm to 300mm but for residential construction the most common block widths used are 100mm, 150mm and 200mm. AAC blocks can be used in a similar manner to traditional masonry units like bricks and be used as a

veneer in timber frame and as one or both skins in cavity wall construction.

The standard panel size is 600mm wide by 75mm thick with lengths ranging from 1200mm to 3000mm. Typically, these AAC panels are used as a veneer cladding over a timber-framed construction.

AAC manufacturers provide a wealth of detailed technical advice that, if followed, should help to ensure successful use of the product.

Movement joints

Movement joints must be provided at 6m horizontal centres maximum (measured continuously around rigid corners). Refer to manufacturer's guidelines for further information.

Footings

AAC block construction requires level footings designed for full or articulated masonry in accordance with AS 2870. Stiff footings are preferred because the wall structure of thin-bed AAC acts as if it were a continuous material and cracking tends not to follow the mortar beds and joints like it does in traditional masonry walling. Thick-bed mortar AAC walls do act more like traditional masonry but are not the preferred method for AAC.

Frames

Frames may be required for various structural reasons. Earthquake provisions tend to require multi-storey AAC structures to have a frame of steel or reinforcement to withstand potential earthquake loads that may induce strong, sharp horizontal forces. It is a relatively simple matter to build AAC block work around steel frames but embedding reinforcement rods can be costly and difficult.

Joints and connections

AAC manufacturers provide proprietary mortar mixes. Although more conventional thick-bed (10mm approx.) mortar can be used with AAC, the manufacturer's approved option is a proprietary 'thin-bed' mortar. Using thin-bed mortar, the procedure of laying the blocks is more like gluing than conventional brickwork construction. This is why many traditionally trained bricklayers may experience a need for a period of adjustment to a different method of working. In addition, brickies are used to lifting bricks with a single hand and AAC blocks often require two-handed manipulation. Although this may appear a slower construction process to lay masonry units, an AAC block is equivalent to five to six standard bricks.

Load bearing walls

AAC is available in blocks of various sizes and in larger reinforced panels. These are sold as part of a complete building system that includes floor and roof panels in addition to interior and exterior walls.

Fixings

AAC has low compression strength. The use of mechanical fasteners is not recommended, as repeated loading of the fastener can result in local crushing of the AAC and loosening of the fastener. There are proprietary fasteners that are specifically designed to accommodate the nature of the material by spreading the forces created by any given load, whether it is a beam, shelf or a picture hook. There are a number of proprietary fixings for AAC with extensive guidance available in product literature. In the event of uncertainty regarding the appropriateness of a fixing, consult the project engineer or fastener manufacturer for guidance.

Openings

AAC is soft enough to be cut with hand tools. Niches can be carved into thicker walls and corners can be chamfered or curved for visual effect. Channels for pipes and wires are easily made with an electric router but with all carving and cutting care must be taken to use appropriate dust reduction strategies and appropriate personal protection equipment should be worn at all times.



This dry-lined interior shows how AAC can be exploited to make niches and unusual openings.

Finishes

AAC blockwork and panels can accept cement render, but the manufacturers recommend using a proprietary render mix compatible with the AAC material substrate. Site mixed cement renders have to be compatible with the AAC substrate, with the render having a lower strength than conventional renders. All renders should be vapour permeable (but water-resistant) to achieve a healthy breathable construction. All external coating finishes should provide good UV resistance, be vapour permeable and be proven suitable for AAC. Consult the manufacturer's literature for further information on coatings.

ADDITIONAL READING

Aroni S et al (eds) (1993), *Autoclaved Aerated Concrete – Properties, Testing and Design*, RILEM Technical Committee, FN Spon, London.

Bave G et al (eds) (1978), *Autoclaved Aerated Concrete: CEB Manual of Design and Technology*, The Construction Press, UK.

Lawson, B (1996), *Building Materials and the Environment: Towards Ecological Sustainable Development*, RAIA, Canberra.

Staines A (1993), *Australian House Building the Easy Hebel Way*, Pinedale Press, QLD.

Principal Author:
Paul Downton

Concrete Slab Floors

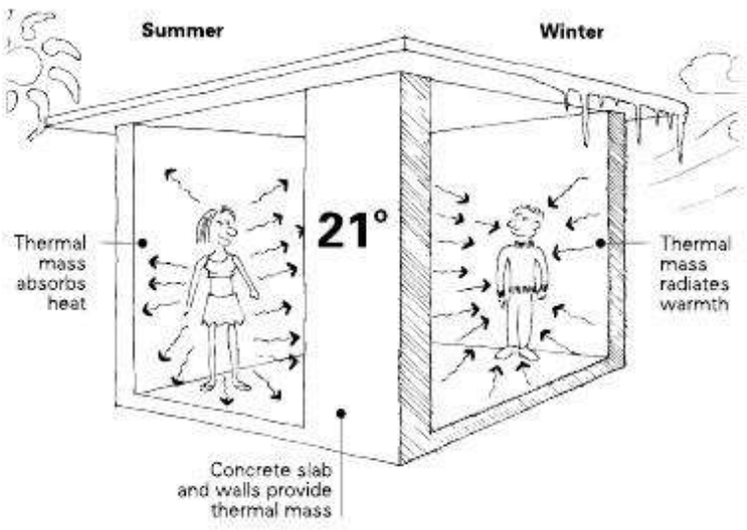
Concrete slab floors come in many forms and can be used to provide great thermal comfort and lifestyle advantages.

THE BENEFITS OF CONCRETE SLABS



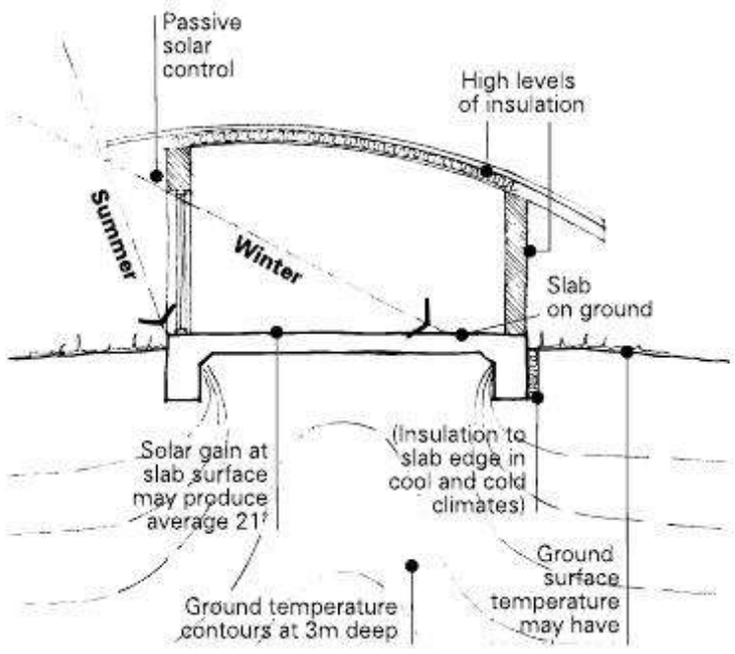
Thermal Mass describes the potential of a material to store and re-release thermal energy. Materials with high thermal mass, such as concrete slabs or heavyweight walls, can help regulate indoor comfort by radiating or absorbing heat, creating a heating or cooling effect. [See: 4.9 Thermal Mass]

Thermal mass is useful in most climates, and works particularly well in cool climates and climates with a high day/night temperature range. To be effective, thermal mass must be used in conjunction with good passive design. [See: 4.2 Design for Climate; 4.5 Passive Solar Heating; 4.6 Passive Cooling]



Design slabs to absorb heat from the sun or other sources during winter. Heat can be stored in the slab and re-radiated for many hours afterwards. In summer, allow slabs to be exposed to cooling night breezes so that heat collected during the day can dissipate.

Earth coupling is achieved when the thermal mass of the slab is in direct contact with the additional thermal mass of the earth below. This greatly enhances thermal performance. Earth coupling is most simply achieved using slab-on-ground construction.



Earth coupling allows the floor slab of a well insulated house to achieve the same temperature as the earth a few metres below the ground surface, where temperatures are more stable (cooler in summer, warmer in winter). In winter, added solar gain boosts the surface temperature of the slab to a very comfortable level.

Durability is one of the other main advantages of concrete slabs. Concrete's high embodied energy can be offset by its permanence. If reinforcement is correctly designed and placed, and if the concrete is placed and compacted well so there are no voids or porous areas, concrete slabs have a long lifespan.

Control of cracking is important. A number of factors affect this and should be considered, including:

> **Size of slab** – if it is large or has two distinct separate parts, control and/or movement joints may be needed;

> **Proper preparation of foundations** – this will prevent settlement cracking;

> **Curing** – curing will help reduce surface cracking. Concrete typically takes 28 days to reach its design strength, and the first three to seven days are critical, beginning as soon as finishing of the slab is complete. An applied liquid curing membrane is usually the most practical method. Covering with a plastic sheet will also work but is harder to maintain. Keeping the concrete continuously wet, while the best method of curing, is not advised due to the large amounts of water that may be required;

> **Addition of water** – excess water added to the concrete mix prior to placing will increase the risk of cracking and may result in dusting of the surface and a decrease in the strength of the concrete;

> **Placing and Compaction** – inadequate placing and compaction will result in a lower strength and/or honeycombed (porous) concrete and lead to increased cracking.

Termite resistance is achieved with concrete slabs by designing and constructing them in accordance with the Australian Standards to minimise shrinkage cracking, and by treating any joints, penetrations and the edge of the slab.

> Slab edge treatment can be achieved simply by exposing the concrete edge for a minimum height or width of 75mm above the ground, forming an inspection zone at ground level.

> Cavity physical barriers are used where a brick cavity extends to below ground, and can be formed by using sheet materials, a fine stainless steel mesh, or finely graded stone.

> Pipe penetrations through concrete slabs should have some form of physical barrier. Options include sheet materials, stainless steel mesh or graded stone.

> Although physical barriers are environmentally preferable, chemical deterrents are also available. These must be re-applied at regular intervals to maintain efficacy.

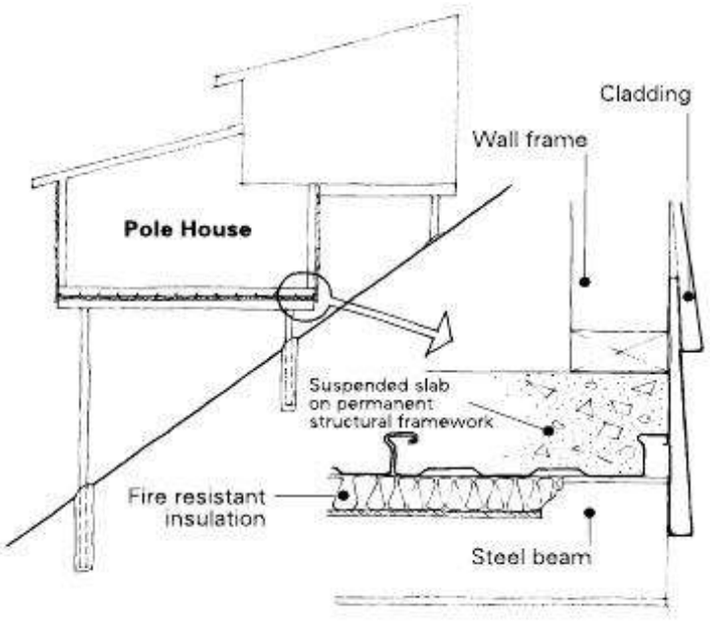
STRUCTURAL ISSUES

Reactive soil sites can be difficult to build on, but 'floating' stiffened concrete raft slabs cope well with these conditions. Some stiffened raft slabs known as waffle raft slabs use void formers at regular intervals, forming closely spaced deep reinforced beams criss-crossing the slab underside.



These void formers are mostly expanded foam boxes, which interfere with earth coupling, but more thermally connective alternatives are available. These include proprietary systems that use recycled tyres, or re-used detergent bottles filled with water and grouped together as void formers.

Steep sites may have geotechnical requirements which make slab-on-ground construction impracticable. Although slab-on-ground construction is more thermally efficient, a suspended slab can be a suitable way to gain the advantage of thermal mass on a steep site. Typical pole frame construction can be adapted easily to incorporate a slab. The slab underside should be insulated in some climates. [See: 4.7 Insulation, Insulation Installation]



Permanent structural formwork or one of the many precast flooring alternatives are usually the most cost effective way of constructing high set suspended slabs. These are normally designed by an engineer and installed by builders.

These systems can provide useful thermal mass in situations where long spans are needed, such as pole homes or upper floors of two storey homes. These systems are often designed and installed as part of one supply contract by the manufacturer.

Suspended autoclaved aerated concrete (AAC) panels can provide clear spans with acoustic and thermal benefits, and allow speedy installation on site. AAC floor panels have approximately 25 per cent of the mass of normal concrete but still provide thermal comfort due to their insulation properties. [See: 5.11 Autoclaved Aerated Concrete (AAC)]

Level sites are well suited to slab-on-ground construction. Use of slab-on-ground allows earth coupling and, because floor levels are close to ground level, facilitates free flow from interior to exterior spaces.

Renovations can often incorporate concrete slabs even when the original building does not. Added rooms can use slab-on-ground or suspended slabs. Renovated rooms with timber floors are often capable of having the timber replaced with a concrete slab, for added thermal mass and quietness underfoot.

These slabs can be either suspended on the original subfloor walls and footings, or if the old floor is close to ground they can be an infill slab on fill. Most advantage is gained if passive design principles are followed. [See: 4.5 Passive Solar Heating; 4.6 Passive Cooling]

Curing of all cement-based building materials is critical to achieving the design strength and other desired properties, especially with structural concrete slabs. Concrete takes 28 days to reach the design strength, although a sufficient minimum design strength may be achieved in less time if the concrete is specified accordingly. It is essential that the curing regime specified by the design engineer is followed exactly.

Compaction is usually achieved by vibrating the concrete. This reduces the air entrapped in the concrete giving a denser, stronger and more durable concrete better able to resist shrinkage cracking. While deeper beams should be compacted, thin slabs (100mm-thick typically) receive adequate compaction through the placing, screeding and finishing operations.

DESIGN ISSUES

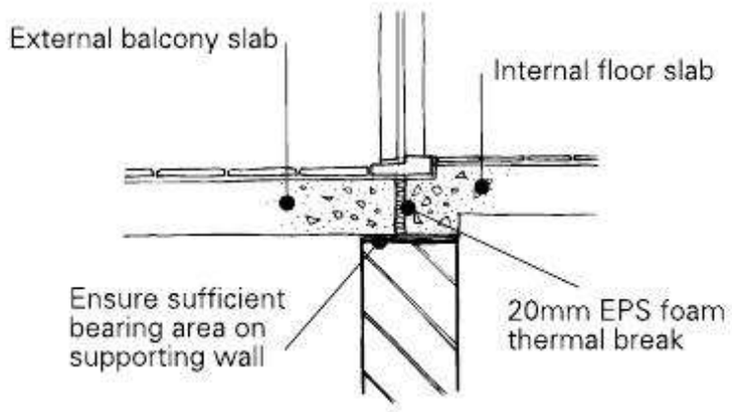
Passive solar design principles and high mass construction work well together, and concrete slabs are generally the easiest way to add thermal mass to a house. Living rooms should face north in all but warm and high humidity climates to enable winter sun to invest warmth into the slab. Concrete slabs perform better as the diurnal temperature range increases. [See: 4.2 Design for Climate]



Natural ventilation must be provided for in the design. On summer evenings, heat stored in the slab must be allowed to dissipate. This is particularly important for slabs on upper storeys, where warm air accumulates. Zone off the upper space from lower living areas where possible and ensure the space can be naturally ventilated. This is particularly important if bedrooms are located upstairs, to maintain night time sleeping comfort.

Insulation of the slab edge is important in cooler climates, to prevent warmth escaping through the edges of the slab. This insulation needs to be designed to complement the footing design, and should be undertaken in consultation with a structural engineer. [See: 4.7 Insulation]

It is possible to retro-fit slab edge insulation to existing slabs on ground. Renovations are an ideal time to do this, but it can be done at any time. Advice from an engineer should first be sought regarding disturbance to foundations and reinstatement of material, and termite barriers must not be breached.



Balconies extended from the main slab of a house may act as cooling or heating fins, carrying precious warmth away to the cold exterior during winter, or transferring heat from summer sun inside. Consider building such slabs independently of the main slab and incorporating a thermal break at the interface.

Acoustics need to be considered. Generally concrete slabs are a great way to reduce music or conversation noise being transferred from one level of a home to another, and between rooms on the same level. These noises will not be transmitted through a slab.

Impact noise needs to be considered. For instance, the sound of high heels on a tiled floor will be transmitted directly to the room below. While seldom a problem in detached houses, an acoustic barrier can be included in the ceiling below.

Open plan houses may transmit more noise than is convenient from one living area to another. Thermally efficient hard flooring will exacerbate this, so other elements within the room need to be designed to limit noise:

> Design the floor plan to be able to close spaces off from each other when needed.

> Large flat ceilings can transmit too much noise. Dropped bulkheads or suspended cupboards around kitchens will help to absorb and dissipate sound.

> Use absorbent materials on wall panels, or add large fabric wall hangings. Heavy drapes and curtains can also assist to absorb sound, as well as keeping warmth in during winter.

[See: 2.7 Noise Control]

FINISHES

For the thermal mass of a concrete slab to work effectively, it must be able to interact with the house interior. Covering the slab with finishes that insulate, such as carpet, will reduce the effectiveness of the thermal mass. However, a wide variety of finishes are available that allow thermal mass to be utilised:



Tiles

Tiles fixed by cement or cement-based adhesives are commonly available in many colours, sizes and patterns. (If thermal mass is to be utilised, avoid rubber-based adhesives due to their insulating effect). Darker colours with a matt surface work better than light shiny finishes. Choices include ceramic tiles, slate tiles, terracotta tiles, pavers and bricks.

Polished concrete

Polished concrete is a term which covers two distinct types of finishes:

> Trowel finished floors, with or without post-applied finishes.

> Ground and polished or abrasive blasted floors.



Some of the finishes below can be used in combination with other finishes to achieve a wider range of results, to suit any style or taste.

Trowel finishes include:

> Steel trowel finish, where a normal hand or machine trowelled finish is used for the surface of the slab, usually with a clear sealer applied.

> Burnished concrete, where the surface is finely steel trowelled, bringing the surface up to a glossy finish free of any trowelling marks.



Coloured concrete can be used in either steel trowel or burnished finishes, to achieve various results. It may be advisable to use experienced specialist contractors to carry out this work. These can be applied as oxides in the mix, or as 'dry shake' pigments applied to freshly screeded concrete and then trowelled in, or by chemically staining the concrete.

Chemical stains are used with either steel trowel or burnished finishes. Metallic salts are carried into the surface of the concrete by mild acids, making the stains deep and permanent.

Saw cuts can be added to enhance or separate panels of colour.



Ground and polished finishes include:

> Exposed aggregate, where the normal grey concrete is ground back by several millimetres to expose whatever aggregate exists in the slab. This is often used in renovations of older buildings to reveal some of their history.

> Exposed selected aggregates, where the cement colour and aggregate in a new slab are carefully selected, so when the surface is ground back they produce desired effects.

Abrasive blasting of the concrete surface will also provide varied effects.

Toppings can also be used on their own or together with some of the effects listed above to provide interesting visual finishes that do not interfere with thermal performance. Terrazzo is one of many toppings which is also ground and polished. Other toppings may be left in the 'as placed' or 'as trowelled' state.

Note that some of these options require careful protection of the slab during subsequent construction works. Also note that many sealer finishes have toxicity impacts but environmentally preferred alternatives are available such as bees wax or other natural wax polishes. These will need regular buffing to maintain sheen.

HEATING

Because concrete slabs offer so much thermal mass, they lend themselves well to long cycle in-slab heating systems. Slab heating is usually used in colder climates where limited solar access is available to the slab. Insulation is required to minimise heat loss to the ground. Despite the fact that latest systems provide flexible thermostat settings for different house zones, slab heating is in operation for the whole of winter and is therefore best suited to houses with permanent or high occupancy. [See: 4.7 Insulation; 4.8 Insulation Installation; 6.2 Heating and Cooling]

Electric resistance heating coils are the most common type of slab heating, and are attached to the reinforcement. These are usually controlled by timed switching so a relatively even temperature is maintained over a daily cycle with top up periods of just a few hours per day. They have a greenhouse gas penalty when fed with coal-fired electricity.

Hydronic heating coils in the slab are very energy efficient, giving lower running costs and heating bills. Hydronic heating slabs can be powered by a range of energy sources, including solar, groundsource heat pumps, gas furnaces and heat recovery units. Unlike electric coil heating, hydronic heating can be reverse cycled in summer, dumping excess heat into the night sky.

Recycling concrete is cost effective, minimises waste, and reduces the need to use more of the earth's resources.

RECYCLED CONTENT IN SLABS

There are two ways to contribute to the recycling of concrete:

> During demolition, by recycling waste concrete.

> During construction, by using recycled materials as a component of new concrete.

Demolition waste makes up 40 per cent of all landfill. Taking demolition waste to landfill is expensive as well as damaging to the environment. Crushable concrete can instead be recycled to make economic and ecological savings. [See: 5.3 Waste Minimisation]

If demolition concrete is kept separate without mixing with other demolition materials, a more usable product can be achieved from the crushing for recycling into new concrete.

Concrete is composed of three main components, coarse aggregate (stone), fine aggregate (sand) and cement. Recycled concrete and masonry can be utilised, as well as other industrial wastes, within these components.

Concrete's main environmental impacts are greenhouse gas emissions from cement production and the mining of raw materials.

Replacing a proportion of the cement with waste products such as fly ash, slag and silica fume can significantly reduce embodied energy and greenhouse gas emissions.

Use of crushed concrete from demolition as aggregate, as well as the use of slag aggregates and manufactured sands to replace nature stone and sand within concrete, decreases landfill, reduces embodied energy and can be low cost. [See: 5.2 Embodied Energy]

Using substitutes for natural stone – Coarse aggregate can be replaced with recycled crushed concrete. The simplest approach is to use up to 30 per cent recycled aggregate for structural concrete. There is no noticeable difference in workability and strength between concrete with natural stone aggregate and concrete with up to 30 per cent recycled aggregate.

It is possible to use up to 100 per cent recycled coarse aggregate in concrete under controlled conditions. However concrete with more than 30 per cent recycled concrete aggregate can have a greater water demand, can be less workable and result in lower strengths.

Using substitutes for natural sand – Fines from concrete crushing can be used to reduce natural sand content, as can other industrial by-products such as ground glass, fly-ash, bottom-ash and slag sands. However, the properties of these products can affect workability, strength and shrinkage cracking.

Using substitutes for portland cement – Cement substitutes (called 'supplementary cementitious materials' or 'extender') for Portland cement include fly ash, ground blast furnace slag and silica fume. These are all waste materials from other manufacturing processes.
Various blended cements are available, some with high substitution of portland cement with SCM's (up to 85 per cent). The reduced amount of portland cement results in a significant reduction in greenhouse gas emissions.

New technologies currently being researched have the potential to reduce greenhouse gas emissions even further.

Obtaining these substitutes – Recycled aggregate (stone and sand) is readily available in many locations, with the only barrier being whether batching plants have the capacity to stockpile additional types of aggregate.
Most batch plants have the ability to provide blended cements. In some smaller plants it may not be feasible to have two cement silos, or an additional silo for fly ash or slag, but hand loading may be an option.

While slag aggregates are readily available in areas close to steelworks, cartage costs may prohibit their use in more remote areas. For similar reasons, manufactured sands and crushed concrete may not be readily available in all areas.

NOTE: The design of concrete structures and the composition of structural concrete MUST be undertaken by a suitably qualified person. The material in this fact sheet is not a substitute for professional advice- always consult a structural engineer.

ADDITIONAL READING

Ash Development Association of Australia
www.adaa.asn.au

Cement, Concrete and Aggregate Association of Australia
www.concrete.net.au

Cement Industry Federation
www.cement.org.au

The Australasian Iron and Steel Slag Association
www.asa-inc.org.au

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Green Roofs and Walls

From the turf roofs of Viking dwellings in Scandinavia to the 'hanging' gardens of ancient Babylon, green roofs have a history reaching back thousands of years. Modern green roofs and walls are building elements designed to support living vegetation in order to improve a building's performance. Also know as 'living' roofs and walls, they are emerging as important additions to the palette of construction techniques for creating healthy, ecologically responsible buildings.



A green roof is a roof surface, flat or pitched, that is planted partially or completely with vegetation and a growing medium over a waterproof membrane. They may be 'extensive' and have a thin growing medium (up to 200mm deep) with 'ground cover' vegetation, or 'intensive' and have a soil 200mm deep or more supporting vegetation up to the size of trees. Green walls are external or internal vertical building elements that support a cover of vegetation which is rooted either in stacked pots or growing mats.

Green roofs are an accepted part of modern building in Europe where some city and even national governments have mandated their use (Linz, in Austria requires green roofs on all new residential and commercial buildings with rooftops larger than 100m^2, German green roof building has been encouraged by the Federal Nature Protection Act, the Building Code and state-level nature protection statutes). Australian examples are less common but in 2007 a national organisation was formed to promote green roofs and Brisbane City Council included green roofs in its proposed action plan for dealing with climate change.

Earth-sheltered houses have green roofs and anyone who has grown climbers across a vertical trellis has had some experience in creating green walls. The growing interest in green roof and wall construction has been encouraged by the increasing availability of technologies that make their construction easier and more economical.

Green roofs are particularly effective in denser, more urban environments, where they can compensate for the loss of productive landscape at ground level. 'Green wall' techniques can be used on homes in suburban settings as part of aesthetic enhancement and improving the overall climate responsiveness of individual dwellings, and even to treat wastewater.

PERFORMANCE SUMMARY

The benefits of green roofs include:

> Longer roof lifespan.

> Improved sound insulation.

> Reduced heating and cooling requirements.

> Reduced stormwater run-off.

> Trapping of gaseous and particulant pollutants.

> Alleviation of urban heat islands.

> Increased biodiversity.

Many of these benefits also apply to green walls.

Green roofs are sometimes referred to as the fifth façade. There are two kinds of green roof: intensive and extensive, each of which is appropriate for different purposes. The intensive roof is typically much heavier, supports more substantial vegetation and is more expensive than 'extensive' roofs that are often light enough that they can be retrofitted to existing buildings without the need to upgrade their structural capabilities.

Extensive green roofs

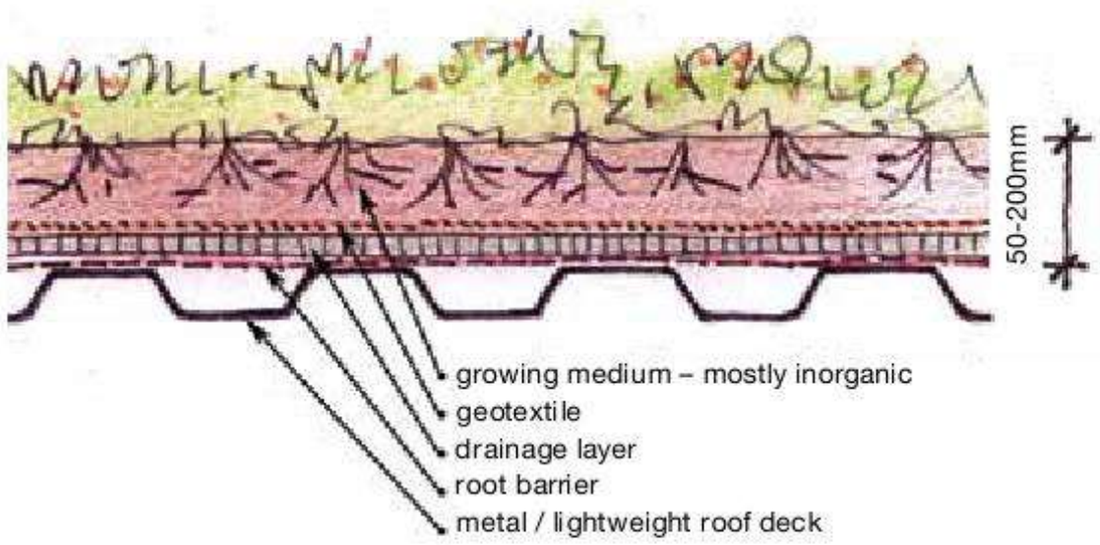
> Shallow growing medium – 50 to 200mm.

> Roof structure similar to conventional roof coverings.

> Vegetation limited to shallow rooting plants.

> Relatively economical.

> Relatively easy to retrofit.



Intensive green roofs

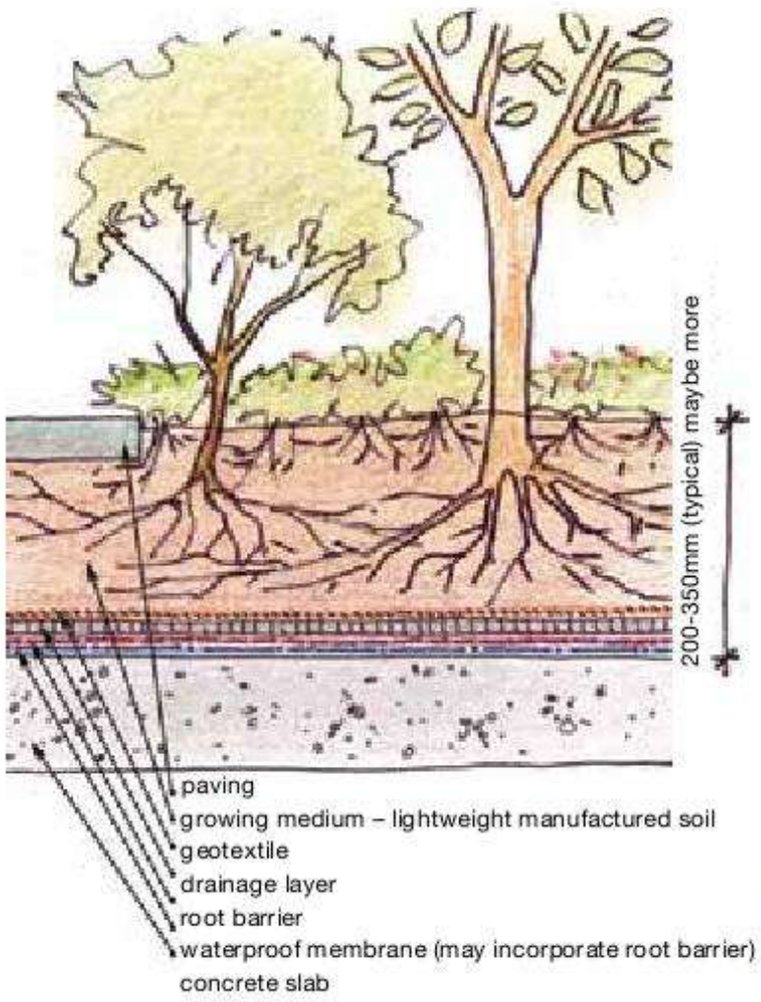
> Deep growing medium – 200mm or greater.

> Requires stronger roof structure.

> Wide range of plantings possible.

> Relatively expensive.

> Difficult to retrofit.



In between these types there are semi-extensive (extensive with areas of deeper soil) and semi-intensive roofs (intensive with areas of shallower soil).

GREEN WALLS

Green walls are like vertical gardens and may be inside or outside of a building. In their more elaborate form, green walls are 'living walls' and may incorporate water elements including ponds and fish. Green walls may also be incorporated into the cooling strategy of a house, as a kind of evaporative air conditioner, and they may even be designed as part of a water treatment system. Green walls include:

> Green facades – pots with vines on trellises.

> Active – with soil/growing medium running up wall.

> Passive – epiphytes.



Appearance

Green roofs can look like anything from a lawn to a forest. Extensive green roofs that use a thin layer of growing medium to support ground cover plants with short roots are generally designed with building performance in mind rather than aesthetic concerns. Sloping and curved extensive green roofs may be seen from ground level.

Intensive roofs can support quite substantial, highly visible vegetation, cascading over the sides of the building or as shrubs and trees rising above the roofline. These are commonly referred to as roof gardens. By creating a landscaped surface green roofs can radically change a building's 'roof line'.

Green roofs and external green walls (which can be small and incidental or large and dramatic) extend the scope for creating pleasant urban environments by introducing plants and greenery that are visually restful or refreshing. Proven therapeutic effects include increased productivity and reduced absenteeism.



Indoor greening can be either an extension of the green wall concept or can include the creation of indoor planters as integral parts of the house. Green walls make it possible to have lots of greenery without using too much floor space. Imagine walking into a room with plants covering one or more of the wall surfaces – living greenery on vertical surfaces can create quite striking impacts.

Green wall systems range from arrangements of planting pots on layers of custom shelving to sophisticated vertical layers of growing medium, geotextiles and purpose made containers. Depending on the size of the wall, large or small plants can be used and the result can be manicured and elegant (think of a privet hedge) or wild and funky.

Green walls can humidify and oxygenate the air and, depending on the plant species, can further improve indoor air quality by acting as filters, trapping dust and absorbing pollutants like formaldehyde.

Structural capability

Green roofs are usually flat but may also be curved or sloping. Supporting structures have to carry all the loads associated with the vegetation, its supporting medium, and the waterproofing and protective layers beneath – plus any live loads from people using the roof.

Extensive green roofs, in particular, can create dessicated, harsh environments for vegetation. Often situated in urban areas, such roofs require low maintenance vegetation tolerant of heat, cold, drought and wind. Although there is limited experience in Australia of such roofs, it is likely that many native plants from coastal and arid inland regions are suited to use in such demanding environments.

Green walls may be freestanding structures or dependent on the building's main structures for support using trellises, cables or frames.

Thermal mass

There is little thermal mass in the vegetative component of green roofs and although there may be some mass in the soil, the usual growing medium is lightweight and is consequently more useful as insulation rather than thermal mass. Green walls have a relatively low thermal mass for the same reason. The supporting structure for extensive roofs (and green walls) is also usually lightweight, with little thermal mass, whereas the structures required for intensive roofs almost invariably employ concrete slabs or similar structures with an inherently high thermal mass.

Insulation

Green roofs may or may not include an insulating layer in addition to the soil and vegetation, but even without such a layer they provide significant thermal insulation. Overall insulation values depend on the type and thickness of growing medium and the type and extent of vegetation. There is little available documentation for R-values which will, in any case, vary according to the degree of saturation of the growing medium.

Green walls can be retrofitted to existing homes to reduce the heat load on façades. The simplest kind is a trellis set with a gap between it and its supporting wall to create shade from vegetation with passive cooling from transpiration of the vegetation and convection of heat up through the gap.

In warmer weather, green walls act like green roofs by reducing the surface temperature of a conventional wall through evapotranspiration and shading. Walls that use irrigation and hydroponic techniques provide additional cooling through evaporation.

Shading windows by deciduous vegetation (bioshading) reduces cooling demands by limiting solar gain in the summer whilst allowing daylight in during winter. The insulating and low thermal absorption properties of green roofs also reduces the urban heat island effect.

Sound insulation

In busy urban settings the acoustically absorbent nature of soil and vegetation of green roofs can insulate against the noise of heavy vehicles like trains, trams, buses and trucks. One office building under the flight path of San Francisco's International Airport, planted with a mixture of indigenous grasses and wildflowers, has been designed to achieve noise transmission reductions of up to 50 decibels.

An extensive thin green roof just 100mm deep will reduce noise transmission by at least five decibels.

Durability and moisture resistance

Green roofs can extend the life of their supporting structure and substrates. By preventing direct solar impact on water-proofing membranes, for instance, a green roof protects against damage from ultraviolet radiation and from constant heating and cooling of the membrane. A vegetated roof can extend the life of a conventional roof by at least 20 years and reduce regular maintenance costs. Similar benefits derive from using green walls that add an extra 'skin' of protection to a building.

Green roofs should be designed to last at least 50 years. Replacement of any components of green roofs are relatively costly so key structural considerations include:

> Longevity of the structure.

> Appropriate drainage.

> Waterproofing.



Fire and vermin resistance

The soil of any green roof is fundamentally fire resistant. The different kinds of vegetation that might be found on a green roof range from shallow-rooted succulents that burn very poorly and offer good fire resistance, to more substantial plants on intensive roofs that can include shrubs and even trees. Although very dry vegetation can present a hazard, the amount of dry vegetation on an extensive roof is unlikely to support more than low intensity fires.

The capacity of any roof-top vegetation to support on-going conflagration is limited and a green roof can be expected to have very good fire resistance, particularly if it is vegetated with succulents or when the growing medium is saturated. There are no relevant Australian codes as yet, but as an example, German building codes provide for 600mm fire breaks every 40m. Fire activated sprinkler irrigation can further reduce risk.

Vermin are offensive animals, insects and worms that are not wanted in human environments. They have not been identified as a problem for green roofs, perhaps because a green roof represents a deliberate effort to incorporate living material into a building and create habitat in which there is less imbalance between humans and other fauna.

Breathability and toxicity

Vegetation in urban areas can filter out fine airborne particles which then wash off into the soil and foliage can absorb gaseous pollutants so it can be reasonably assumed that green roofs provide the same services. Studies have shown that green roofs can trap up to 95 per cent of heavy metals in the local atmosphere.

Sustainability (environmental impacts)

Green roofs and walls contribute towards a wide range of sustainable development objectives, including:

> Stormwater management.

> Climate change mitigation and adaptation.

> Conservation and enhancement of biodiversity.

Retention and binding of contaminants (bird droppings or atmospheric pollution) can assist removal of harmful pollution from run-off into aquatic ecosystems.

The potential for food production on green roofs is being actively investigated in Australia. Led by Central Queensland University (CQU), research includes using urban organic wastes via vermiculture for production of vegetables and development of urban rooftop 'microfarms'.

The heat island effect is reduced by green roofs. Researchers at the Welsh School of Architecture recently concluded that green roofs and walls can cool the local climate around a building in a city by between 3.6°C and 11.3°C and the hotter the climate, the greater the cooling effect.

By lowering ambient roof temperatures, green roofs enable solar panels mounted over them to operate more efficiently, with energy outputs up to 15 per cent more than from panels on asphalt or gravel covered roofs.

Electromagnetic radiation can be reduced by more than 99 per cent with a 100mm substrate depth.

Habitat can be created to increase biodiversity and attract wildlife including rare or migratory birds. Encouraging birds, butterflies and bees has been a significant aspect of some overseas suburban green roofs, whilst a large US manufacturer has a bee farm on the four hectare green roof above its new truck factory.

Green roofs can reduce the costs of dealing with the predicted nationwide increase in peak rainfall events associated with climate change in Australia by providing storm-water retention and slowing the run-off of rainfall. Student research at the University of Queensland has shown that run-off reductions of up to 42 per cent is achievable with only 100mm of soil planted with moderate growth turf, and that as the soil depth and vegetation water use is increased, so does retention capacity.

Domestic greywater treatment has been achieved in Australia using a green wall consisting of a series of three planter troughs which act as filters, removing nutrients, polluting compounds and organic matter from the water.

[See: 7.4 Wastewater re-use]

Buildability, availability and cost

Construction techniques are well understood and documented internationally with an increasing number of proprietary green roof systems available and Australian experience is developing rapidly. Green roofs present higher construction costs than conventional roofs with limited short term return on investment. Long term returns are potentially very good. Without legislation to encourage green roof construction, Australian uptake of the

technologies will be driven by building rating systems that value green roofs and recognition of improved market values.

Individual properties benefit from reduced maintenance and running costs and in North America and the UK green roofs are synonymous with quality, which is reflected in increased property values.

TYPICAL CONSTRUCTION

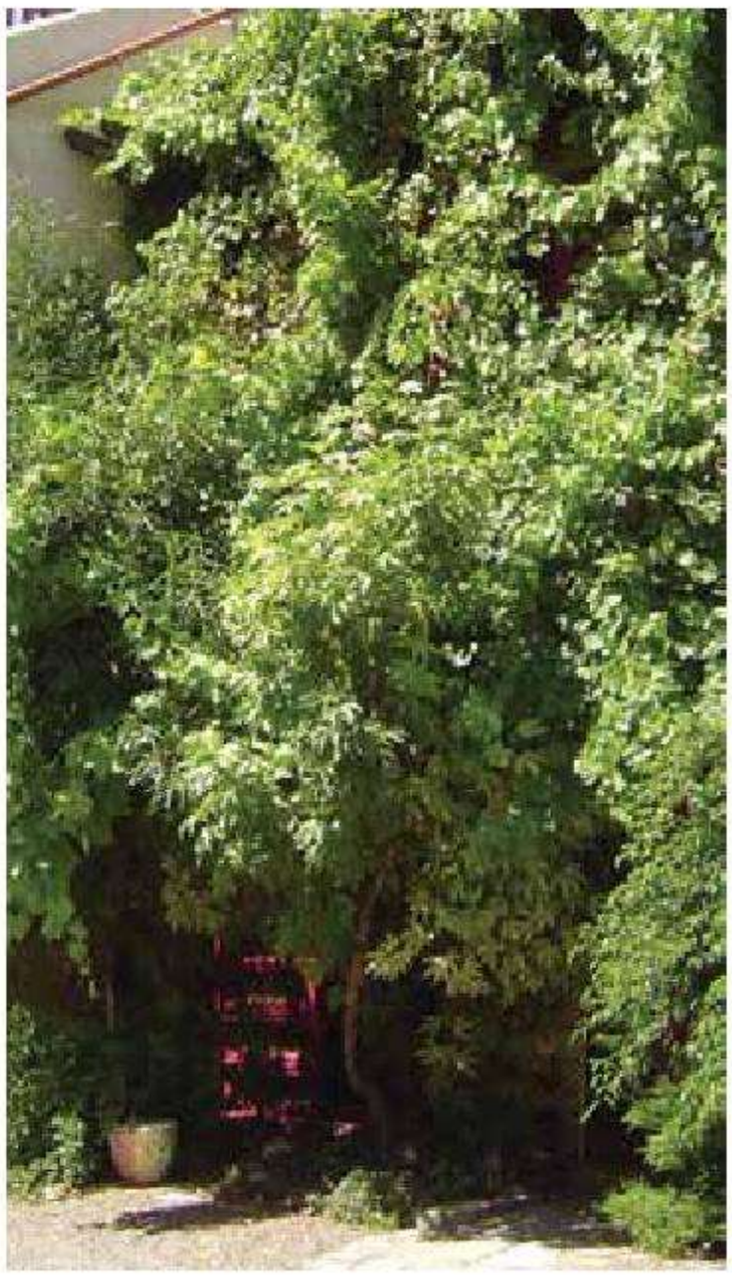
On top of the structural components, there are typically seven layers to a green roof:

1. Waterproofing membrane (either built-up roof, single-ply membrane or fluid-applied membrane. Modified bitumen or plastic sheeting most typical).
2. Root barrier (polyethylene sheeting, copper or copper compounds in the membrane).
3. Insulation (optional).
4. Drainage layer (synthetic drainage mesh, granular aggregate).
5. Filter fabric (geotextile).
6. Growing medium – also known as planting medium or substrate (manufactured soil, crushed brick or other inorganic material).
7. Vegetation (shallow-rooted on extensive roofs, deeper-rooted on intensive roofs).

Green walls are constructed with plants rooted in sheets of fibrous material which may be fixed to a wall or frame, or they may be constructed more like vertical arrays of pots or planters. Some proprietary green wall systems come in the form of modular panels. Plants may be pre-grown in these panels or planted after the panels have been installed.

Materials include steel for supporting frameworks, HDPE plastic for plant containers, and geotextiles. In exterior applications, irrigation may be from the top via soaker hoses or similar. Interior applications may use drip trays.

Both green roofs and green walls need to allow for irrigation of vegetation without loss of soil and to provide reservoirs of water to carry plants through periods of low water availability.



Things to watch out for

When installing a green roof it is important to consider:

> The climate zone. [See: 4.2 Design for Climate]

> Micro climate and roof orientation.

> Local habitats and species.

Design issues

> Structure.

> Membranes.

> Mats.

> Drainage.

> Trellises.

> Plant selection.

> Integration with building functions generally.

The correct growing medium for the climate and plant selection is essential, particularly for extensive roofs. Plant selection for green roofs requires careful consideration as different conditions apply to vegetation on the roof compared with ground level and long term plant maintenance is essential.

Maintenance demands are reduced by integrated irrigation, but a small green wall needs no more tending than more conventional indoor plant arrangements. Larger installations may include programmable and automated watering systems.

ADDITIONAL READING

There has been limited reference material published in English, and, as yet, no substantial publications that deal specifically with Australian conditions.

Dunnett N and Kingsbury N (2004), *Planting Green Roofs and Living Walls*, Timber Press, US.

Earth Pledge (2005), *Green Roofs: Ecological Design and Construction*, Schiffer Publishing, US.

Green Roofs Australia
www.greenroofs.org.au

Snodgrass E and Snodgrass L (2006), *Green Roof Plants*, Timber Press, US.

Werthmann C (2007), *Green Roof: A Case Study*, Princeton Architectural Press, US.

Principal author:
Paul Downton

Energy Use

The average household's energy use is responsible for over seven tonnes of greenhouse gas emissions. These emissions can be significantly reduced through use of renewable energy, more efficient appliances and energy conservation measures. The Energy Use group of fact sheets shows you how.

Choosing the most appropriate energy source can significantly reduce your energy bills and improve the environmental performance of your home. A choice of energy sources is available to new home buyers, existing owners and tenants.

Conventional electricity from the supply grid currently produces the largest amount of CO_2 of any energy source per unit of energy used, except in Tasmania where hydro electric power is the predominant source of electricity. Hydropower is used to a lesser extent in some other states, with fossil fuel power stations providing most of the electricity on the Australian mainland.

Renewable energy sources produce no greenhouse gases in operation and reduce or eliminate the need for additional coal fired power stations and large hydro-electric dams.

Natural gas produces only about one third the greenhouse gas emissions compared to conventional electricity.

Minimising demand for energy through conservation and efficiency is the most cost effective means of reducing operational and environmental costs for all home owners and tenants.

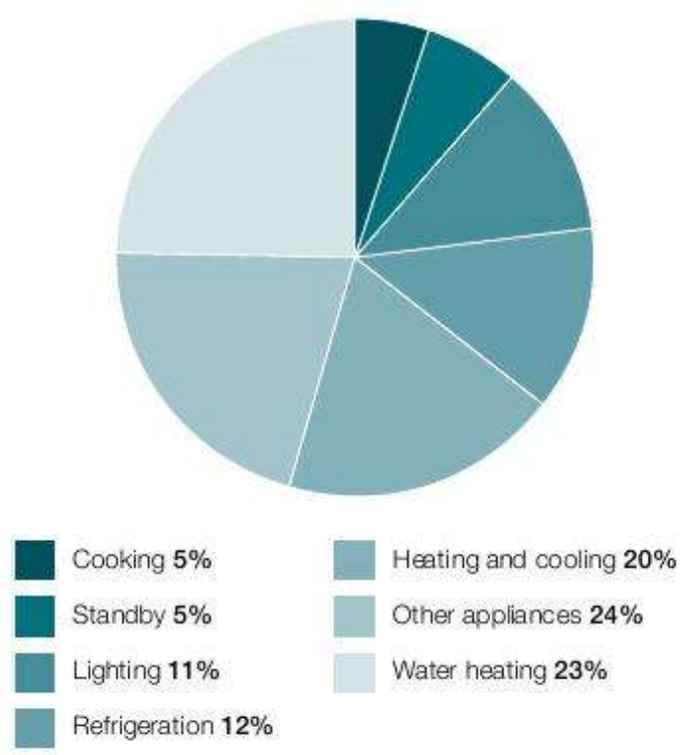
Space heating and cooling and water heating account for nearly 63 per cent of household energy use.

Heating and cooling, appliances (such as refrigerators, televisions and computers) and water heating use the most energy in the home and generate the most greenhouse gas emissions.

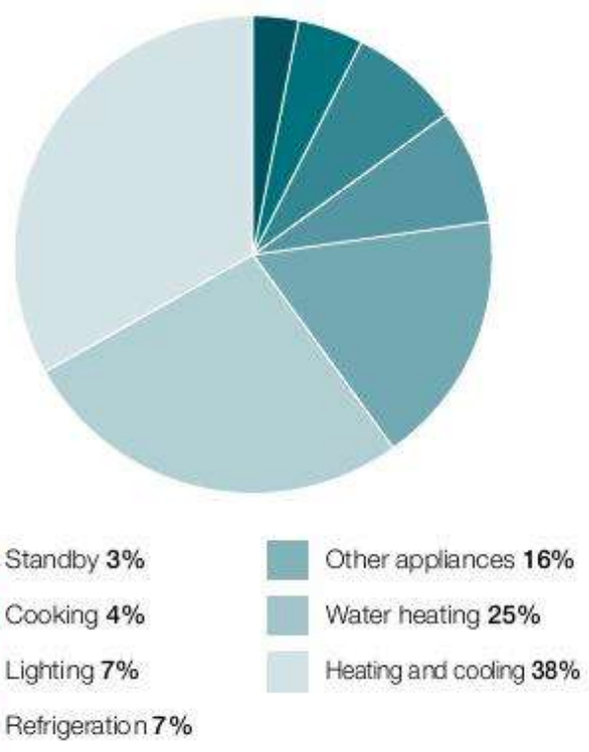
Look for ways to reduce consumption through efficient use.

Monitor your energy bills and check for unexpected increases and how they can be reduced through more efficient energy use.

Greenhouse gas emissions from home energy use (Baseline Energy Estimates, 2008)



Home energy use (Baseline Energy Estimates, 2008)



The percentage of greenhouse gas emissions from home energy use depends on the carbon intensity of the energy source. For example, the carbon intensity of electricity is much higher than that of natural gas or wood per unit of delivered energy. Therefore, although heating and cooling is the highest energy use in the home, as natural gas is typically used for heating, it is not the highest greenhouse gas emitter.

The NABERS Home Rating tool can be a valuable tool to track energy and water use.
[See: 1.5 rating Tools]

ENERGY SOURCES

The main sources of household energy are electricity, natural gas and wood. A small number of homes use LPG, coal, coke or heating oil.

Energy can come from either renewable or non-renewable sources. Renewable sources such as solar, wind and hydro-power are naturally replenished and produce very few greenhouse gas emissions when operating. Non-renewable energy comes from diminishing stocks of fossil fuels and can produce large amounts of greenhouse gases.

Most electricity comes from coal fired power stations that release high levels of CO_2 and other pollutants into the environment. Losses in the transmission system from the power station to your home also create inefficiency.

Using natural gas results in only about one third of the greenhouse gas emissions compared to grid electricity.

Hydro electricity generated in Tasmania directly produces almost no greenhouse gas. However, the construction of new large-scale hydro-electric dams can be sources of large amounts of greenhouse gas and may have other adverse environmental effects.

Electricity

Electricity is the most widely available energy source and the only one able to run the full range of household appliances. But it is the most greenhouse intensive. It is also usually the most expensive per unit of energy used.

Consumers of grid electricity can help offset environmental impact by purchasing 'GreenPower'.

GreenPower is often the easiest and least expensive way to purchase electricity from renewable sources.

GreenPower™ Accredited Renewable Energy



Most electricity retailers have an accredited GreenPower option for a slightly higher unit charge. By choosing GreenPower, you are supporting the expansion of renewable systems. Contact your electricity supplier or visit www.greenpower.gov.au.

Households can generate their own electricity from renewable sources. These can be either grid interactive or self sufficient, stand alone systems. [See: 6.6 Renewable Energy]

Renewable electricity systems are initially expensive to install but have low operating costs and minimum environmental impact. Government rebates are available to offset the initial costs.

Electricity consumption can be reduced through energy efficiency and fuel switching. As energy costs rise and awareness of environmental issues increases, the value of houses with energy efficient features and renewable energy supply is expected to rise in the market.

Gas

Natural gas is less expensive to use than electricity and produces fewer greenhouse gas emissions. However, gas is also a non-renewable fuel. It is largely used for water heating, room heating and cooking. It can, however, also be used for clothes drying, as a vehicle fuel and even for refrigeration.



Natural gas is not available everywhere but liquefied petroleum gas (LPG) can be used instead. It produces similar greenhouse gas emissions to natural gas but must be transported by tanker or in cylinders, which adds to its financial and environmental cost. LPG costs more than twice as much to use as natural gas.

Adequate room ventilation is required when using unflued gas appliances. [See: 3.3 The Healthy Home]

Wood

Wood can be a renewable energy source if it comes from sustainably managed forests. Its use should make no net contribution to greenhouse gases if trees are planted to replace those used, but fossil fuels are usually used in collection and transportation.

In many non-urban areas, wood is widely used for heating, cooking and heating water. Wood is generally not a desirable energy source for urban areas due to local air pollution problems. Some efficient, low pollution stoves are available but are more expensive.

Other renewable sources

Solar water heaters and passive solar building techniques reduce the need to use non-renewable energy sources. [See: 4.1 Passive Design Introduction; 6.5 Solar Hot Water]

Other energy sources

Other fuels such as coal, coke, briquettes and heating oil are available but should only be used in small quantities. Air quality is an issue in urban areas for all solid fuels.

The following, in order of priority, will minimise environmental impacts:

1. **Renewable sources** – such as GreenPower, use of on-site renewable electricity generation and solar hot water systems.
2. **Hydro-electricity** – available in Tasmania.
3. **Natural gas** – or LPG when not available.
4. **Wood from sustainable sources** – in urban areas be aware of transport and air pollution impacts.
5. **Grid electricity** – available on the mainland.

EFFICIENT ENERGY USE

Using energy efficiently is the best way to reduce energy bills and environmental impacts while maintaining or even improving comfort levels.

Some solutions cost nothing at all. Most investments in energy efficiency will pay for themselves through lower energy bills.

Hot water

Choose the most efficient hot water service and the best energy source to meet your needs. Solar, gas and electric heat pump systems produce far fewer greenhouse gas emissions than conventional electric storage systems. Gas boosted solar is the most greenhouse efficient form of water heating.

Locate water heaters close to those areas where hot water is used.

Showers usually use the most hot water in a home. Install WELS 3 Star rated water efficient showerheads. The WELS scheme ensures they will provide a satisfying shower.

Set the thermostat between 60 to 65°C on storage hot water systems and 50°C on instantaneous systems.

Insulate hot water pipes.

Turn off the hot water system when on holidays.

Hot water accounts for about 25 per cent of household energy use.

Put a timer or manual boost switch on the electric booster of solar water heaters and on peak electric storage systems to avoid heating water when not needed. [See: 6.5 Hot Water Service]

Heating and cooling your home

Use high efficiency gas, electric heat pump or wood heaters (where appropriate) for room heating rather than electric convection and radiant heaters. Radiant heaters are suitable for bathrooms when used for short periods of time.

Use passive design principles to increase comfort and minimise the need for heating and cooling.

Gas heaters and room air conditioners have energy rating labels. Choose the right sized heater or air conditioner for your needs with the most stars on the label.

Avoid centralised systems unless your home is well insulated. Ensure centralised systems have zone controls and thermostats.

Use ceiling fans instead of air coolers. If cooling is required, use evaporative systems in low humidity areas.

If air conditioning is needed choose high efficiency models.

Cooking efficiently

There are currently no energy rating labels for cookers to help choose the most efficient models.

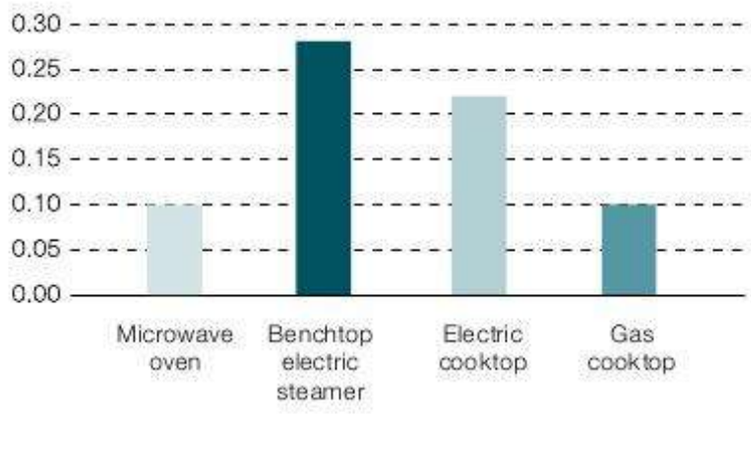
In general, choose gas cooktops rather than electric. They are often cheaper to use, and have more responsive controls and produce less greenhouse gas emissions.

A gas cooktop will produce less than half the greenhouse gases of a standard electric unit.

A gas oven will also usually produce less greenhouse gas than an equivalent quality electric model.

However some very efficient electric cooktops and ovens are available. Ask your retailer or the manufacturer for information.

Kilograms of greenhouse gas generated by cooking vegetables



When using gas, kitchen ventilation must be adequate. Use a range hood vented outdoors to get rid of combustion gases and steam.

Fan forced ovens are about 30 per cent more efficient than conventional units, which can waste up to 90 per cent of the energy used.

Some electric ovens can be divided into compartments for cooking small items.

Look for ovens with high levels of insulation and triple glazed, low-e coated windows.

Avoid opening the oven door unnecessarily when cooking. Make sure the door seal is clean and in good condition.

Use a microwave when possible rather than an oven, as they use less than half the energy.

Try not to over fill the kettle. Boil only the amount of water needed.

Use a kettle or gas cooktop to boil water rather than a microwave oven or electric cooktop.

Efficient cooking methods such as using pots with fitted lids, simmering instead of boiling and using a pressure cooker will save energy.

Match the size of pots to the size of the element or flame.

Cook outside on hot days if possible to avoid heating the house.

Appliances

Electrical appliances account for about 30 per cent of household energy use.

When purchasing white goods (refrigerators, freezers, clothes washers, clothes dryers and dishwashers) look for the Energy Rating label. This label gives a star rating and annual energy consumption for the appliance. The more stars, the more efficient the appliance.

Choose an appliance with the highest number of stars. Sometimes an efficient appliance may cost a little more to buy, but it will soon pay for itself in reduced energy bills.

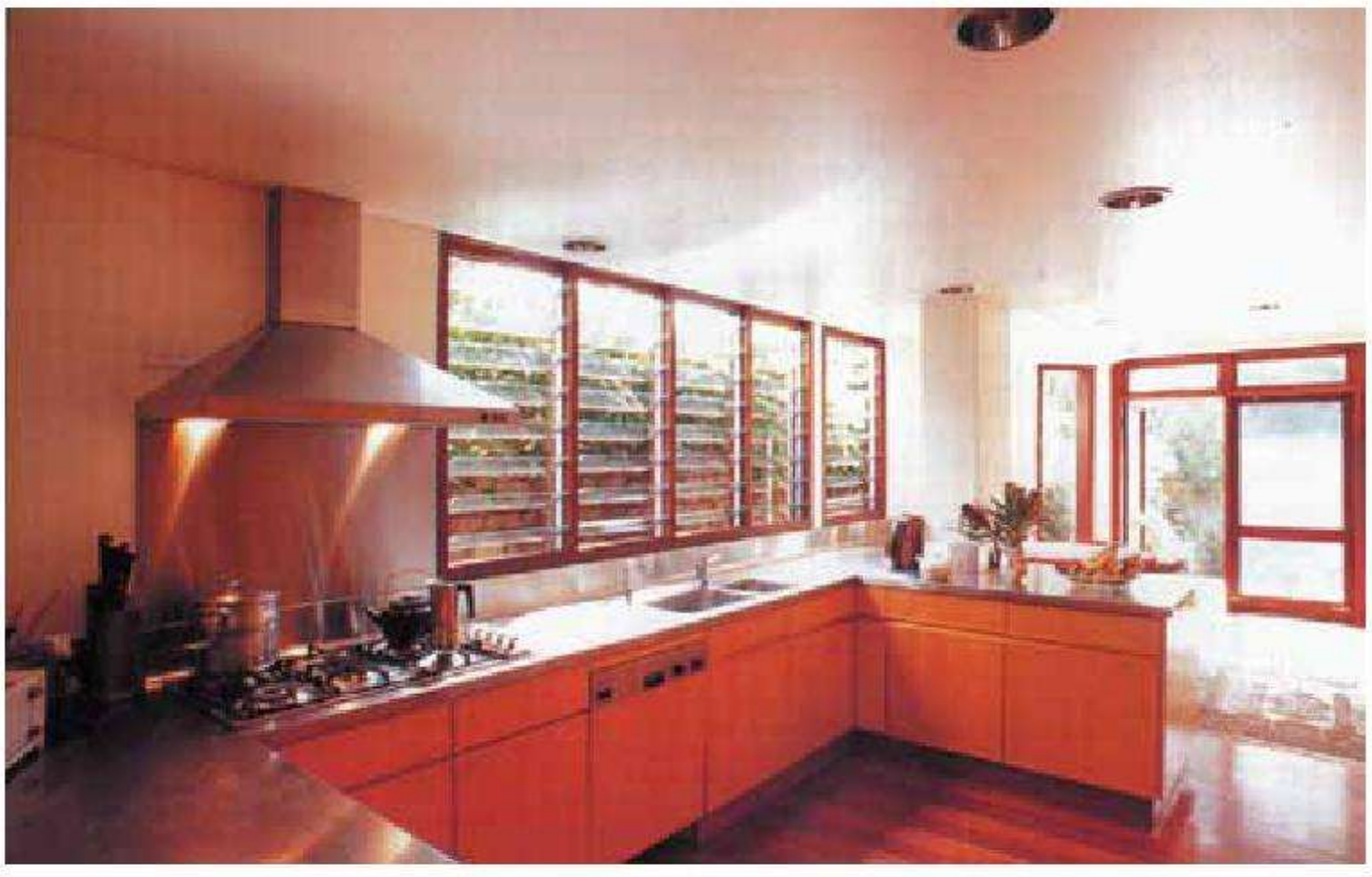
Buy appliances that are the right size for you. A larger model will use more energy than a smaller one with the same star rating. Always check the energy label for the number of kWh (units of electricity) used per year.

Choose appliances with a WELS star rating for water efficiency. [See: 7.2 Reducing Water Demand]

Choose appliances with energy or water saving features, such as clothes washers with cold wash cycles, economy or 'eco' cycles and load size selection.

Avoid using appliances unnecessarily. Dry clothes on a line rather than in the clothes dryer.

Follow the manufacturer's instructions for defrosting fridges and freezers.



Use appropriate load sizes for clothes washers and clothes dryers.

Use cold wash cycles and other energy saving features.

Maintain your appliances according to the manufacturer's instructions. An appliance in poor condition usually uses more energy than one in good condition. [See: 6.4 Appliances]

Other equipment

There are many small items around the house that can use a lot of energy over a year, such as pool filter pumps, electric towel rails and computer games. Ensure they are not left on unnecessarily.

Lighting

Use fluorescent or compact fluorescent lamps – they are energy efficient and long lasting.

Avoid using low voltage downlights for general lighting as they are not energy efficient.

Compact flourescent replacements for down lights are becoming available.

Turn off lights when not needed.

Use timers or sensors on outdoor security lights.

Use separate switches for each light fitting.

Consider using solar lighting for outdoor areas.

Use the minimum wattage lamp to provide sufficient light.

Fluorescent bulbs use about one quarter of the energy of normal bulbs.

Use task lighting to supplement general lighting if needed.

Use well designed windows and skylights to provide natural light while keeping winter warmth in and summer heat out. [See: 4.10 Glazing; 4.11 Skylights; 6.3 Lighting]

Reducing stand-by energy consumption

Standby energy is drawn when some electrical equipment is not actually being used, such as when the TV is turned off with the remote control rather than with the switch on the set or at the wall. It is sometimes used to power digital displays or maintain memory settings, but often it is just wasted energy.

Be aware of the standby energy use of electrical equipment such as TVs, videos, clocks, computers, faxes, microwaves, security systems, battery chargers and power packs.

Standby energy use can account for 10 per cent or more of household electricity use.

Some appliances, such as videos and microwaves with digital displays, can use much more energy over a year in standby than in actual operation.

Standby energy consumption can be reduced by using appliances endorsed with the ENERGY STAR® logo.

ENERGY STAR® is an international standard for energy-efficient electrical equipment developed by the US Environment Protection Authority.

The standard only applies to stand-by energy use and does not cover energy used during operation, although ENERGY STAR® equipment is often more efficient in operation too.

The program applies to home entertainment equipment such as computers, monitors, printers, TVs, DVD players, audio equipment and faxes.

The ENERGY STAR® function is not always enabled on new appliances. Ask your retailer to enable it or follow the directions in the instruction manual. Switch equipment off at the power outlet when possible because even ENERGY STAR® equipment still uses some standby power.

More information is available on the ENERGY STAR® website at www.energystar.gov.au

Home office and entertainment equipment

Ensure equipment is ENERGY STAR® compliant and make sure that energy efficiency features are enabled.

Large screen TVs use more energy than those with smaller screens.

If buying a computer consider buying a laptop – they require less materials to make and less energy to run.

An LCD screen for desktop computers will use less energy and take up less space.

Switch off computers and printers if you won't be using them for half an hour or more.

Look for printers and faxes that can use recycled paper. Use recycled ink and toner cartridges. Re-use blank sides of used paper.

Switch off equipment at the wall instead of leaving in standby mode, especially when you go on holiday.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on energy efficiency, including what rebates are available.
www.gov.au

Australian Energy Star, Australian Government
www.energystar.gov.au

Australian Greenhouse Office (2005), *National Greenhouse Gas Inventory 2005*.
www.greenhouse.gov.au/inventory/2005/pubs/inventory2005.pdf

Department of the Environment, Water, Heritage and the Arts. 2008. *Australian Residential Sector Baseline Energy Estimates 1990 – 2020*.

Energy Rating
www.energyrating.gov.au

Global Warming Cool It, Australian Government
www.greenhouse.gov.au/gwci

Principal author:
Geoff Milne

Contributing author:
Chris Riedy

Heating and Cooling

Very little energy is required to make a well designed house comfortable. A highly efficient house may need no non-renewable energy inputs for heating and cooling. Such homes are possible across much of Australia.

Even for existing homes there are many ways to reduce energy bills, improve comfort and help the environment.

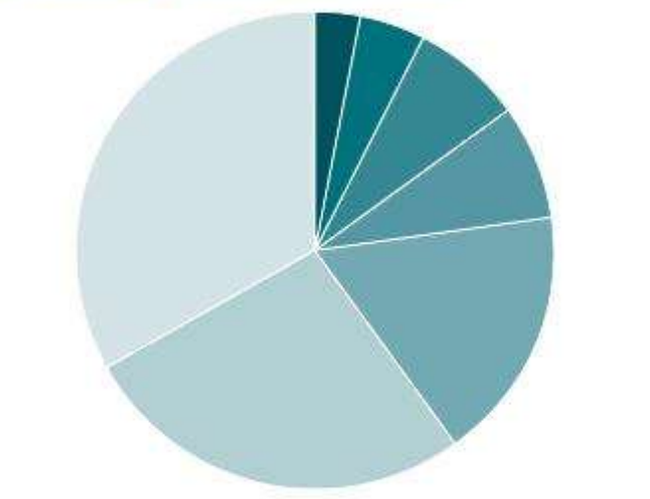
Mechanical heating and cooling should never be used as a substitute for good design.

It is better to invest more money in an energy efficient building than spend it on heating and cooling.

The principles of thermal comfort and the importance of air movement, humidity and radiant heat are explained in the passive design section. [See: 4.1 Passive Design]

Heating and cooling account for 38 per cent of household energy use making it the largest energy user in the average home.

Home energy use
(Baseline Energy Estimates, 2008)



HEATING

Use passive design principles to increase comfort and reduce the need for heating. Insulate the roof, walls and floor, seal off draughts, let in winter sun and draw curtains at night. This applies to existing homes as well as new homes. [See: 4.1 Passive Design]

There are two main types of heating – radiant and convective.

Radiant heaters predominantly heat people and objects by direct radiation of heat. Convective heaters warm and circulate the air in a room.

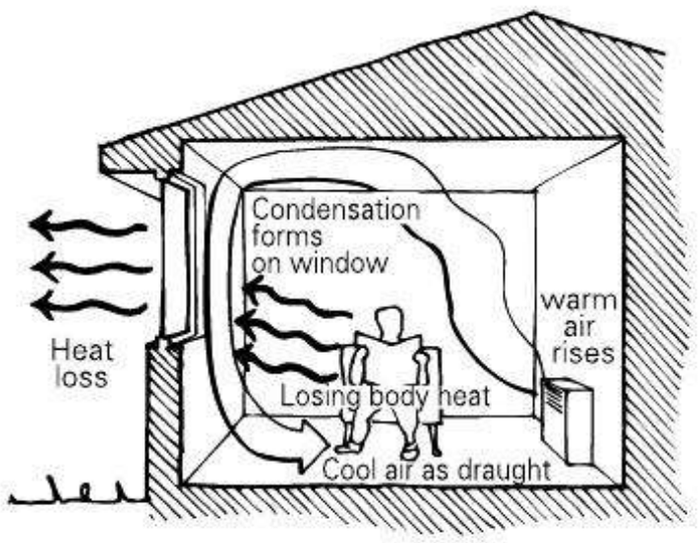
Other forms of heating, such as heated floors, also heat by conduction through direct contact.

Different forms of heating are best in different circumstances:

> In larger rooms with high ceilings, a combination of radiant and convective heating is best.

> In small rooms, space convective heating is effective.

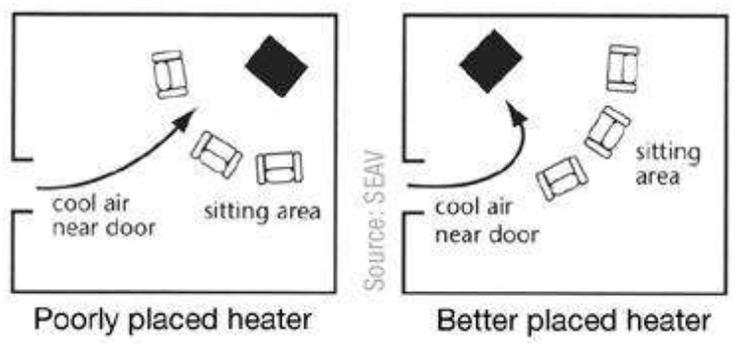
> In larger draughty rooms or bathrooms, radiant heating works best.



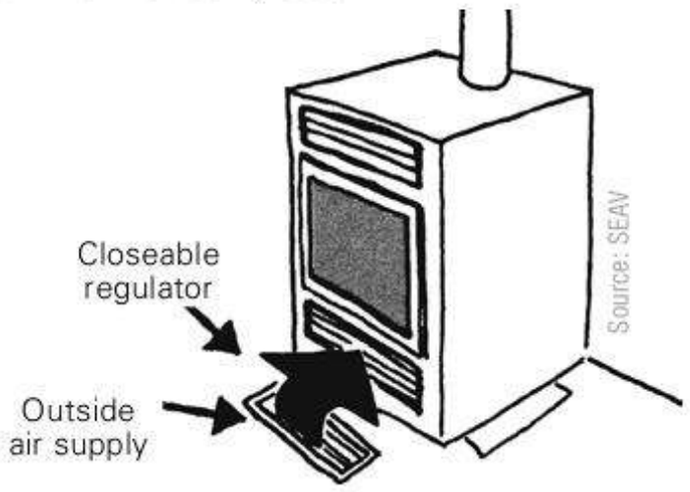
All heaters produce air movement as the hot air rises from the heater to the ceiling. Air is cooled when in contact with windows and poorly insulated walls. The cooled air falls and is drawn back along the floor to the heater.

Sitting in draughts created by air movement can make you feel much colder. Your body radiates heat through exposed windows making you feel cold. minimise draughts from windows and use heavy curtains with snug pelmets to stop convection and radiant heat loss. Always consider appropriate clothing to stay warm and reduce the effects of draughts.

Position your furniture to deflect or avoid draughts.



If you have a suspended floor, you can reduce the flow of air through the living space by putting a vent in the floor in front of the heater to supply air. But make sure it can be closed off when not being used.



Ask the following questions before buying a heater:

> Does the room need to be heated or will eliminating cold draughts and improving insulation be enough?

> How many rooms need to be heated?

> How big are they?

> How often and for how long will heating be required?

The Australian Consumers' Association provides an on line calculator to help you estimate what size heater you might need.

See: www.aca.com.au/cp/energy/quizheatingcalc.cfm, then talk to an expert who can give you appropriate advice.

Energy choices

Gas heaters and efficient reverse cycle heat pumps produce only one third the amount of greenhouse gas emissions of standard electric heaters.

Gas heaters and reverse cycle heat pumps have energy labels to help you choose the most efficient model. It should be noted that there are indoor air quality issues surrounding the use of unflued gas heaters.

Wood can be an excellent fuel because it is a renewable energy source, if sustainably harvested. However, air pollution from wood fires and the transport of firewood to urban areas are environmentally detrimental.

About 20 per cent of homes use wood for heating, but the wood is often obtained from unsustainable sources.

Use only sustainably harvested wood to avoid habitat destruction and rare species extinction.

Do not use treated timbers that may give off toxic pollutants when burned.

Burn wood only in high efficiency, low emission heaters.

CENTRAL HEATING

Central heating usually uses more energy than space heating as more of the house tends to be heated. However, an energy efficient house with central heating may use less energy than an inefficient house with space heating. Several types of central heating are available.

Central heating can often heat a whole house, whether individual rooms are occupied or not. Space heating heats the one or two rooms that are in use.

Ducted air

Hot air is circulated through roof or underfloor ducts, providing convective heat. Gas or a reverse cycle heat pump can be the heat source.

Design the system so that the extent of the area heated can be controlled. The system should include zoning to allow for shutting off heating to unoccupied areas. Ducted systems should be designed and installed by accredited experts.

Ducts should be the correct size and have adjustable outlets (registers). Ducts need to be larger if also used for cooling.

Insulate ducts to at least R1.5 and make sure all joints are well sealed. [See: 4.7 Insulation]

Floor outlets are often better than ceiling outlets for heating as they deliver heat to where it is most needed, but well designed ceiling outlets can work well.

A return air path from every outlet back to the central system is very important. Without it the warm air will escape and the system will suck cold air in, dramatically reducing the effectiveness of the system.

Hydronic systems

Hot water or coolant is circulated through radiator panels in rooms, providing a mix of convective and radiant heat.

Hydronic systems are usually gas fired but can be heated by a wood fired heater, solar systems or heat pump. Solar systems can use gas or wood heating as a back-up. Hydronic systems have the advantage of adaptability of energy sources as energy markets change.

Each panel or room should have its own control.

Low water content systems are best as they reduce energy use.

It is very important that the water circulation pipes are well insulated.

Exterior walls behind panels must also be insulated to prevent heat loss to the outside. Use wall cavity insulation, or a layer of installed reflective foil on the internal wall behind the panel.

In-slab floor heating

Concrete floors can be used to store heat from off-peak electric cables or hydronic pipes set into the slab. These are insulated during building construction or renovation.

Electric in-slab heating generally has the highest greenhouse gas emissions of any heating system.

The best system for minimising greenhouse gas emissions is hydronic pipes using:

> Solar with gas back-up.

> Efficient slow combustion wood heater with a wetback.

> Geothermal or water-body heat pumps.

In-slab systems provide a combination of radiant, convective and conductive heat.

In-slab systems are slow to warm and cool due to the high thermal mass of the slab, and are therefore unsuitable for houses where heating is only needed occasionally. They are ideal as back-up for passive solar heating of thermal mass on cloudy or extremely cold days.

Avoid heating areas of the slab which are exposed to the sun in winter.

Slab edges must be insulated. Ideally the entire slab should be insulated from the ground to minimise heat loss. Walls should be insulated from the slab to reduce heat loss.

Heating zones and thermostats are essential to reduce energy use.

The table below assumes well designed and efficiently operated systems. Running costs and greenhouse gas emissions are general and you should obtain expert advice before making decisions on which type is best for you.

Comparison of central heating system

SYSTEM TYPE	RUNNING COST	GREENHOUSE GAS EMISSIONS
Hydronic zoned with wood / solar heat source	low	very low
High efficiency ducted natural gas	low	low
Hydronic zoned natural gas or heat pump	low	low
Ducted reverse cycle heat pump	medium	medium
In-slab high off-peak electric	medium	high

SPACE HEATING

Electric heaters

These devices heat a smaller area – one or perhaps two rooms. There is a wide range available.

Electric portable heaters

Electric portable heaters can be cheap to buy but are expensive to run and sometimes ineffective. They include the following:

> Radiant heaters, such as bar heaters, are good for bathrooms as they provide almost instant heat direct to your body and do not directly heat air. Less warm air is lost when an exhaust fan is used compared to other heater types. No thermostat is fitted so a timer or switch should be used. Turn off radiant heaters when leaving the room for any length of time.

> Fan heaters heat the air and provide convective heat. Larger upright models are more effective. They can warm smaller rooms quickly. Some have thermostats to help reduce energy use.

> Convector heaters heat the air, which then rises naturally. They are not recommended for rooms with high ceilings or poor insulation levels or where there is a high ventilation rate.

> Oil filled column heaters provide a mix of convective and radiant heat but are slow to respond. Some have thermostats, timers and fans. They are more suitable for larger rooms with high ceilings.

Electric systems may produce high greenhouse gas emissions – up to six times as much as an efficient gas central heating system.

Electric fixed heaters

Reverse cycle heat pumps provide convective heat and are the most energy efficient electric heater.

Wall panel convectors use peak electricity and are expensive to run.

Off-peak electric storage heaters provide a mix of radiant and convective heat. They use bricks to store heat produced overnight using off-peak electricity. Unless carefully controlled they can lead to overheating in periods of milder weather.

Gas heaters

Gas portable heaters

Unflued portables can provide either convective or radiant heat and run on natural gas or LPG.

Adequate ventilation is needed to maintain good air quality, which can significantly reduce efficiency. An efficient externally flued heater is usually preferable but may not always be an option, particularly for tenants. In these cases, units are available which burn cleaner, producing lower combustion emissions, requiring less ventilation.

Unflued gas heaters often create condensation problems – usually at the opposite (coolest) end of the house. Care is needed to ensure they don't lead to mould growth.

The use of unflued heaters is restricted in some states.

Gas fixed heaters

Wall units and floor consoles can provide convective and/or radiant heat. They usually contain fans to circulate hot air. Most are flued, requiring less ventilation and producing fewer condensation problems.



In low humid climates, humidity trays may be required to maintain room humidity levels. These need to be topped up regularly.

Gas pot-belly stoves and fireplace inserts provide mostly radiant heat. High mass structures nearby can store and convert this to convective heat.

Wood and other solid fuels

Open fireplaces

Open fireplaces provide radiant heat, but are highly inefficient, with up to 90 per cent of the heat energy going up the chimney. Large amounts of cold air are drawn into the room to replace air lost up the chimney. They are the least efficient of all wood heating methods and produce the highest levels of air pollution. Open fires are better at producing ambience than heat.

Fireplace inserts are available in two forms:

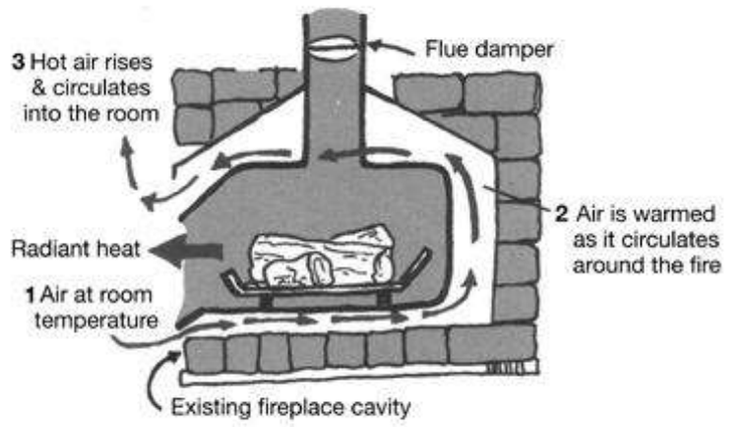
> Efficient slow combustion heater.

> Steel framed open fire.

They provide a combination of convective and radiant heat.

Open fire inserts are marginally more efficient than open fires as they draw more heat from the firebox through convection. They can also reduce problems with smoking chimneys.

However, inserts are still only about 30 per cent efficient and should only be used occasionally. Dampers are very important and must be closed when the fireplace is not in use to prevent heat loss.



Slow combustion inserts are up to 60 per cent efficient if they are installed correctly by sealing the chimney at ceiling level and providing vents back into the room to reclaim heat from the flue and case. If the wall behind the fireplace is external it should be insulated.

Non-airtight potbelly stoves provide mainly radiant heat and are only about 40 per cent efficient.

Slow combustion stoves and heaters provide convective and radiant heat and can be up to 70 per cent efficient. They are most suitable for large spaces that need heating for long periods. They can take a long time to heat up and cool down. Many can be fitted with a wetback to heat water.

All slow combustion stoves must comply with AS/NZS 2918 for flue gas emissions. Only approved slow combustion stoves should be installed.

Operating tips for wood heaters

Get a good fire going as quickly as possible. This will allow the heater to draw air and function properly, with little smoke production.

Allow a hot fire to burn for at least one hour before turning it down for overnight burn.

Avoid unnecessarily running your heater on low overnight. This will save a lot of wood and reduce creosote formation. High pollutant emissions are usually caused by operating wood heaters with the air supply closed off.

Load firewood with approximately 25mm gaps between the logs to let in adequate air and help to develop pockets of glowing coals.

Use only dry, untreated wood from sustainable sources.

Inspect your flue or chimney once a year for blockages such as bird's nests or creosote build up. Have it swept if necessary.

Check the seals around heater doors and ash-removal trays.

Close off chimneys when they are not being used, to prevent major heat losses through the chimney cavity.

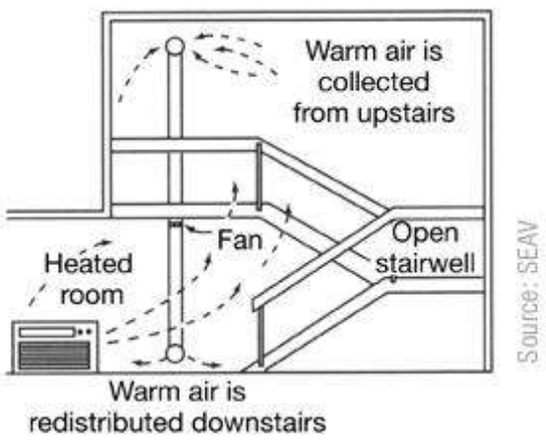
The table below assumes well designed and efficiently operated systems. Running costs and greenhouse gas emissions are general and you should obtain expert advice before making decisions on which type is best for you.

Comparison of space heating systems

SYSTEM TYPE	RUNNING COST	GREENHOUSE EMISSIONS
High efficiency natural gas	low	low
Slow combustion wood heater	low	low
Reverse cycle heat pump	medium	medium
Off-peak electric storage	low	high
Electric portable heaters and panel	high	high

Heat shifters

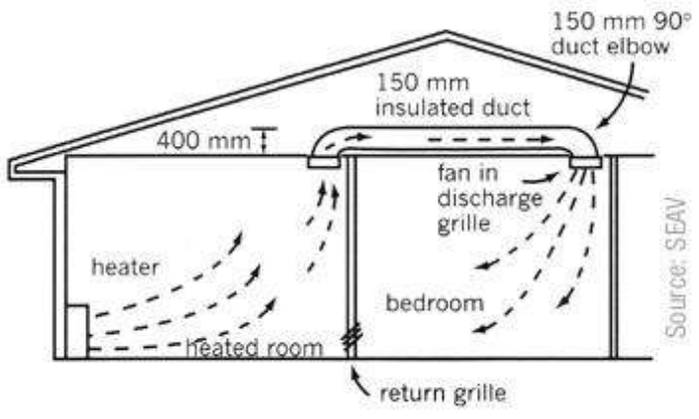
Heat shifters consist of a fan and ducting and cost little to run and install. They move air from warm areas to cooler areas.



Heat shifters redistribute warm air that collects upstairs back downstairs, or warm air from the ceiling back down to floor level.

They can also provide heat for rooms that only require low levels of heating, such as bedrooms.

Make sure the fan isn't left running when not needed, and that there is a return air path back to the heat source.



COOLING

Use passive design principles to increase comfort and reduce the need for cooling. Insulate your home and shade windows from summer sun. Mechanical cooling should never be used as a substitute for good design. [See: 4.6 Passive Cooling]

Mechanical cooling devices

Points to consider when choosing cooling systems:

> Does the air require cooling or will creating a cooling breeze be enough?

> How big an area needs to be cooled? A single living area is often sufficient to survive a few days of summer heat wave in many climates.

> How often and for how long is cooling needed?

> Is space cooling or a whole house ducted system required? Whole house systems are more expensive to buy and generally cost more to run.

There are many variables to consider and expert advice should be sought before proceeding with the design or purchase of a mechanical cooling system.

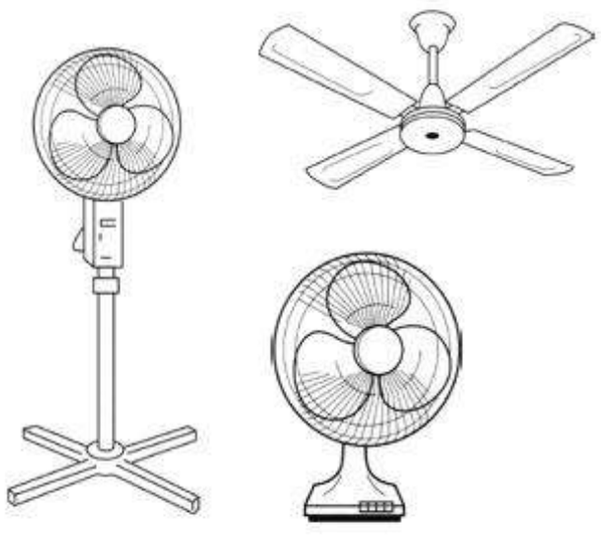
Fans

The three major methods of mechanical cooling are fans, evaporative coolers and air conditioners.

Fans should be the first choice for mechanical cooling.

With good design and insulation, fans can often provide adequate cooling for acclimatised residents in all Australian climates. They save money and the environment.

Fans are the cheapest to run and have the least greenhouse impact, while air conditioners are expensive to run and produce more greenhouse gas.



Fans cost little to buy and run. They circulate air but do not reduce temperature or humidity.

Portable table and floor fans or fixed ceiling and wall models are available.

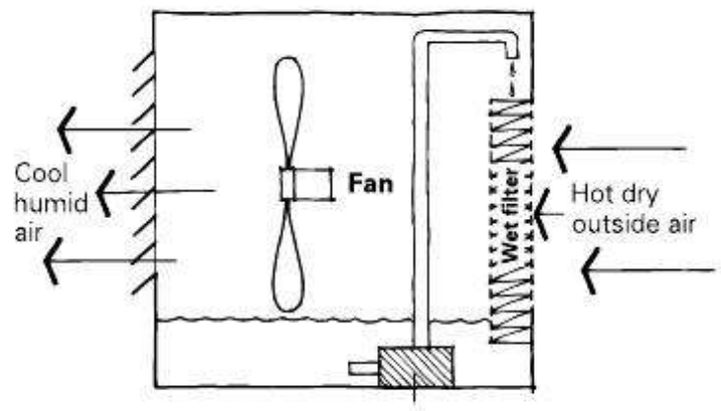
Fans are useful in combination with an air cooling system as the extra air movement provides comfort at higher thermostat settings.

Evaporative coolers

Your second choice for mechanical cooling should be evaporative coolers.

Evaporative coolers work best in low humidity as the air has greater potential to absorb water vapour. They are significantly less effective in climates with high humidity.

They will cool the air to just above the 'wet bulb' temperature. You can check with your local bureau of meteorology to see if the 'wet bulb' temperature is at a comfortable level for you in summer.



Pump to circulate water through filter

Some doors and windows must be open for evaporative cooling to allow the hot air to escape from the house. Smaller and older units do not use a thermostat, just a fan speed control. Newer, whole-house systems can be fitted with electronic thermostats and timers.

Operating costs can be low as only the fan uses energy. Evaporation provides the cooling energy. However, many units have inefficient fans that consume more energy than necessary.

Evaporative coolers use water on the cooling medium. You should check with your council to see if there are ant restrictions on using water for evaporative cooling.

Purchase costs are moderate.

Care is needed when using portable units not to place them next to open windows and doors that can let in a lot of heat on a windy day.

Portable units have to be topped up with water regularly, about four litres per hour. For central systems water use can be 25L or more per hour on hot, dry days and this needs to be considered in water restricted situations. Make sure the bleed-off rate isn't excessive – ask the installer to set it to the recommended minimum.

Window and door mounted systems also exist.

Close off ducts and cover the roof unit in winter to reduce heat losses.

Refrigerated coolers (air conditioners)

If thermal comfort cannot be achieved with passive design, fans or evaporative cooling, air conditioning should then be considered.

While normally giving a higher degree of comfort, air conditioning consumes more energy and creates more greenhouse gases than fans and efficient evaporative cooling systems.

Air conditioning can provide comfort in any climate.

For efficient air conditioning, the house or room should be sealed and highly insulated with bulk and reflective insulation. Windows must also be shaded from the summer sun. [See: 4.4 Shading; 4.7 Insulation]

Purchase costs are higher than evaporative coolers.

Efficiency varies between units and models.

Systems using inverter technology can show energy savings of up to 30 per cent vs standard units, however, are more expensive. The Australian Greenhouse Office lists which products are regulated by Energy Labelling Programs and Minimum Energy Performance Standards. See www.energyrating.gov.au

Always choose the most efficient model for your application.

Air conditioners are available as portable, wall, window, split and ducted systems.

Correct sizing of air conditioners is very important. Always have a cooling load calculation done by an expert before purchasing. The Australian Consumers' Association has an on-line calculator as a guide to the size system you might need. See www.choice.com.au/calculators/quizcoolingcalc.asp

The Australian Institute of Refrigeration Air Conditioning and Heating (AIRAH) has a website that can assist you in selecting the appropriate cooling options. See www.fairair.com.au

Operating tips

Shade outdoor components from direct sun.

Some units are noisy in operation. Split systems (where the compressor is outside) are quieter inside but consider your neighbours when locating external components.

Reverse cycle models can also be used for heating. Units that use electric heating elements cost more to run and produce more greenhouse gases.

Adjust louvres to point cold air towards the ceiling if possible because cool air falls.

For ducted systems, install a zoning system so only rooms requiring air conditioning are cooled.

Purchase systems that have controls such as timers to schedule activation and shut off.

Never set the thermostat at a temperature below what you require. Setting it lower does not make the unit cool faster.

Always aim to set the thermostat as high as possible.

Types of air conditioners

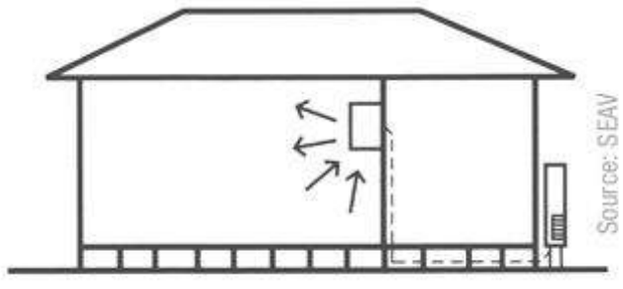
Portable split units

Portable split units consist of separate indoor and outdoor components connected by a flexible hose that is passed through a partially opened window or door. They plug into a standard power outlet. They are generally not as efficient as other types of air conditioners, but are suitable for small rooms up to about 20m^2. Always check the energy rating label.

Through wall/window units

Through wall/window units are placed in an existing external window or a hole made in an external wall. Smaller units can use a standard power outlet, but larger ones may need special wiring.

They are generally less efficient than fixed split systems and suitable for single rooms up to about 50m^2.



Split system unit.

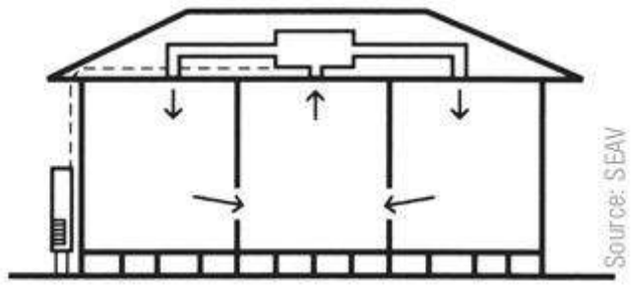
Fixed split systems

Fixed split systems are generally the most efficient domestic air conditioners. The indoor wall or floor mounted unit can be up to 15m from the outdoor compressor.

Multi-split systems have more than one indoor unit running off the outdoor compressor.

Ducted units

Ducted units are used to cool large areas or an entire house.



Ducted unit.

Ducts must be well insulated, to at least R1.5, and joints sealed to prevent condensation and leakage. The roof should have reflective foil insulation installed and be vented to dispel hot air.

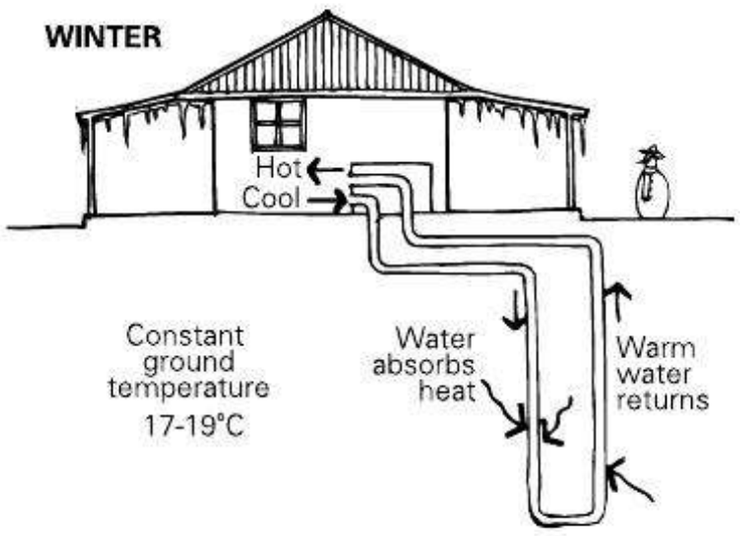
Systems should be zoned to cool only those areas occupied and to allow different conditioning in living and sleeping areas.

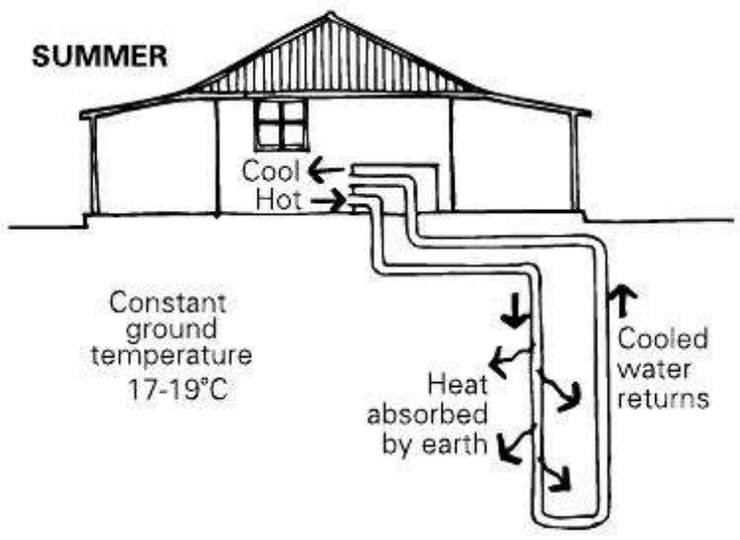
Alternative heat exchangers

Reverse cycle air conditioners, in both cooling and heating modes, mostly use an air to air heat exchanger, like a refrigerator. This dissipates heat extracted from the room to the outside when cooling or from the outside air into the room when heating.

In colder climates, it is important to ensure the unit is properly selected in the heating and cooling modes.

Air to water or air to ground (also called geothermal) exchangers are far more efficient. Heat exchange pipes are run through a body of water or deep into the ground where the temperature is relatively stable all year round.





Geothermal systems are highly efficient, producing up to four units of heat output for each unit of electricity input. They can also be used to run the hot water service.

Although expensive to install, depending on whether a bore or shallow trench is used, they have very low running costs.

They are ideal where there are large heating and/or cooling loads, and are most suitable for multi-housing developments.

PRACTICAL TIPS FOR HEATING AND COOLING

Do not leave heating and cooling appliances on overnight or when you are out, although slow combustion stoves can be left on in very cold weather. If you must have the house comfortable when you arrive home, ensure you have a timer and turn your system on about 15 minutes prior to your return.

Locate thermostats in the most used rooms and away from sources of heat and cold.

Each degree of extra heating in winter or cooling in summer will increase energy consumption by about 5 to 10 per cent. Set the thermostat to 18° to 20°C in winter and 25° to 27°C in summer.

Dress appropriately for the weather. Putting on a sweater is better than turning the heater up.

Maintain your heater. Keep reflectors shiny and free of dust. Clean air filters regularly.

Service all heaters and coolers according to the manufacturer's instructions. Pay special attention to air filters.

Close windows and doors in areas where a heater or air conditioner is on unless ventilation is required for un-flued gas appliances.

Close drapes or blinds, especially in the evening when you are heating.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on energy efficiency.
www.gov.au

Australian Consumer Association
www.choice.com.au

Australian Institute of Refrigeration, Air Conditioning and Heating
www.airah.org.au

Department of the Environment, Water, Heritage and the Arts (2008), *Australian Residential Sector Baseline Energy Estimates 1990 – 2020.*

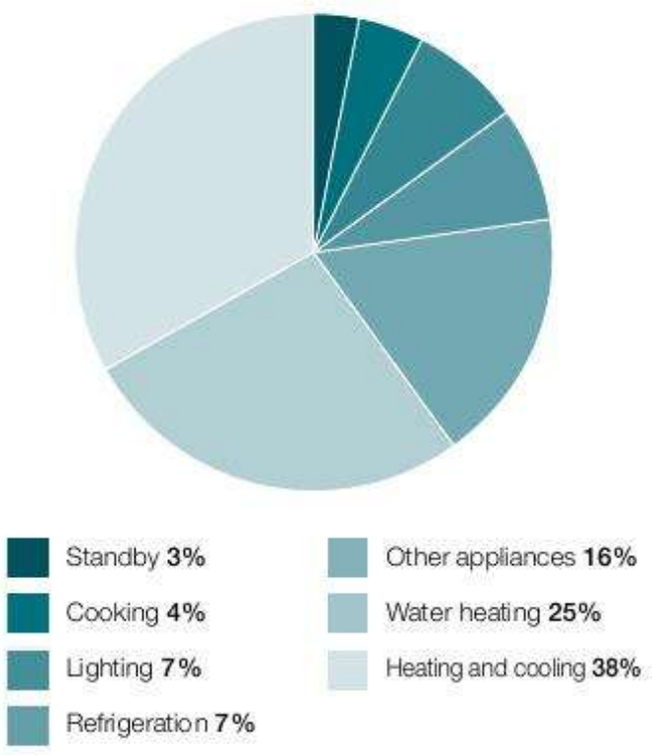
Energy Rating
www.energyrating.gov.au

Principal authors:
Geoff Milne
Chris Reardon

Lighting

Household lighting energy use in Australia has been rapidly increasing in recent years due to the construction of larger homes and the installation of more light fittings per home. Most homes could reduce the amount of energy they use for lighting by 50 per cent or more by making smarter lighting choices and moving to more efficient technologies.

Home energy use
(Baseline Energy Estimates, 2008)



In February 2007 the Australian Government announced plans to phase-out inefficient lighting technologies where viable energy efficient alternatives exist by introducing minimum energy performance standards (MEPS).

A range of lighting types are, or will be, required to meet these MEPS and be registered with relevant state regulatory authorities to be legally sold in Australia.

Under the first stage of the phase-out of inefficient incandescent lighting, an import restriction on traditional pear shaped light bulbs used for general lighting services came into effect from 1 February 2009, followed by a sales restriction from 1 November 2009. This sales restriction also applies to compact fluorescent lamps (CFLs) and extra low voltage (ELV) halogen non-reflector lamps that are not compliant with Australian Standards.

Other lamp types were required to meet the Standards from October 2010. The phase-out schedule can be viewed at www.climatechange.gov.au/what-you-need-to-know/lighting.

Good lighting is about more than just light levels. The same level of light can provide effective or ineffective lighting. Some lighting can make rooms flat and featureless even when it's bright. A lighting designer will be able to help you design more effective lighting, but make sure they know you also want an energy efficient system.

An efficient and effective lighting system will:

> Provide a high level of visual comfort.

> Make use of natural light.

> Provide the best light for the task.

> Provide controls for flexibility.

> Have low energy requirements.

TYPES OF LIGHTS

Incandescent lamps

Incandescent lamps or bulbs have for many years been the most commonly used type of lighting. They work by heating an electric element to white hot. They are inexpensive to buy and are available in a wide range of shapes and sizes, but their running costs are high.

Incandescent lamps are the least energy efficient type of lighting, and are being phased out where ever possible over the next few years.

Almost all of the electrical energy used by incandescent lamps is converted into heat rather than light. Standard incandescent bulbs only last about a thousand hours and must be regularly replaced. Incandescent lamps are most suitable for areas where lighting is used infrequently and for short periods, such as laundries and toilets.

Incandescent spotlights have built-in reflectors that reflect the light forward. Light output decreases over time as some of the tungsten in the filament evaporates and coats the glass bulb.

Halogen lights are also a type of incandescent lamp. The halogen gas in the bulbs prevents evaporated tungsten from depositing on the glass bulb. They are more expensive to buy but last up to four thousand hours. They can be either mains voltage bulbs (240V) or low voltage bulbs (typically used in downlighting).

A number of manufacturers are now producing traditional pear shaped lamps containing a halogen bulb. Although more efficient than traditional incandescent lamps, these still use much more energy than a fluorescent lamp. A 60 Watt standard lamp can be replaced by a 42 Watt halogen or a 12 Watt CFL for the same light output.

Ceiling fires have increased significantly with the more common use of downlights that penetrate the ceiling. Care must be taken to ensure that minimum clearances around downlights are maintained and that transformers are not underneath the insulation. Wherever possible, avoid recessed light fittings as these are a major source of heat loss. [See: 4.8 Insulation Installation]

Low voltage halogen lamps (commonly known as downlights) are not low energy lamps. While they are slightly more efficient than standard incandescent lamps of the same wattage, large numbers of these lamps are required to light a room because they emit a narrow beam of light. Each downlight also requires a transformer that can consume an additional 10 to 15 Watts on top of the bulb energy.

More efficient electronic transformers are available which use only a few Watts.

Because they are designed to be spot lights, downlights are not appropriate for general room illumination. They are most suitable for highlighting features such as paintings or for task lighting directly over a cooking area or study desk. If using downlights, fit lower wattage and more efficient bulbs. Efficient 35W lamps are available that produce as much light as a standard 50W lamp. You may even be able to replace a 50W lamp with a 20W lamp. Compact fluorescent lamps and LEDs designed for down lighting are an energy efficient alternative that should be considered.

Large numbers of low voltage halogen lamps are often fitted to light large spaces. This is an inefficient way to light a room and results in unnecessary energy consumption both through the lights themselves and the heat loss due to the holes in the ceiling and gaps in the insulation.



Fluorescent lamps

Compact fluorescent lamps (CFLs) and linear or tubular fluorescent lamps are the most energy efficient form of lighting for households. Fluorescent lamps use only about one quarter of the energy used by incandescent bulbs to provide the same light level.

Fluorescent lamps work by causing a phosphor coating on the inside of a glass tube to glow. Different types of phosphor emit different coloured light.

Although more expensive to buy, fluorescent lamps are much cheaper to run and can last up to twenty thousand hours. With careful design they can replace incandescent and halogen lights in most situations.

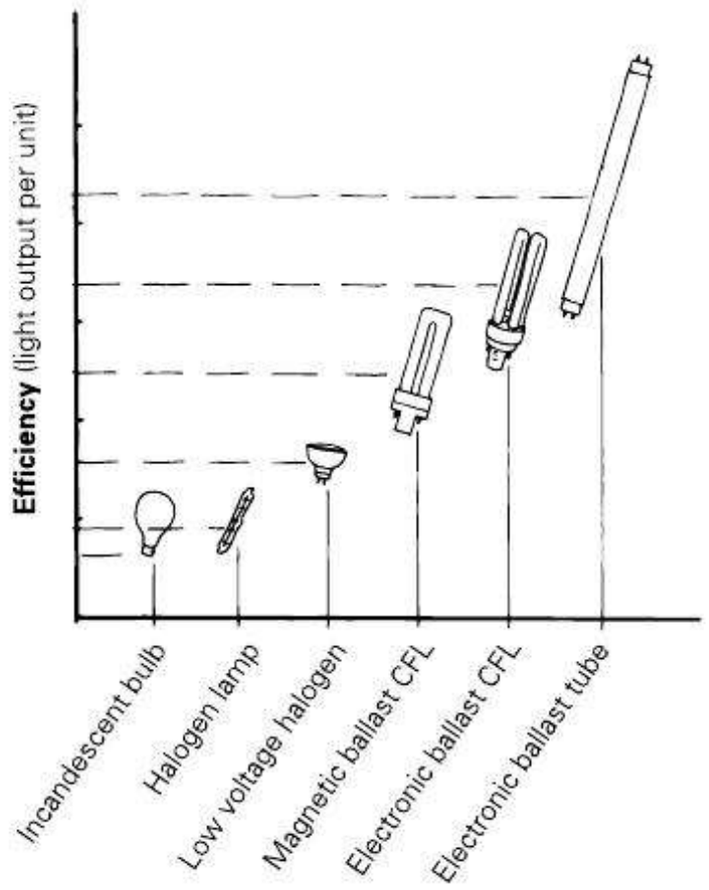
Fluorescent lamps are ideal for areas where lighting is required for long periods of time, such as the living room and kitchen, and for security lighting. They also produce less heat, helping keep your home cooler in summer.

There is much greater variation in the quality of fluorescent lamps sold in Australia than there is for other lighting types. In the past some poor quality fluorescent lamps were sold. To counter this, at the same time as bringing in regulations to phase out inefficient lighting the Government introduced a performance and quality standard for compact fluorescent lamps.

Fluorescent lamps are a developing technology and there have been many improvements in the performance of both linear and compact fluorescents lamps (CFLs) in recent years. Fluorescent lamps that cover a range of desired colours, including the 'warm' light of most incandescent globes (around 2700° Kelvin) are readily available. Cool white tubes have a higher colour temperature (around 5000° Kelvin) and are better suited to garages and workshops. A lamp of 3000°K to 3500°K is most appropriate for replacing halogen lamps. By selecting the appropriate wattage and colour fluorescent lamp a large range of lighting effects are achievable. When mixing different types of lighting in a room try to use similar colour temperatures.

There are two main types of fluorescent lamps – tubular and compact.

Tubular lamps, also known as fluorescent tubes, are available in a straight or circular style. They are cheaper to buy than CFLs, but unlike CFLs require special fittings. Tubes are ideal for kitchens, garages and workshops.



CFLs, also known as long-life bulbs, are usually designed to fit into conventional bayonet or screw fitting light sockets and so are the ideal replacement for inefficient incandescent bulbs. They come in a wide range of shapes and can replace incandescent lamps in most fittings, including heritage lighting and downlights.

CFLs can replace incandescent light bulbs in many light fittings. Not all light fittings are suitable for conversion to CFLs but most can be successfully converted with the right choice of lamp.

Most CFLs cannot be used with conventional light dimmers, but some can. Others have built in 'step' dimming, operated by the light switch. If you need to dim them make sure you buy the right lamp.

CFLs take a short time to reach full brightness – this varies from lamp to lamp but has improved with the new quality standard recently introduced. In situations where you need bright light instantly, such as in stairwells, you may wish to choose a brighter CFL. Look for one with a short start up time or use a halogen lamp.

Ballasts

All fluorescent lamps need a ballast to start them. For tubes, the ballast is separate and usually located in the light fitting. CFL ballasts are generally built into the lamp base. However, some CFLs have a separate tube and ballast. As the ballast is more expensive and lasts longer than the tube, the tube is detachable and can be replaced when it fails. Few domestic light fittings are currently specifically designed for separate ballasts, although desk lamps and some surface mounted models are available.

Ballasts can either be older magnetic types or newer electronic versions. Electronic ballasts are more expensive to buy, but are more energy efficient. They also start the lamp more quickly, produce less flicker and make the lamp last longer.

Magnetic ballast lamps cannot be dimmed, but some electronic units can.

Light Emitting Diodes (LEDs)

LEDs are currently used in countless applications including lighting displays in household appliances, mobile phone screens, and traffic signals.

LEDs for general lighting purposes are an emerging lighting technology which is expected be the future of household lighting. Most lighting companies are developing LED bulbs for direct replacement into normal fittings and a wide range is expected to be available in the next couple of years.

The claimed benefits of LEDs include lifetimes of up to 100,000 hours and potentially very high efficiency levels. However, there is currently a wide range of claimed efficiency levels on the market for LEDs and no agreed standard on how to measure the efficiency and light quality. The performance of some LED lamps is over-stated. The best LEDs on the market at the moment are about the same efficiency as CFLs.

One big advantage of LEDs is that in some cases they can be a direct replacement in low voltage halogen downlight fittings without needing any wiring changes. Before replacing

halogen fittings with LEDs, you will need to check the compatability with your existing downlight transformers.

If buying LEDs, choose a well known brand and look closely at the performance figures to make sure you would not be better off with a fluorescent equivalent.

Some current LED models have poor light quality and low light output but they are rapidly improving. LEDs can also be more expensive but as technology improves and demand increases, costs should come down.



Comparison of lighting costs

The cost of running a light is directly related to the wattage of the globe plus any associated ballast or transformer. The higher the wattage, the higher the running cost.

CFLs are the cheapest form of household lighting when the life cycle cost is considered.

The type of lighting you choose will affect the amount of electricity you use, your lighting bill, and your greenhouse gas emissions.

EFFICIENT LIGHTING CHOICES

Choose the right light

The most energy efficient light is natural light. Well designed north-facing windows, skylights and light tubes let in light without adding to summer heat and winter cold. Light coloured interior surfaces, especially in south-facing rooms and hallways, reflect more light and reduce the level of artificial lighting required.

Most rooms need two types of lighting. General lighting is needed for all over illumination. Task lighting is used to illuminate specific areas such as benchtops and desks. Different light bulbs and fittings should be used for these two purposes. Accent lighting can also be used for decorative or dramatic effects.

Pendant or surface-mounted light fittings can be used to provide general lighting. Use desk, table or standard lamps where most light is needed, such as for reading, so less lighting is required in the rest of the room.

Use fluorescent lights where lighting is required for long periods of time, such as living rooms, over kitchen benches or on desks.

The light output of CFLs is reduced at low temperatures, so they may not be suitable for outside use in very cold areas, or you may need to use a higher wattage lamp.

Incandescent lamps are inefficient and so will not be available in the future for general lighting. However, some specialty use incandescents will continue to be sold until energy efficient alternatives become available.

Downlights are designed for spotlighting as they provide bright pools of light rather than general illumination. Up to six downlights may be required to light the same area as one pendant light. Think about other ways of lighting with fluorescents before installing halogens. If used, fit lower wattage and more efficient bulbs.

Choose light fittings that allow most of the light through so a lower wattage lamp can be used. Some light fittings can block 50 per cent or more of the light.

Switches and controls

Provide multiple switches to control the number of lights that come on at any one time. Using one switch to turn on all the lights in a large room is very inefficient. Place switches at the exits from rooms and use two-way switching to encourage lights to be turned off when leaving the room.

'Smart' light switches and fittings use movement sensors to turn lights on and off automatically. These are useful in rooms used infrequently where lights may be left on by mistake, or for the elderly and disabled. Make sure they have a built-in daylight sensor so that the light doesn't turn on unnecessarily. Models which must be turned on manually and turn off automatically, but with a manual over-ride, are preferable in most situations.

Use timers, daylight controls and motion sensors to switch outdoor security lights on and off automatically. Similar controls are particularly useful for common areas, such as hallways, corridors and stairwells, in multi-unit housing.

Some controls are not compatible with fluorescent lamps so make sure you buy one that is.

Consider using solar powered lighting for garden and security lights.

Modern dimmer controls for incandescent lights (including halogens) save energy and also increase bulb life. However, reducing light output to 50% will only save about 25% of the energy. If you find that you dim some lights most of the time, you would be better off replacing them with lower wattage bulbs.

Most standard fluorescent lamps cannot be dimmed, but special dimmers and lamps are available. When installing new light fittings and controls ensure they are compatible with CFLs.

Use lights efficiently

> Rooms are often excessively lit. Make sure you are not using a higher wattage bulb than is necessary.

> Turn off unnecessary lights, including fluorescent lamps, especially if leaving a room for more than ten minutes.

> Clean light fittings regularly to allow more light to pass through.

> Decorating with light coloured finishes and furnishings can allow lighting levels to be reduced.

> Install lights appropriate for the location – ideally maximising natural light, reducing the number of holes in the ceiling and insulation, and with switches in easy-to-use locations.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on energy efficiency.
www.gov.au

Australian Consumer Association
www.choice.com.au

Department of the Environment, Water, Heritage and the Arts (2008), *Energy Use in the Australian Residential Sector 1986-2020.*
www.energyrating.gov.au/library/details2008-energy-use-aust-res-sector.html

Energy Efficient Lighting, Australian Government
www.climatechange.gov.au/what-you-need-to-know/lighting

Lighting Council Australia
www.lightingcouncil.com

ReNew: technology for a sustainable future magazine, *Lighting Buyers Guide*, Issue 94
www.renew.org.au

The Basics of Efficient Lighting – Lighting Reference Manual.
www.energyrating.gov.au/library/details2009-ref-manual-lighting.html

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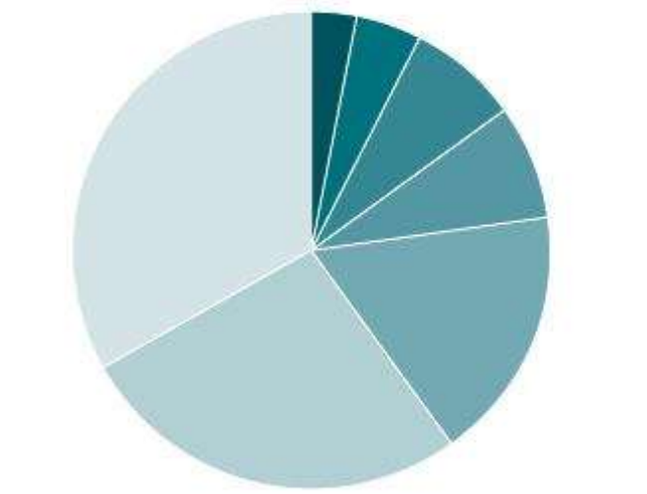
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Last updated:
November 2010

Appliances

Household appliances account for a substantial portion of household energy consumption and greenhouse gas emissions. This fact sheet outlines ways to use appliances efficiently.

Home energy use
(Baseline Energy Estimates, 2008)



By selecting appliances carefully you can save money and reduce your environmental impact without compromising lifestyle.

CHOOSING AND USING WHITE GOODS

Apply the following guidelines

Avoid buying appliances that you don't really need.

If you need to buy an appliance, choose one that is the right size for your needs and is as efficient as possible. Appliance rating schemes can help you to select the most efficient appliance, see over page.



Operate appliances efficiently by closely following the instructions.

Maintain appliances carefully.

Turn appliances off when not in use, preferably at the power outlet. Many appliances continue to draw standby power when switched off, contributing up to ten per cent of household electricity use. [See: 6.1 Energy Use Introduction]

Purchase the most efficient appliance available by choosing the highest rating product.

Seek advice from consumer groups, such as the Australian Consumers' Association.

Think about the best layout and placement of appliances to maximise efficiency when designing a new laundry or kitchen.

Do you really need it?

This is the first question to ask when you are thinking of buying an appliance. For example:

Do you really need a clothes dryer when you could use the sun and a clothesline without cost?

Do you really need a second fridge?

Can you think of a way to do without an extra appliance, to save both the cost of buying and running it and the environmental impact of its use, manufacture and disposal?

Size considerations

Buy the right sized appliance to suit your needs. A large model with the same star rating as a smaller model uses more energy and generates more greenhouse gas. Ensure the retailer considers what size appliance you need.

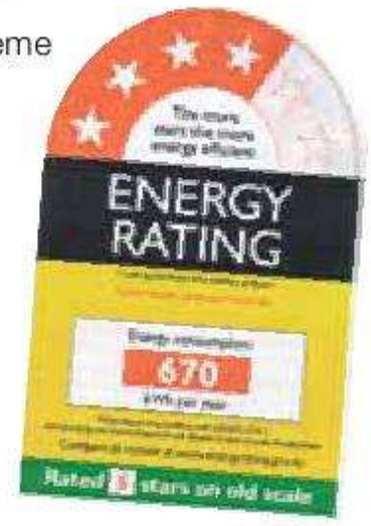
Ongoing cost

When choosing an appliance many people ignore the ongoing costs of maintenance and operation.

Ongoing running costs can easily exceed the original purchase price of an appliance so consider the full lifetime cost when choosing an appliance.

Energy efficient appliances cost less to run and have less environmental impact than similar appliances with lower energy efficiency. Using efficient appliances can save you hundreds of dollars each year in running costs.

THE APPLIANCE ENERGY RATING SCHEME



The Energy Rating Scheme is a mandatory national labelling scheme for:

> Refrigerators.

> Freezers.

> Clothes washers.

> Clothes dryers.

> Dishwashers.

> Air conditioners.

Look for the Energy Rating Label that shows the star rating and other useful information about energy consumption. Choose an appliance with a high star rating.

Add the purchase cost and the lifetime running cost to get a more accurate picture of the total cost of an appliance.

Appliances with a higher star rating generate fewer greenhouse gas emissions.

The Energy Rating Label must be displayed on the above listed appliances when offered for sale. It gives a star rating between one and six stars. The greater the number of stars the higher the efficiency. Total energy consumption in kWh per year under test conditions is also shown (in the red box). If two suitable appliances have the same star rating choose the one with the lower energy consumption.

Reverse cycle air conditioners can be used for heating or cooling and their efficiency is different for the two modes of operation. The Energy Rating Label for reverse cycle air conditioners shows separate star ratings and energy consumption figures for heating (in red) and for cooling (in blue).

A detailed website (www.energyrating.gov.au) provides additional information on the Energy Rating Scheme. The site lists the energy rating and approximate annual energy costs for all appliances on sale in Australia. You can search for an appliance that best meets your needs. The site also provides tips on appliance selection and background information on how appliance ratings are determined.

Televisions, game consoles, set-top boxes, video, CD and DVD players and recorders do not carry energy rating labels in Australia, neither do computers, scanners or printers. Nevertheless the collective energy demand of these appliances in a modern household is significant. Taken together, the electrical power use of these commonly used appliances may outweigh that consumed by traditional white goods.

A large screen television used 6 hours a day, can generate around half a tonne of greenhouse gases a year – more than a family fridge.

Digital technologies have led to the emergence of 'convergence' in which previously unrelated devices operate interactively with one another. As an example, CD players, radios, cameras and telephones used to be quite separate devices but now consumers can buy mobile phones that play music, email and take photographs. In the home, this phenomenon of convergence has lead to such things as refrigerators that contain a computer, and the increasingly popular home theatre.

Turn off appliances not in use where possible, although this is not always as easy as it sounds. A continual power draw is becoming the default condition for many appliances. As electronic devices have become more sophisticated they have become more and more likely to have sleep or standby modes rather than a hard off switch that disconnects the mains from all electrical circuits in the appliance.

Very few home entertainment products for example have an off switch. This means that significant power is wasted even when the device is put into passive standby mode by the remote control. Even more power is wasted when devices such as DVDs, set-top boxes and CD players are left active standby after use. In this mode they can use twice as much energy as they do when powered down to passive standby mode.

Switch off at the powerpoint.


Courtesy of Fisher and Paykel

CHOOSING AND USING APPLIANCES

Fridges and freezers

Choosing a fridge or freezer

Running a six star 360L fridge will produce almost half a tonne less greenhouse gas each year than a three star model.

Buy appliances that are the right size, especially freezers as their energy demand is high. A larger model will use more energy than a smaller one with the same energy star rating. One large fridge will usually be more efficient than two smaller ones.

Look for features such as easily adjustable shelving, easy access to the thermostat, simple thermostat controls, separate thermostats for fridge and freezer compartments, a door-open alarm and rollers or castors that will make cleaning and operating the fridge easier.

Chest freezers are usually more efficient than upright models as cold air does not escape every time you open the door. Upright freezers with enclosed drawers (not baskets) are a good compromise.

Through-the-door features such as cold water dispensers and ice-makers use more energy and cost more. Avoid these if possible.

Upright units with one door above the other are generally more efficient than units with side by side doors.

A cool cupboard will keep many fruits and vegetables well in most climates, allowing you to choose a smaller fridge. Cool cupboards should be located in the coolest part of the house and have good airflow in at floor level and out at the ceiling.

Using your fridge or freezer

> Place the fridge or freezer in a cool spot out of direct sunlight and away from cookers, heaters and dishwashers.

> Ensure 75mm air space around all sides of the cabinet. If in an alcove make sure the top is also ventilated.

> Make sure the door seal is clean and in good condition. It should hold a piece of paper tightly in place when shut.

> Set the fridge thermostat to between 3°C and 5°C. The freezer should be set to between -15°C and -18°C. Every degree lower requires five per cent more energy. A fridge thermometer is a good investment.

> Avoid overloading the fridge or freezer. Try to leave about 20 per cent free space for air circulation.

> Defrost manual models regularly or when ice is more than five millimeters thick.

> Turn the second fridge off when not needed. Do not put it in a hot garage or veranda.

> Avoid placing hot food in the fridge.

Dispose of old fridges properly to avoid release of ozone damaging CFCs. Your local council should be able to offer advice.

Clothes washer

Choosing a washing machine

Choose a washer that's the right size for your needs. An oversized model will often be filled with partial loads.

Select the most energy and water efficient model.

Front loaders are usually more water and energy efficient. They are gentler on clothes, use less detergent and save space as they can be installed under a bench. They usually have a higher spin speed so clothes come out dryer. Some have only a cold water connection.

Top loaders usually use more water despite shorter wash times. They may be less expensive to buy but are often harsher on clothes. A suds saver feature is very desirable.

Look for models with dual water connection, cold wash cycles and auto load sensing or load size selection. Heating the water for a hot load can generate up to 4kg of greenhouse gas – a cold wash will produce less than 0.5 kg.

Models with a high spin speed and reverse tumble action are also desirable, especially if you use a clothes dryer.

Look for an economy cycle.

Using your washing machine

Wash a full load rather than several smaller loads and use suds saver if available. Don't use too much detergent. Making detergent produces a lot of greenhouse gases and using too much pollutes our waterways.

Use the economy cycle.

Most of the energy used in washing clothes is for heating the water. Use cold water where possible.

Clothes dryer

Choosing clothes dryers

Consider buying a gas fired or heat pump model clothes dryer. They are more expensive to buy and install but much cheaper to run.

Drying a load of washing in an electric dryer generates more than 3kg of greenhouse gas.

Look for an auto-sensing feature, easily accessible lint-filters and other features such as reverse tumbling and special fabric cycles.

Using clothes dryers

> Use a clothes line or rack to dry instead of a dryer.

> Avoid over loading or over drying.

> Do not put wet clothes in the dryer. Part dry or spin dry them first, using the maximum spin speed of the washer.

> Clean the lint filter after each load.

> Externally vent the dryer to remove moist air from the room.

> Run the dryer on medium instead of high.

Dishwasher



Choosing a dishwasher

Choose the right size for your needs so you will not always be washing partial loads. Two drawer models are available and can be more efficient in households where regular small loads are required.

A well designed dishwasher will wash better at lower temperature and with less detergent than a poorly designed one.

Select the most energy and water efficient model.

Look for models with hot and cold connections or cold connection only. Hot connection only models use much more energy as the whole cycle will use hot water, not just the wash phase.

Research performance well. Basket and rack design is important.

Look for an economy cycle.

Using a dishwasher

> Avoid rinsing dishes under the hot water tap.

> Scrape plates well before packing the dishwasher.

> Always clean the filter between washes.

> Run the dishwasher only when fully loaded.

> Use cold water cycles as much as possible in dishwashers. Select the cycle with the lowest temperature and the minimum time to get the job done.

> Avoid using drying cycles – open the door instead.

> Use the economy cycle.

Audio visual appliances

The hours of usage of home entertainment and computer equipment is increasing. The Australian home for example has an average of 2.4 televisions watched by at least one family member for between 5-8 hours a day. The average television size has increased from 51cm in 2000 for a cathode ray tube TV to 106cm for a Plasma type. Energy consumption has increased dramatically as a result. In addition, the ubiquity of computers with associated scanners, printers, additional displays and 24 hour internet access make them a significant part of energy use.



To minimise energy use from home entertainment and computer equipment, where possible switch the appliance off at the power point to avoid energy consumed in standby mode. If that isn't possible use the 'hard off' switch on the appliance (if it has one) or turn the appliance off with the remote control to reduce standby power use.

Other equipment

Swimming pool and spa equipment can consume large amounts of energy. Pumps and heaters should be as efficient as possible and be used as little as practicable.

Home automation

Home energy management and automation systems are not intrinsically energy efficient. If you are contemplating investing in any kind of home automation, consider the potential for achieving additional energy efficiencies through the design of the system.

[See: 6.10 Home Automation]

The www.energystar.gov.au website contains useful product information and tips.

AUSTRALIAN CONSUMERS' ASSOCIATION

The Australian Consumers' Association (ACA) regularly undertakes benchmark testing of products, including a full range of appliances.

The results of these benchmark tests are published in the ACA magazine CHOICE and are available on-line at the ACA website at www.choice.com.au for a fee. Most public libraries subscribe to CHOICE.

The tests often provide information on energy efficiency and environmental impact that can assist in deciding which appliance to buy.

The tests also cover a range of other features such as price, safety, warranty details and performance that can help you to choose the best appliance.

BUILDING DESIGN CONSIDERATIONS

When designing a new kitchen or laundry, think about the best layout and placement of appliances to maximise efficiency.

Refrigerators and freezers should be located out of direct sunlight and away from other sources of heat such as ovens and stoves. This is an important consideration in kitchen design.

Appliances that require hot water should be located as close to the hot water service as possible to reduce heat losses in pipes.

Where possible choose appliances that have a high rating for water efficiency.

[See: 7.2 Reducing Water Demand]

ADDITIONAL READING

Contact your State / Territory government or local council for further information on energy efficiency.
www.gov.au

Australian Consumer Association
www.choice.com.au

Department of the Environment, Water, Heritage and the Arts (2008), *Australian Residential Sector Baseline Energy Estimates 1990 – 2020.*

Energy Rating
www.energyrating.gov.au

Water Rating
www.waterrating.gov.au

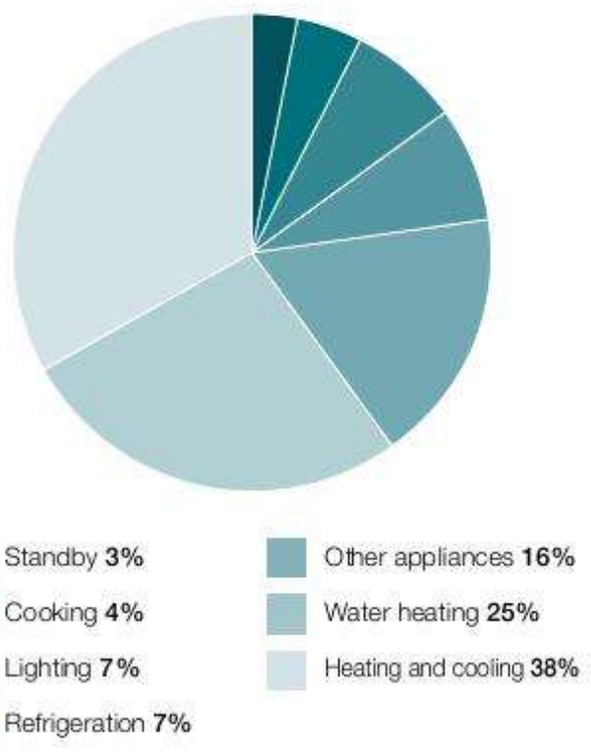
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Hot Water Service

Water heating accounts for 25 per cent of the energy used in an average home and is responsible for 23 per cent of the total greenhouse gas emissions from home energy use. Reducing your hot water use and using renewable energy sources to heat water are great ways to reduce your environmental impact.

Home energy use
(Baseline Energy Estimates, 2008)



By installing the most appropriate and efficient water heater for your household size and water use patterns you can save money and reduce greenhouse gas emissions without compromising your lifestyle. An efficient hot water system can also add value to your home and help you to meet local council or state/territory regulations.

More than half of hot water use is in the bathroom, a third is in the laundry and the remainder is in the kitchen. One of the best ways to reduce your energy bills is to reduce hot water use by installing water efficient showerheads and taps – you will save on energy and water.

25 per cent of energy used in the home is used to heat water.

TYPES OF HOT WATER SYSTEM

There are two basic types of water heater – storage systems and instantaneous (or continuous flow) systems. Each system can use a variety of energy sources to heat water.

Storage water heaters

Water is heated and stored in an insulated tank for use when it is required. These systems can operate on mains pressure or from a gravity feed (constant pressure) tank.

Mains Pressure – Hot water is delivered at a similar pressure and flow rate to cold water so more than one outlet can usually be turned on without greatly affecting pressure. The storage tank is usually located at ground level inside or outside the house. Mains pressure systems have been the most popular systems in recent decades.

Constant Pressure or gravity feed – Hot water is delivered at lower than mains pressure from a tank located in the roof of the house. Pressure depends on the height difference between the tank and the point of use. Gravity feed systems are most common for older properties and properties not connected to mains water. They are often cheaper to purchase and last longer than mains pressure systems.

For either type of system, storage tanks may be made of copper, glass (enamel) lined steel or stainless steel. Copper and glass-lined tanks typically have a sacrificial anode to reduce tank corrosion, which needs to be replaced every few years. Warranties offered for tanks typically range from five to 10 years.

Instantaneous water heaters

Instantaneous systems heat only the water required and do not use a storage tank. They can operate on natural gas, LPG or electricity. Gas models are available with either electronic ignition or a pilot flame. They can be mounted internally or externally.

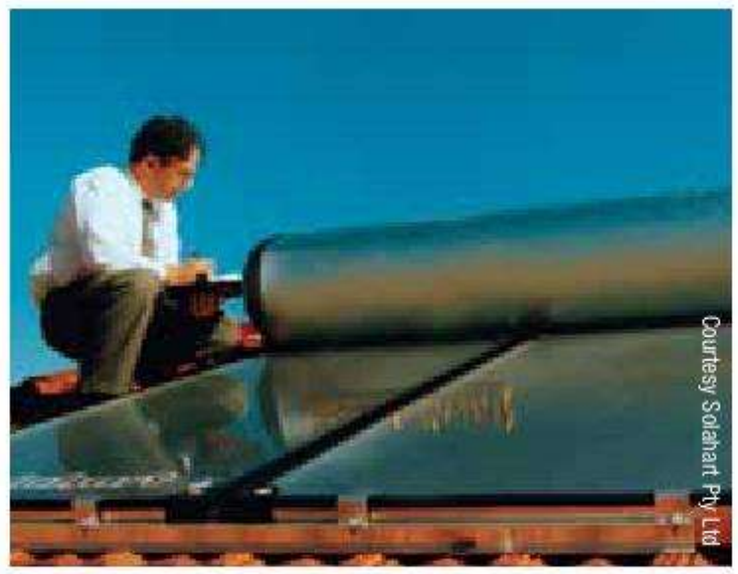
Because instantaneous systems heat the water as it is used, they cannot run out of hot water. Standard units can only deliver adequate hot water to one or two points at the same time but high performance gas units can supply several points at once.

Instantaneous water heaters can be fitted with sophisticated temperature controls, including controls that allow the user to set the desired water temperature at the point of use (eg in the shower). This means that water is not overheated and that hot water does not need to be diluted with cold water to achieve a suitable temperature, resulting in energy savings.

ENERGY SOURCES FOR HEATING WATER

Solar energy

Solar hot water systems are storage systems and, depending on your climate, can provide up to 90 per cent of your hot water for free using the sun's energy. Solar hot water systems cost more to buy and install than other hot water systems, but can save energy and reduce your bills. Seek expert advice to help you choose the most cost effective solar water heater for your needs. Be sure to consider the energy source for boosting (gas or electricity), energy tariffs, ease of installation and product cost.


Courtesy Solahart Pty Ltd



To provide hot water on cloudy days or when demand exceeds supply, most solar water heaters come with a gas or electric booster. A gas booster usually produces less greenhouse gas emissions.

Booster systems located inside the storage tank can be inefficient – cutting in and pre-empting the sun. Override switches and timers can correct this problem if well managed. An increasingly popular approach is to use an inline gas booster that works like an instantaneous water heater – it guarantees a suitable temperature while maximising the solar contribution.

The solar collector and storage tank is generally located on the roof of your home, facing north. The storage tank can also be located inside the roof or at ground level.

Rebates are available to assist with the purchase cost of solar water heaters. Refer to www.livinggreener.gov.au/rebates-assistance for more information about rebates.

At the end of this fact sheet is detailed information about solar hot water systems.

Natural gas

Natural gas water heaters generate far fewer greenhouse gas emissions than electric storage systems using mainland grid electricity. This is because natural gas burns cleaner than the coal that is burnt to generate most electricity in mainland Australia. Using gas directly in the home also avoids the energy losses associated with the generation and distribution of electricity.

Natural gas water heaters generate far fewer greenhouse gas emissions than standard electric storage systems.

Gas storage systems have quicker heat recovery times and generally use a smaller tank than a comparable electric storage system. This improves efficiency and makes indoor installation easier. Systems installed inside the house need a flue that leads outside to vent exhaust gas.

Instantaneous hot water systems usually use natural gas as it is cheaper for this application than LPG and electricity.

To compare energy use of gas storage and instantaneous gas water heaters, check the star rating label. [See: 6.1 Energy Use Introduction]

Electricity

The Australian Government, and state and territory governments, are working together to phase out greenhouse intensive hot water systems, starting in 2010. This phase out will reduce energy consumption and greenhouse gases and may also assist householders save money on their electricity bills. Refer to www.climatechange.gov.au/en/what-you-need-to-know/appliances-and-equipment/hot-water-systems for more information about the phase out.



Quantum Energy Systems

Electricity can be used for standard storage water heaters, for heat pump systems or for boosting solar systems. An expensive three-phase electricity supply is usually needed for instantaneous systems.

Electric heat pumps are an efficient type of electric storage water heater that extracts heat from the environment (air, water or ground) to heat water. Like solar water heaters, they cost can save energy and reduce your energy bills. Seek expert advice to help you choose the most cost – effective heat pump and electricity tariff for your needs.

Heat pumps that draw heat from the air use only about one quarter to one half of the energy of a standard electric storage system. They operate like a refrigerator but in reverse. The ambient air is used to heat a refrigerant, which converts to a gas. The gas is then compressed, generating heat, which is transferred to the water. The refrigerant is expanded back to a liquid and the cycle repeats.

Electricity is not used to directly heat the water but to move the refrigerant around the system. This is why the electricity use is much lower than for storage systems.

Heat pumps work most efficiently in warm, humid climates. They are not suited for installation outdoors in cold climates and where regular freezing or very cold and dry conditions are experienced. Some heat pumps are manufactured to work more effectively during brief frost conditions but they will cost more to run in these conditions and are not recommended for use in prolonged cold periods. Note that some heat pumps may require an electric booster element if operated in regions where it is cold. The cost of running a heat pump may increase if it is required to boost during the day when electricity tariffs may be high. Electricity tariffs differ across the states and territories. For further information talk to your plumber or electrician, ask your supplier about the heating specifications of the product you are considering and contact your energy retailer to find out what tariffs may apply.

Ground source (or geothermal) heat pumps use a water body, shallow trench or deep bore instead of the air as a heat source. They usually provide both space heating and water heating. Electricity is used to pump water around a loop buried in the ground or immersed in a water body. The enclosed water absorbs heat from the surroundings. Geothermal heat pumps can produce more than four units of heat energy for every unit of electrical energy used. They are best suited to multi-residential applications, where plenty of space is available.

Heat pumps can be located and designed to utilise waste heat from air conditioners and refrigerators.

Government rebates may be available to assist with the purchase cost of heat pumps. Refer to www.livinggreener.gov.au/rebates-assistance for more information about rebates.

Electric storage water heaters – Standard electric storage water heaters use a heating element inside the tank to heat the water, just like an electric kettle. When powered using mainland grid power in Australia, they are responsible for the most greenhouse gases of any water heater and are not recommended. Emissions from electric storage water heaters can be greatly reduced by using GreenPower or other renewable energy to run the water heater.

Electric storage water heaters of less than about 150L usually use peak electricity and are the most expensive of all to run.

Larger electric storage water heaters generally use cheaper off-peak electricity tariffs, where available, heating water at restricted times (usually overnight).

To reduce the chance of running out of hot water, tanks are often oversized and overheated, increasing energy consumption and greenhouse gas emissions. An electric storage water heater can indirectly produce as much carbon dioxide each year as the average family car.

While an electric storage water heater may be cheap to buy, it may be expensive to run and this should be taken into account when deciding which water heater to buy.

CHOOSING A HOT WATER SYSTEM

Of the many different types of water heaters on the market, the best hot water system for your home will depend on your situation. Consider the following.

Household size – The number of people living in your home and your water consumption patterns (ie whether you all shower at the same time of day; run the dishwasher, washing machine and bath at the same time) will determine the size of the system you need and help to identify the best system and energy source for your needs.

Cost – The purchase cost and operating costs of your hot water system both need to be considered. The energy used by your water heater will impact on your energy bill for years to come so consider carefully before buying.

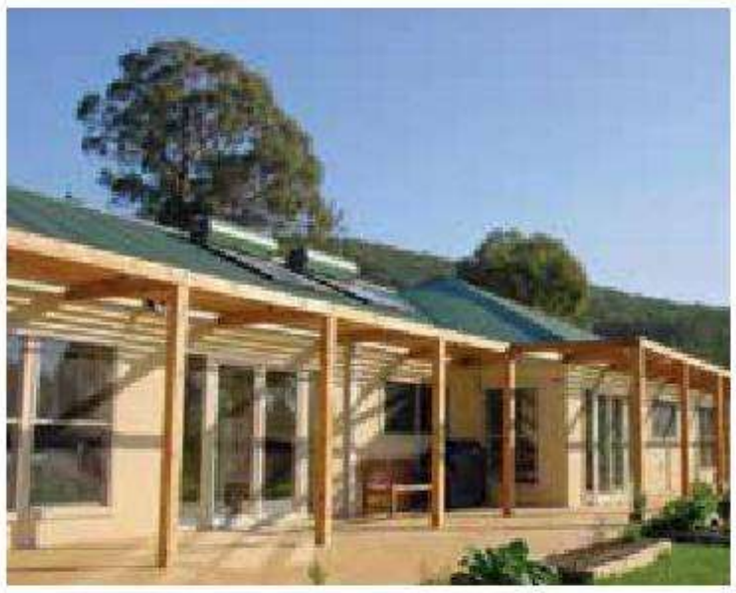
Government rebates are also available on some energy efficient systems. Refer to www.livinggreener.gov.au/rebates-assistance for more information about rebates.

Space available – In existing homes it may not be possible to install some systems due to lack of space or a difficult layout.

Existing water heater – Some existing hot water systems can be easily converted to more sustainable types. For example, the best replacement for the old style ceiling mounted gravity service is often a roof-mounted solar system, as plumbing usually requires minimal alteration.

Available energy sources – Your choice may also be limited by the available energy sources. Natural gas is not available in some areas and solar energy may not be ideal in cooler climates or shaded areas.

The energy source of a hot water system has a large impact on greenhouse gas emissions. Natural gas hot water systems typically generate fewer greenhouse gas emissions than electric storage hot water systems and solar hot water systems can generate even fewer greenhouse gas emissions.



Local climate – Sunny locations with good solar radiation allow solar hot water systems to operate most effectively. In warm climates there is also less energy needed to raise the temperature of the water storage tanks if they are located outside, as the difference between the air temperature and the temperature of the hot water is smaller.

The amount of emissions generated by your hot water system depend on:

> Greenhouse intensity of the energy source.

> Age and efficiency of the hot water appliance.

> Amount of solar radiation available for solar hot water systems.

> Amount of heat available in the ambient air for heat pump hot water systems.

> Heat lost by hot water storage tanks to the outside air.

> Volume of hot water consumed.

The following recommendations can be used to minimise greenhouse gas emissions:

> Where gas is available and solar access is good, a gas boosted solar water heater will generate the lowest greenhouse gas emissions.

> Where gas is available but solar access is poor, an instantaneous gas system or electric heat pump is usually the best option for small to medium households.

> For large households (5 people or more), a gas storage system gives similar performance to an instantaneous gas system at lower cost.

> Where gas is not available an electric-boosted solar system or an electric heat pump will minimise emissions.

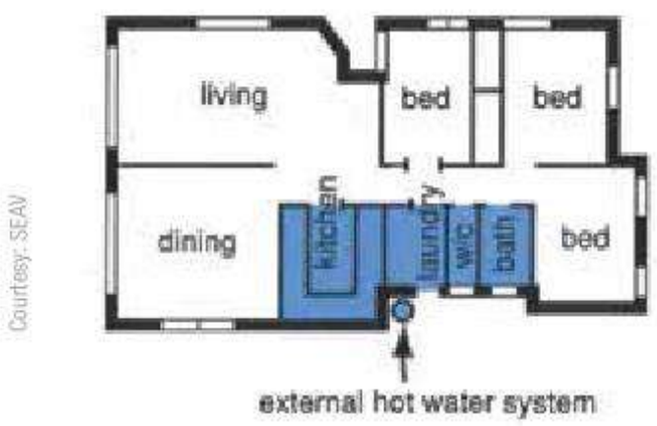
> For multi-residential developments, a large, cost-effective solar water heater can be effectively combined with instantaneous gas boosters in each unit, or a geothermal heat pump could be cost-effective for blocks of five or more units.

DESIGN AND INSTALLATION

About 30 per cent of the energy used to heat water in a storage system is wasted due to heat loss from the tank and associated pipework. This can be reduced through careful design and installation.

Keep hot water pipes as short as possible to minimise heat loss. In new or renovated homes, locate wet areas close together with the water heater close to all points of hot water use. If this is not possible, locate it close to the kitchen where small, frequent amounts of hot water are used. Another alternative is to install a water recirculation system. These systems are generally compatible with any hot water system type. They recirculate water in the pipes until hot water is detected, to avoid wastage.

Estimate your hot water needs accurately to ensure your system is not oversized or undersized for your household. If storage system tanks are too small for the number of people in the house hot water can run out. If the tank is too large, operating costs will be excessive.



Courtesy: SEAV

Storage systems lose heat through the tank walls. Reduce heat loss from electric hot water heaters by wrapping the tank with an insulation blanket. Insulation blankets are unsuitable for gas storage systems.

Insulate hot water pipes, particularly externally exposed pipe leading from the water heater to the house and the pipe leading to the relief valve (on storage systems). Note: Standard green lagged hot water pipes are inadequate for external protection in cold and cool temperate climates. Apply additional insulation or 'lagging'. At least 10mm of foam insulation is needed.

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The tempering valve, required to limit hot water to 50°C to prevent scolding, should be located as close as possible to the tank to minimise pipe heat losses. Be sure to comply with your state or territory government requirements for locating a tempering valve.

For storage systems consider installing a timer to ensure water is not heated when it's not needed, and a switch so the system can be turned off when you go on holiday.

Design new homes with a roof pitch and orientation suitable for a solar water heater. You may not want to install one now but it leaves the option open for the future. A north-facing roof with a pitch of between 22° and 40° is usually adequate.

A hot water supply system must be designed and installed in accordance with Section 8 of AS/NZS 3500.4:2003 Heated Water Services (including amendment 1) or clause 3.38 of AS/NZS 3500.5:2000 (including amendments 1,2 and 3). A solar hot water supply system located in climate zones 1,2 and 3 is exempted from complying with the above mentioned requirements. For further information please refer to the Building Code of Australia (BCA) Volume Two, Part 3.12.5.

HOT WATER TIPS

Reducing your use of hot water is a great way to save on your energy bills, regardless of what type of water heater you have. [See 7.2 Reducing Water Demand]

Showering uses the most hot water in a household. Installing a water efficient (3-star) showerhead can reduce this use by about half. If you have an instantaneous water heater, make sure that your water efficient showerhead is compatible and does not reduce flow excessively. Check with the manufacturer of your heater.

Use a shower time to remind everyone in the household to save water.

Buy washing machines and dishwashers that have a cold or warm water or economy cycle option and use these cycles as much as possible.

Immediately repair dripping hot water taps and leaking appliances, including the relief valve from your water heater.

Ensure that the thermostat on storage hot water systems is set at 60°C. A higher temperature than this means that energy is used unnecessarily and a lower temperature than this may allow harmful bacteria to thrive. Instantaneous hot water systems should be set to no more than 50°C.

Turn off your water heater when you go on holidays.

Maintain your system and have it serviced according to manufacturer's instructions.

SOLAR HOT WATER

Installing a solar water heater can greatly reduce your energy bills as it will use energy from the sun to heat water at zero cost.

Using solar energy to heat water produces no harmful greenhouse gas emissions. A solar water heater can provide up to 90 per cent of your total hot water requirements, depending on the climate and the model of heater.

The upfront cost of a solar water heater (including installation) is higher than electric or gas water heaters. Government rebates are available from the Australian Government and several State Governments to assist with the initial purchase cost of a solar water heater.



Solar evacuated tube hot water system.

Although the initial cost of a solar water heater is higher, it can save energy and reduce your bills. The time required to break even (the payback period) depends on the climate, the type of system installed and the energy tariff applied. Solar water heaters have additional benefits, as they last longer than conventional water heaters and add to the value of your home.

HOW DO THEY WORK?

Most solar hot water systems use solar collectors or panels to absorb energy from the sun. Water is heated by the sun as it passes through the collectors. It then flows into an insulated storage tank for later use.

In passive systems, water flows due to a thermosiphon effect between the collectors and the tank. In active systems, water is pumped between the collectors and the tank.

The storage tank is usually fitted with an electric, gas or solid fuel booster that heats the water when sunlight is insufficient. Some solar water heaters also have frost protection to prevent damage in frost prone areas.

Solar hot water supply located in climate zones 4,5,6,7 and 8 is required to comply with Section 8 of AS/NZS 3500.4 2003 Heated Water Services (including amendments:1, 2 and 3.) For further information please refer to the Building Code of Australia (BCA) Volume Two, Part 3.12.5.

Solar collectors

Solar collectors trap and use heat from the sun to raise the temperature of water. There are two main types of solar collector: flat-plate and evacuated tube collectors.

Flat-plate solar collectors – These are the most common type. They are comprised of:

> An airtight box with a transparent cover.

> A dark coloured, metallic absorbing plate containing water pipes.

> Insulation to reduce heat loss from the back and sides of the absorber plate.

One slight disadvantage of flat-plate collectors is that they only operate at maximum efficiency when the sun's rays strike perpendicular to the flat plate. They also suffer some heat loss in cold weather.

Evacuated tube solar collectors – This kind of collector consists of:

> A series of transparent outer glass tubes that allow light rays to pass through with minimal reflection.

> Each tube contains an inner water pipe coated with a layer that absorbs the sun's rays, generating heat. Water runs through this inner tube and is heated.

> A vacuum (hence 'evacuated') exists between the outer tube and the water pipe, which acts as insulation, reducing heat loss.

Evacuated tube systems are more efficient than flat-plate systems, particularly in the cooler months and on cloudy days. This is due partly to the vacuum insulation (which minimises heat loss) and partly to the fact that the curved surface of the tubes allows the sun's rays to strike perpendicular to the water for a greater part of the day. Evacuated tube systems weigh much less than flat-plate systems but cost significantly more. Individual tubes can be replaced in the event of damage, making long term maintenance potentially less costly. In warmer climates,

such as Darwin, the additional cost of evacuated tubes is usually not warranted as a flat plate solar collector will provide most of the energy needed for water heating.

Properly maintained solar thermal collectors should outlast the life of the storage tank. When the tank needs replacing, the existing collectors can be connected to the new tank.

Frost protection

Frost protection for solar collectors is essential in frost prone areas. During a frost, water can freeze in the solar collector and damage it unless preventative measures are taken. Common types of frost protection include:

> Knock valves (mechanical drain down valves). These valves can be problematic as they often jam open and drain the tank, or fail to operate, causing severe damage.

> Electric heating elements, which are vulnerable in the event of power failure.

> Closed circuit systems, which separate the heating fluid from the water (see illustration next page). Closed circuit systems are usually the best option in frost prone areas as they ensure that water does not flow through the solar collectors and therefore cannot freeze in the collectors.

Open circuit vs closed circuit

In an open circuit system, water flows directly through the solar collectors, into the storage tank and then through pipes into your home.

In a closed circuit system a fluid other than water flows through the collectors, picks up heat from the sun, and transfers this heat to water in the storage tank through a heat exchanger.

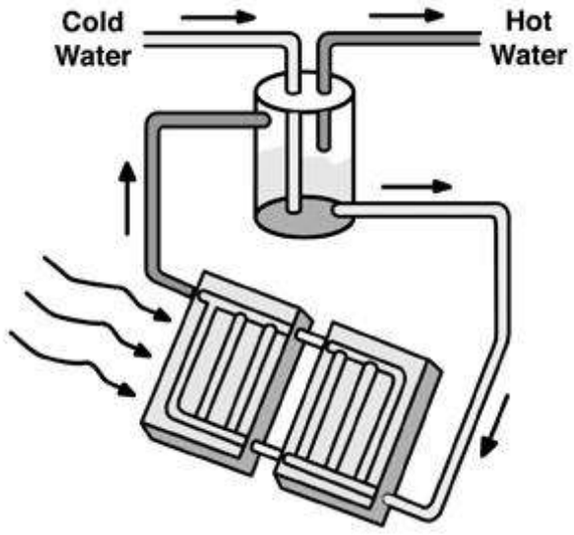
Closed circuit systems are most commonly used for frost protection (see illustration next page). A fluid with a lower freezing point than water is used to avoid ice formation in the solar collectors. It is important to choose the fluid carefully as some become 'gluggy' and reduce efficiency.

Some closed circuit systems pump hot water through the collectors when temperatures approach freezing. This lowers efficiency significantly. Avoid systems with this feature.

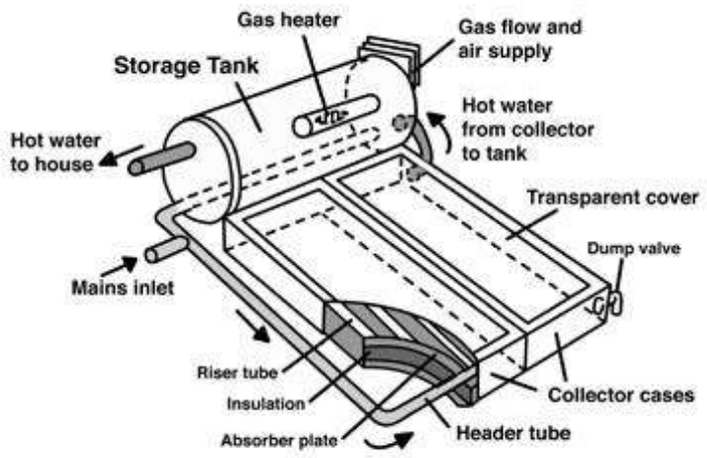
Passive vs active systems

Passive (or thermosiphon) systems

In Passive systems (or thermosiphon systems) the tank is placed above the solar collectors so that cold water sinks into the collectors, where it is warmed by the sun, and rises into the tank. A continuous flow of water through the collectors is created without the need for pumps.



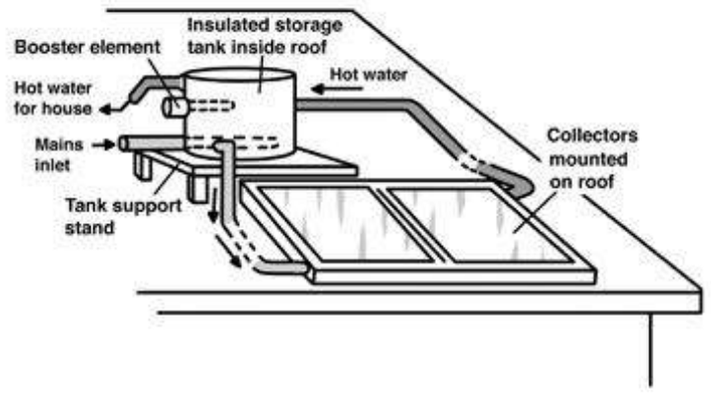
Passive systems come in two types: closed-coupled or gravity feed.



In a close-coupled system the horizontal storage tank is mounted directly above the collector on the roof. Heated water is supplied at mains pressure. This arrangement is the most cost effective to install but efficiency is reduced in cool and cold climates by heat loss from the tank.

Additional insulation of tanks is desirable in these climates. Alternatively, tanks can be detached and moved inside the roof space, although this increases the cost.

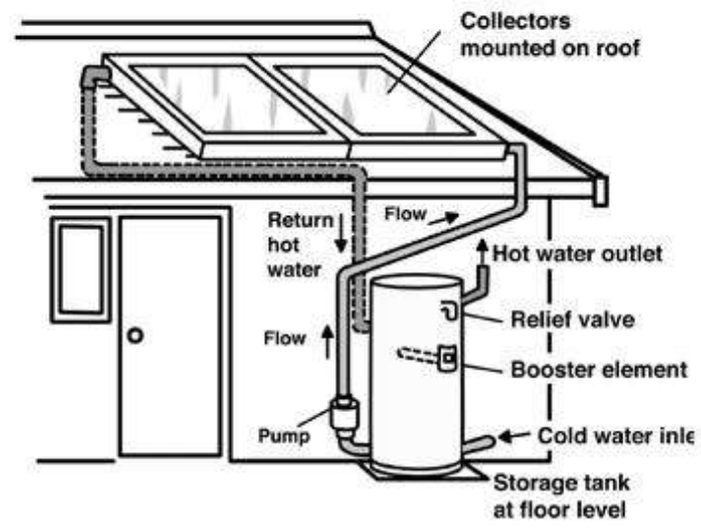
In a gravity-feed system, the storage tank is installed in the roof cavity. These systems are cheapest to purchase but household plumbing must be suitable for gravity feeding, including larger diameter pipes between the water heater and the taps. A common alternative is to use a closed circuit gravity feed system to heat mains pressure water using a heat exchanger.



Active (or pumped) systems

In active systems (also known as pump systems or split systems), solar panels are installed on the roof and the storage tank is located on the ground or another convenient location, that does not have to be above the solar collectors. Water (or another fluid) is pumped through the solar collectors using a small electric pump.

Because active systems do not require a roof-mounted tank they have less visual impact, particularly when the solar collectors are mounted flush with the roof. However, active systems are usually more expensive to purchase and require more maintenance than passive systems.



Active systems use more energy than passive systems because extra energy is required to pump fluid around the system. There are also additional heat losses in the pipes between the tank and the solar collectors. However, if renewable energy is used to power the pump and a high level of insulation is used for the pipes and tank, active systems can reduce greenhouse gas emissions as much as a passive system. [See: 6.1 Energy Use Introduction]

Active systems are often used for solar conversions, when solar collectors are added to an existing hot water system. They may also be used when the roof can't support a passive system.



CHOOSING A SOLAR WATER HEATER

Seek expert advice before deciding which solar water heater to buy.

Climate considerations are very important when selecting a solar water heater and your state government advisory centres can provide excellent local advice.

The Australian Consumers' Association (Choice) provides detailed information to help you choose the best solar water heater for your location and budget.

Manufacturers and retailers may also be able to help with detailed selection guidelines.

Storage tanks

Tanks are manufactured from stainless steel, copper or mild steel coated with vitreous enamel.

Copper-lined tanks are only suitable for low-pressure systems. The other tanks are suitable for mains pressure.

Vitreous enamel tanks are fitted with a 'sacrificial anode' that needs to be replaced every few years to protect against corrosion (more frequently where water quality is poor). Other tanks do not require this protection.

Outdoor storage tanks can suffer frost damage and significant heat losses in cool climates. In such climates they should be located indoors whenever possible, as part of a drying cupboard.

Booster systems

Solar water heaters can be gas, electric or solid fuel boosted.

Electric boosters use an electric element inside the storage tank to heat water.

Gas boosters use a natural gas burner to heat water either in the storage tank or more commonly as a separate unit downstream from the storage tank. Inline gas boosters are becoming more common as they guarantee that hot water will be delivered at the desired temperature, while maximising the solar contribution.

Solid fuel boosters heat water through a heat exchanger, commonly known as a 'wet back' system.

Gas and solid fuel boosted systems produce less greenhouse gas emissions.

Boosters can be manually operated or automatically controlled by a thermostat that cuts in when tank temperatures fall below desired levels. If boosters are not appropriately designed and operated they can defeat the purpose of having a solar water heater by reducing the solar contribution.

For example, thermostat controlled boosters located inside the tank often cut in at night, which means that when the sun rises, there is little useful heating to be done.

In well designed solar water heaters that use an electric booster inside the tank, the booster heating element will be positioned to maximise solar contribution. Hot water enters the tank at the bottom, so the element should be high up in the tank to avoid interference with hot water coming in. However, if it is too high in the tank it will not be able to heat enough water on cloudy days.

Timers can also be used to manage boosters and ensure that you get the maximum solar contribution. Talk to your supplier about correct operation of timers.

Choosing the right size

The best size of storage tanks and solar panels depends on the number of people in the home, how efficiently they use water, the climate and the efficiency of the water heater.

Reducing your hot water demand can reduce the size and cost of the system you need. [See: 7.2 Reducing Water Demand]

Manufacturers or suppliers will advise the best size for your application.

POSITIONING YOUR SOLAR WATER HEATER

For optimum performance throughout Australia solar hot water systems should face solar north. Orientation can deviate up to 45° from north without significant loss of efficiency. Use a compass to check orientation. [See: 4.3 Orientation]

For maximum efficiency, ensure that the solar collectors are not shaded by trees or nearby buildings, particularly in winter when the sun is low in the sky.

For best performance, solar collectors need to be installed at an angle to the horizontal. This maximises the annual amount of sunlight falling on the panels. It is usually recommended that the solar collectors are installed at the same angle to the horizontal as the angle of latitude at the installation location. In Australia, this angle varies from 17.5° in Darwin to 53° in Hobart. In some cases, it may be desirable to increase the angle somewhat to improve winter performance and reduce overheating in summer.

In practice, many solar water heaters are installed at the roof pitch angle as it is cheaper and usually more aesthetically pleasing to install solar collectors flush with the roof, rather than use supports to achieve a greater angle. Roof pitch angles in Australia are commonly between 20° and 30°, so this will often reduce performance in winter. In existing homes, the benefits will usually outweigh the costs. In new homes, design of roof areas to accommodate a suitable solar collector angle may be possible.

OTHER INSTALLATION TIPS

A complete thermosiphon system, when full of water, can weigh several hundred kilograms. Most roofs can support a storage tank without reinforcement but you need to check this before installation. Talk to your builder, designer or engineer to find out.

Be sure to insulate all components, including pipes, to get the best performance from your system. This is particularly important for thermosiphon systems where there is a long distance between the tank and the hot water taps. It is critical in cold climates.

Make sure the booster control is in an accessible location and has an indicator light you can see from inside to remind you to turn it off when not required.

OPERATING AND MAINTAINING YOUR SYSTEM

Follow the manufacturer's maintenance recommendations.

Set the temperature of your booster thermostat to 60°C. A lower setting may allow growth of harmful legionella bacteria.

In favourable climates during summer, water temperatures in a solar water heater can approach boiling point. Heat dissipation devices may be required to prevent water from boiling. It may also be necessary to fit a mixing valve to reduce water temperatures experienced at the tap to safe levels during summer.

Carry out jobs that need hot water early in the day so that the water left in the tank will be reheated by the sun, ready for use at night.

Regularly clean solar panels to remove dust. You can use a broom with some detergent to give them a scrub.

Flush out collectors to remove sludge. Heat pump systems do not require flushing.

Make sure you turn the booster off when going on holidays and consider turning it off during summer if conditions are favourable.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on hot water systems, including what rebates are available.
www.gov.au

Australian Consumer Association
www.choice.com.au

Department of the Environment, Water, Heritage and the Arts (2008), *Energy Use in the Australian Residential Sector 1986-2020.*
www.energyrating.gov.au/library/details2008-energy-use-aust-res-sector

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www.orer.gov.au/swh

ReNew: technology for a sustainable future magazine, *Solar Hot Water Buyers Guide*, Issue 97
www.renew.org.au

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Last updated:
November 2010

Renewable Energy

There are many options for using clean renewable energy sources in the home. Systems based on solar and wind are becoming increasingly accessible. This fact sheet outlines key considerations.



Electricity accounts for about 53 per cent of the energy used in Australian households, but creates around 87 per cent of the greenhouse gas emissions because most electricity is generated by burning fossil fuels. Coal, oil and gas are non-renewable energy sources.

Renewable power systems use renewable energy sources to produce electricity with very low greenhouse gas emissions.

Renewable energy sources such as the sun, wind and water are continuously replenished from natural sources.

When fossil-fuelled generators are used as back up, some greenhouse gases will be produced.

Renewable energy systems usually operate at low cost but can be expensive to install. The cost per kWh for the system life includes the installation and maintenance costs and remains unaffected by future energy price rises.

The design and installation of a these systems is a complex task requiring specialist knowledge. The former Australian Business Council for Sustainable Energy (BCSE) now the Clean Energy Council has a register of accredited designers and installers who can ensure systems comply with the appropriate Australian Standards. The register can be accessed on the website at www.bcse.org.au.

Rebates may be available to offset the initial cost of installing renewable energy power systems (REPS).

RENEWABLE SOURCES

The most common systems used in Australian homes are photovoltaics and wind turbines. These can be used individually or in combination.

Photovoltaic panels

Photovoltaic (PV) modules convert sunlight into electricity PV modules also commonly referred to as PV panels, are made up of a connected group of PV cells to form a usable size and electricity output. They have no moving parts and are therefore reliable and require little maintenance. PV panels can be expected to last 20 years or more. PVs are suitable for use in urban areas as they take up little space and make no noise.

Solar cells are usually monocrystalline, multicrystalline, or amorphous type.
[See: 6.7 Photovoltaic Systems]

The different module types are suited to different applications. Always seek expert advice before deciding which to use.

Solar modules come in different sizes ranging from two Watts peak (Wp) output up to 300Wp output. The most common modules sold in Australia are in the 60Wp to 80Wp range.

Solar modules can be mounted on a frame (either free standing or on the roof) or incorporated in the building fabric. Building Integrated PVs are more commonly installed in grid-connected systems than stand-alone systems.

Wind generators

Wind generators or turbines use the wind to turn a propeller that drives a generator. They come in many shapes and sizes. The most common is the horizontal axis turbine with blades like an aircraft propeller and a tail or vane to direct it into the wind. Larger wind generators are more suited to non-urban areas as the turbine needs to be mounted on a tower and makes some noise in operation.



A number of vertical axis and more aerodynamic wind generators are being developed and show promise in overcoming wind turbulence and noise problems in urban use.

Domestic wind generators are usually used in stand alone power systems and designed to charge a battery bank. [See: 6.9 Batteries and Inverters]

A wind turbine produces an alternating voltage and current, and these are rectified to provide DC at the correct voltage to charge batteries, similar to the system in a motor vehicle.

Domestic sized wind generators range from 300 Watts to 5kW, but in some instances a 10kW or 20kW turbine could be used.
A typical installation will use a 1kW turbine.

The wind generator must be installed on the highest tower that is practical and cost effective for the site. The typical tower used in domestic wind generator systems is between 10-20m tall.
[See: 6.8 Wind Systems]

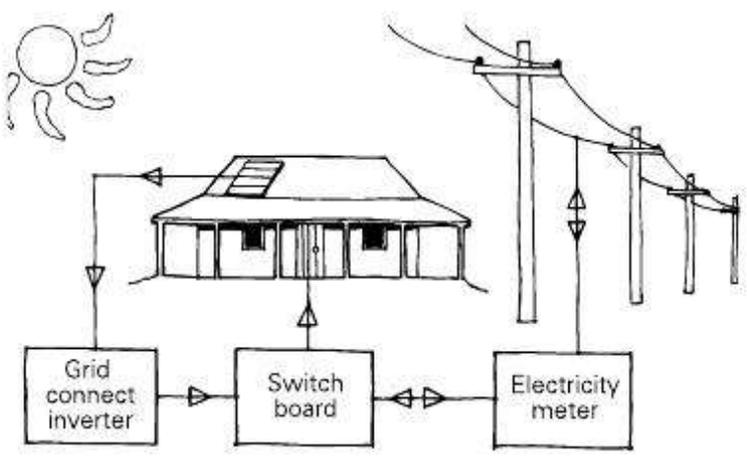
Note: Micro Hydro generators are a less common renewable energy power system. The unit operates by converting the energy from flowing water to electrical energy.

SYSTEM TYPES

Most renewable systems are unable to provide energy at all times as there may be insufficient sunlight, wind or water available. To fill the gaps, electricity can be supplied from storage batteries or generators in stand alone systems or from the electricity grid in grid connected systems.

Grid connected systems

Grid connected systems interact with the electricity supply grid. Grid connected systems are generally located in urban areas and PVs are the usual energy source. The main components of the system are the renewable energy source and a grid interactive inverter.



Grid connected system.

The inverter converts the low DC voltage generated by the system to the normal 240V AC household supply. It also monitors the operation of the system to control how much electricity is drawn from or fed to the grid.

If the household uses more energy than the renewable sources can supply, the shortfall is provided by the grid so power is always available.

If the system is supplying more energy than is needed, the excess is fed into the grid. Often the meter just runs backwards when electricity is going into the grid, so the household only pays for the difference between what is imported and what is exported. Different suppliers have different buy-back rates and metering arrangements. Check with your energy supplier for precise details.

System sizing is not critical as the grid is used for backup when the system output is insufficient for household needs.

As a rule of thumb, a one kWp monocrystalline array will produce about 1,500kWh of electrical energy per year and will require 9m^2 of space. An amorphous system will require more space. The system designer will specify and size it accurately for your particular location and load.

As the peak output of the system is determined by the size of the inverter, it can be useful to install a larger inverter than initially required. The excess capacity will allow additional modules to be added later. The size of the inverter will depend on your budget.

Most grid connected systems do not have storage batteries and do not provide a guaranteed continuous power supply. If the grid goes down the inverter will cut out for safety reasons and there will be no energy available.

Where continuity of supply is critical for part of the load a special type of inverter and batteries may be used to give unprecedented supply, but this adds to the cost of the system.

Stand alone power systems

Sometimes known as Remote Area Power Supplies, these systems are also used in less remote rural areas where the cost of connection to the electricity. They are more complex and expensive than grid connected systems because they need to be self-sufficient.

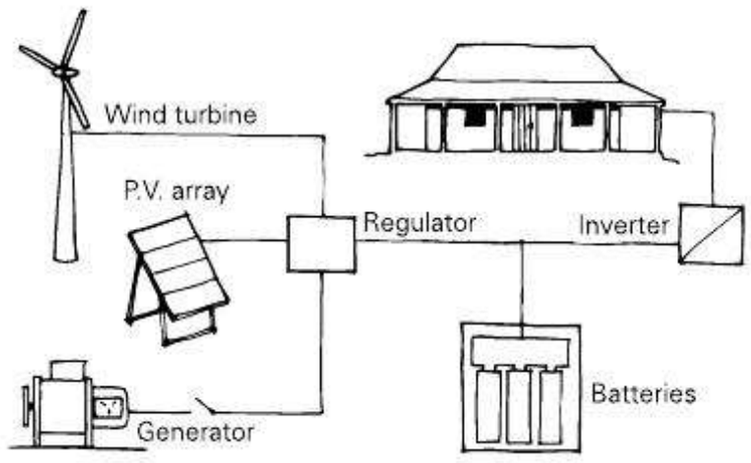
The main components of a stand-alone system include:

> A renewable energy source.

> Control equipment for battery charging and backup power source operation.

> Storage batteries.

> An inverter.



Stand alone power system.

Note: an inverter is not required if the home runs 12 and 24V DC appliances. Although DC appliances are usually more energy efficient than their AC counterparts, they are more expensive and the range is limited. DC systems also need larger capacity and more expensive wiring. Some stand alone power systems use a combination of AC and DC appliances.

A generator set is commonly required for emergency backup. These are generally installed in PV and wind systems, but not micro-hydro where an adequate water supply is continuously available. They are used for:

> Charging the batteries.

> Supplying specific high power loads.

> Emergency back-up in periods of unfavourable weather or when loads are larger than the original design.

It is generally recommended that the system includes a generator for battery charge equalisation. [See: 6.9 Batteries and Inverters]

Your stand alone power system should be designed to meet the required household load. Excess energy generated is stored in batteries for use when the renewable source is not available. The battery bank should be sufficient to provide power for several days.

Stand alone systems are usually installed where electricity supply is not available or connection costs are high. However, some people install these systems to be independent from the mains supply or to have reliable power in areas where blackouts are common.

In some cases it may be appropriate to use more than one type of renewable energy source, such as a photovoltaic system with a wind system.

REDUCING ENERGY CONSUMPTION

Investing in energy efficiency will avoid unnecessary expenditure on system capacity.

This is particularly important for systems that must be self-sufficient. They do not have access to the electricity supply grid for back-up and you may have to resort to using expensive fuels such as diesel. For grid connected systems, using less energy reduces the amount purchased from the grid or increases the amount that can be sold back to the grid. This saves you money.

Before installing a renewable energy system, your electricity usage needs to be calculated and minimised through energy efficiency or use of alternate fuels to reduce the size and cost of the system.

General rules

Use energy sources other than fossil-fuel electricity where possible, eg solar for hot water. If solar is not suitable consider an efficient heat pump system. [See: 6.5 Hot Water Service]

Limit the use of high power demand electrical appliances such as cookers, microwave ovens, water heaters, room heaters, clothes dryers, air conditioners, vacuum cleaners and hair dryers.

Buy energy efficient appliances, especially fridges and freezers. [See: 6.4 Appliances]

Use externally heated water from solar systems for clothes and dishwashers – do not let them heat their own water.

Use passive design building principles to reduce the need for heating and cooling. [See: 4.5 Passive Cooling; 4.6 Passive Heating]

Use natural lighting and energy efficient fluorescent lighting. [See: 6.3 Lighting]

Be aware that many appliances use stand-by energy when not actually being used. Televisions, videos, clocks, computers, faxes, battery chargers, power packs, etc. still use power when they are 'switched off'. These small loads may be enough to switch on the inverter, and inverters are often very inefficient at low load. Turn appliances off at the wall switch when not in use and buy Energy Star approved models. [See: 6.1 Energy Use Introduction]

GREENPOWER

GreenPower enables householders to buy accredited renewable energy from the electricity grid.

GreenPower is a national accreditation program that sets stringent environmental and reporting standards for renewable electricity products offered by energy suppliers across Australia. GreenPower aims to increase Australia's capacity to produce environmentally friendly renewable electricity by driving demand for alternative energy generation.

Accreditation is essentially an endorsement from an independent authority. In GreenPower's case this means the renewable energy product is endorsed by a collection of state governments that manage the GreenPower program. For a renewable energy product to gain endorsement from the GreenPower program it must be generated from:

> Eligible renewable energy sources that meet strict environmental standards.

> A new renewable energy facility that was built since January 1997 (Other renewable energy exists, but it may not be accredited because it was built before 1997, and was already contributing energy to the electricity grid).

Accreditation ensures that energy companies are producing renewable energy of the same standard, making it easier for customers to choose between different renewable energy products. From a customer's perspective, the GreenPower label demonstrates at a glance that they are supporting renewable energy that is best for the environment and the renewable energy purchased will decrease greenhouse pollution.

Since 1997, more than 645,000 residential and commercial customers Australia wide have contributed to reducing greenhouse gas emissions by buying GreenPower, resulting in savings of nearly 4.5 million tonnes of greenhouse gas emissions.

You can get more information on GreenPower from www.greenpower.gov.au and you can check with electricity retailers to see the options for buying accredited GreenPower offered under various names.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on renewable energy, including what rebates are available.
www.gov.au

Australian Business Council for Sustainable Energy (2006), *Australia's Renewable Energy Use: Technologies and Services.*

Clean Energy Council
www.cleanenergycouncil.org.au

Department of the Environment, Water, Heritage and the Arts (2008), *Australian Residential Sector Baseline Energy Estimates 1990 – 2020.*

Gilchrist G (1995), *The Big Switch – Clean Energy for the 21st Century*, Allen and Unwin, Sydney.

Green Electricity Watch
www.greenelectricitywatch.org

GreenPower
www.greenpower.gov.au

Renewable Energy, Australian Government
www.greenhouse.gov.au/renewable

Renew: technology for a sustainable future, Alternative Technology Association
www.ata.org.au

The Australia and New Zealand Solar Energy Society
www.anzes.org

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Photovoltaic Systems

Photovoltaic technology has been used to power homes for many years, and with good reason. Sufficient sunlight falls on Australia to provide the nation's total energy needs. With a few solar modules the homeowner can capture some of this abundant energy. This fact sheet should be read in conjunction with 6.6 Renewable Energy.



Historically a niche product, photovoltaics are now being used to provide price-competitive, zero greenhouse emission energy to homes and businesses across the country.

Australian government rebates will only be paid if systems are installed by accredited installers. Installers can be found on the Clean Energy Council website at www.bcse.org.au.

SOLAR MODULES

Solar modules come in two distinct categories – crystalline silicon and amorphous silicon.

Crystalline solar modules are covered with tempered glass on top and a tough ethylene vinyl acetate (EVA) material at the back. The glass and backing material protect the solar cells from moisture.

The most efficient crystalline silicon cells are made from slices of a large single crystal ingot (hence known as monocrystalline). While multicrystalline or polycrystalline cells have a speckled appearance from multiple small crystals which slightly reduces their efficiency.

Crystalline modules need to be cool. Output efficiency of crystalline PV arrays decreases by 0.5 per cent per degree Celcius over the standard test temperature of 25°C. Good ventilation is required at the back of modules. Exposure to cool breezes when siting modules is an important consideration.

Amorphous silicon is one of a number of thin film technologies. This type of solar cell can be applied as a film to low cost substrates such as glass or plastic in a variety of module sizes.

Advantages of thin film cells include easier deposition and assembly, low cost of substrates or building materials, ease of production and suitability to large applications.

Efficiency of thin film modules is lower than that of crystalline modules but all the types of modules are price competitive. Those currently on the market degrade in output by up to 10 per cent when first exposed to sunlight but quickly stabilise to their rated output.

Thin film modules have various (often flexible) coating and mounting systems. Some are less susceptible to damage from hail and other impacts than those covered in glass.

Solar modules can be supplied with a frame, usually constructed of anodised aluminium, or as an unframed laminate.

More solar modules are being fabricated as building materials so that they can be integrated into the building fabric. They include solar roof tiles, wall materials and semi-transparent roof material for atriums and skylights.

It is anticipated that further development of thin film technology will lead to a proliferation of cost effective, PV coated building materials that can be integrated with the building fabric to reduce costs, see 'Building Integrated PV'.

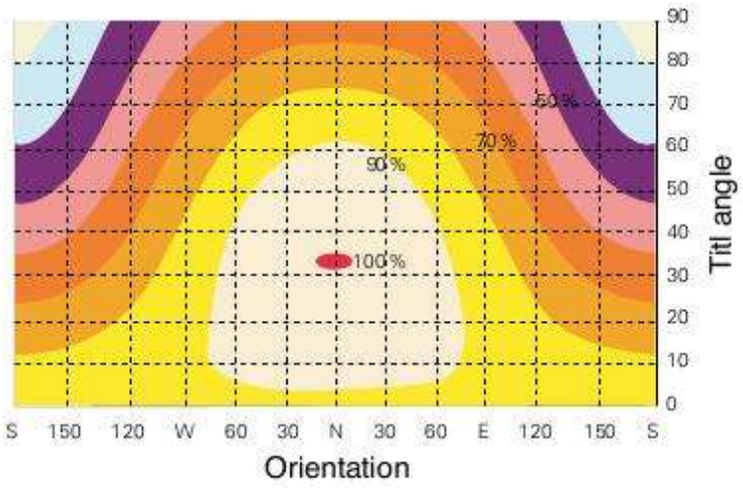
All PV modules need to be cleaned periodically to maintain their efficiency.

SITING

Orientation

Solar modules produce most power when they are pointed directly at the sun. It is important to install them so that they receive maximum sunlight. Ideally they should be in full sun from 9am to 3pm in mid winter.

The chart below for latitude 35°S shows the effect of orientation and elevation on module output, expressed as a percentage of the maximum possible output. Note that a wide range of elevation and orientation angles will still provide useful output, Your installer will orient the modules to best meet your needs irrespective of the angle of your roof.



Variation of solar module output with orientation and tilt angle for latitude 35°S.

Elevation

For stand alone PV systems (SAPS), where winter operation is crucial, the angle should be the latitude plus 15°.

For grid connected systems the angle should be latitude minus 10° to maximise the amount of energy produced annually. Latitude adjustments for grid connected systems in most climates fit within an acceptable roof pitch range (eg. for Sydney's latitude this is close to 22° for grid connected systems on a common roof pitch).

Output power of an array is directly proportional to power received from the sun. This will vary throughout the day. The rated maximum output of the module might only be achieved occasionally, depending on the actual site.

System designers calculate the output energy from the peak sun hours, which is a measure of the available solar energy. It is numerically equal to the daily solar radiation in kWh/m^2 (Note: it is not the same as the number of hours of sunlight). Peak sun hours varies throughout the year. Peak sun hours are usually averaged and presented as a monthly figure.

The following table shows the monthly and annual peak sunhours for various locations in Australia.

	MELBOURNE	SYDNEY	BRISBANE
January	6.9	6.7	6.5
February	6.4	5.8	6.2
March	5.2	5.7	5.7
April	3.8	4.4	4.8
May	2.8	3.6	4.2
June	2.4	3.4	4.1
July	2.7	3.3	4.2
August	3.3	4.4	5.2
September	4.3	5.2	6.0
October	5.3	5.8	5.9
November	6.1	6.3	6.0
December	6.6	6.9	6.3
Annual	4.6	5.1	5.4

The peak power output of modules is rated in kilowatt peak (kWp), and is measured under standard test conditions. The table below indicates the annual load in kilowatt hours (kWh) that can be met by a 1kWp grid connected system and a stand alone system for different annual average peak sun hours. Output over the year will vary in line with the monthly sunhours as shown in the table above.

The figures for the systems differ due to the different efficiencies of associated equipment such as inverters and batteries.

ANNUAL PEAK SUNHOURS	4	4.5	5	5.5	6
kWh/YEAR GRID CONNECT	1120	1260	1400	1540	1680
kWh/YEAR STAND ALONE	810	910	1015	1115	1215

A typical Sydney household has an electricity usage of about 5,000kWh per year. A house with energy efficient appliances and using non-electric cooking, heating and hot water could use as little as 1,000kWh per year.

Shading one of the cells in a module is similar to opening a switch in a circuit and stopping the current flowing. This results in a loss of power from many cells, not just the one that is shaded. Partial shading can cause hot spots' that can damage the module. This occurs in mono and poly crystalline modules but not in amorphous modules. Arrays should not be located near trees that will grow and shade the modules.

Standard solar modules are supplied with junction boxes on the back to facilitate electrical interconnection. Some modules used in grid connected systems now have leads and plugs/sockets for easier installation.

Bypass diodes are supplied within junction boxes for mono and poly crystalline modules. These bypass diodes allow current to flow through them when cells are shaded, minimising the possibility of cell damage from shading.

At night solar cells act as a resistance and current will flow from the battery bank into the module. The amount of power lost due to this process is greater in poly crystalline modules than mono crystalline modules.

Blocking diodes should be installed in junction boxes to prevent this. Your installer will provide the appropriate equipment where needed.

In SAPS the PV array needs to be installed as close as possible to the batteries to minimise the power loss between the modules and the batteries. The system designer will determine the size of the cable to minimise the power loss between the modules and the batteries. [See: 6.9 Batteries and Inverters]

If modules are mounted some distance from batteries, they can be wired in series to allow higher voltage and lower current. An electronic component called a maximiser is used to convert output to the correct battery voltage.

INSTALLATION

Modules can be fixed on the ground, wall or roof with a frame mount, or integrated into the building fabric.

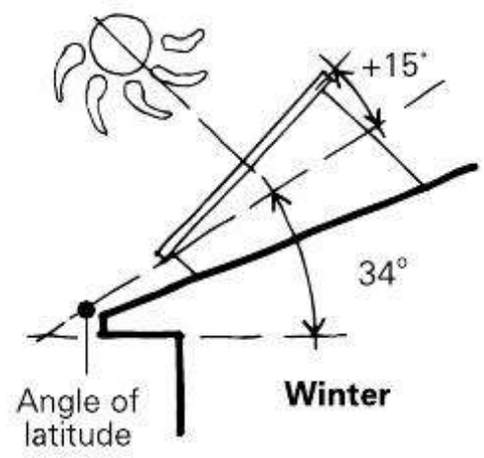
Array frames

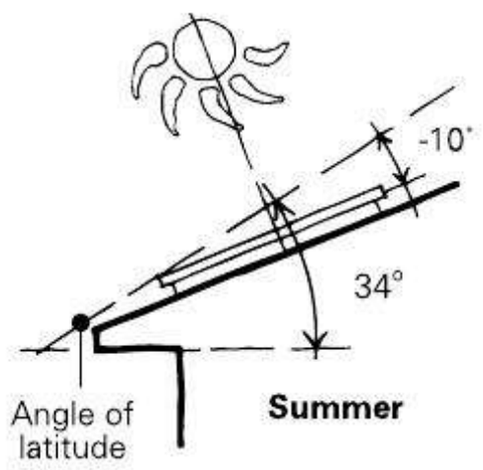
Solar array frames are tilted so that the modules face the sun. In Australia modules face north. In tropical areas this means the sun will be south of the array for part of the summer but this does not greatly affect output, see 'Orientation and elevation'.

Array frames can be fixed, adjustable or tracking. System designers choose the right frame for your system.

Fixed frames are set at the optimum tilt angle for the system. Optimum tilt angle is dependent on the type of load and available solar power.

As a rule of thumb, if the main loads are in winter months when solar availability is reduced, tilt angles should be more vertical (approximately equal to latitude plus 15º) to maximise exposure to the low winter sun. If major loads are cooling and refrigeration the tilt angle should be reduced (approximately latitude minus 10º) to maximise output during summer. For grid connect systems the summer optimum angle should be used to maximise annual output of the modules.





Solar panels should face due north. Sydney angle of latitude is 34°.

Adjustable frames allow the tilt angle to be varied manually throughout the year to maximise output year round. In practice it has been found that although many people change the tilt angle of the frame in the first few years of operation, they forget to do this as the years progress. If this situation is likely, it is best to fix the array at optimum angle.

Tracking array frames follow the sun as its path across the sky varies throughout the day and year. They are controlled either by an electric motor or the use of a refrigerant gas in the frame that uses the heat of the sun to move the gas around the frame to follow the sun.

Trackers are more expensive than fixed array frames but by following the sun they provide more power throughout the day. They are most beneficial at higher latitudes where the available solar energy is lower. However, tracking arrays, being mechanical devices, require maintenance and may reduce system reliability.

The outputs of crystalline modules are affected by temperature. As the temperature increases, the output of the solar module will decrease. Amorphous solar modules are less affected. To keep mono and polycrystalline modules cool they should be well ventilated, with a gap of at least 150mm behind them to allow airflow.

Array frames must be designed to meet Australian wind loading standards.

Avoid corrosion. If the array frame and module frame are made of different metals they must be separated by an isolating material to prevent electrochemical corrosion. This also applies if mounting a module on a metal roof.

For PV systems of more than 1kWp, it is worth considering the installation of a maximum power-point tracker. This is a control device that ensures that there is always the maximum energy transfer between the modules and the load. Grid interactive inverters generally have a MPPT built in. For stand alone systems the benefit will depend on the particular application, and the designer will advise whether it is appropriate.

The ability of the roof framing to be able to withstand the concentrated wind load from the stand must be checked and if necessary the roof may require strenghtening.

BUILDING INTEGRATED PV (BIPV) MODULES

True building integration requires that the PV product is either fully integrated into or replaces an existing building element.

PV installations are currently a considerable additional expense, but if done well BiPV construction should add considerable value to a home.



Installing semi transparent PV panels.

BiPV products requiring few additional installation details beyond standard construction practice are beginning to appear. These are not yet common in Australia. PV can be integrated into roofs, facades, skylights or awnings. Facade systems are not recommended in Australia as the energy output is lower due to vertical elevation and generally high sun angles.

Many BiPV installations do not allow effective cooling of crystalline modules which results in lower output. This needs careful consideration in the design.

Don't hide BiPV systems. Expose them as a prestigious element of modern architecture.

New buildings should be designed so that PV elements face north at the near optimum tilt angle. See 'Siting'.

ROOF INTEGRATION

Rooftop systems can be either partially or fully integrated. In the latter case the elements must also fulfil the usual functions of strength, watertightness, drainage, etc. Careful detailing is required.

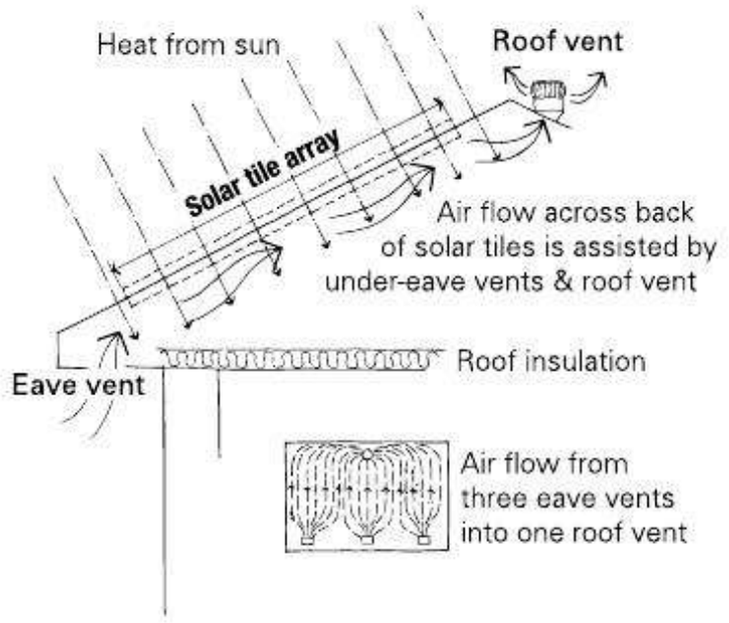
Partially integrated systems use special mounting structures to hold the cells, but require an additional waterproof layer.



Newington village used a partially integrated PV system.

Solar tiles or shingles are designed to replace conventional tiles or roofing. They allow easy access to the rear of the tiles for ventilation and maintenance. The roof space must be ventilated to keep the tiles cool.

Roofs are often at a pitch that is close to the optimum PV module tilt angle. For example, the optimum tilt angle for a grid connected system in Sydney is about 24°, which is very close to the most common roof pitch.



PV roofing elements need to be compatible with any non-PV elements for structural and aesthetic reasons.

Shading elements such as BiPV awnings reduce cooling load at the same time as generating electricity. They are usually quite accessible for cleaning purposes.

Semi-transparent PV modules can replace glass skylights and glass roofing in many situations. The dappled light quality can be used effectively by skilled designers.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on renewable energy, including what rebates are available.
www.gov.au

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www.shop.ata.org.au

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www.anzes.org

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www.iea-pvps.org

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Wind Systems

A growing amount of renewable electricity is being harnessed from the wind. Australia has an abundant supply of wind resources, which, if utilised adequately, can save significant greenhouse gas emissions. This fact sheet provides an overview of installing and using wind systems.



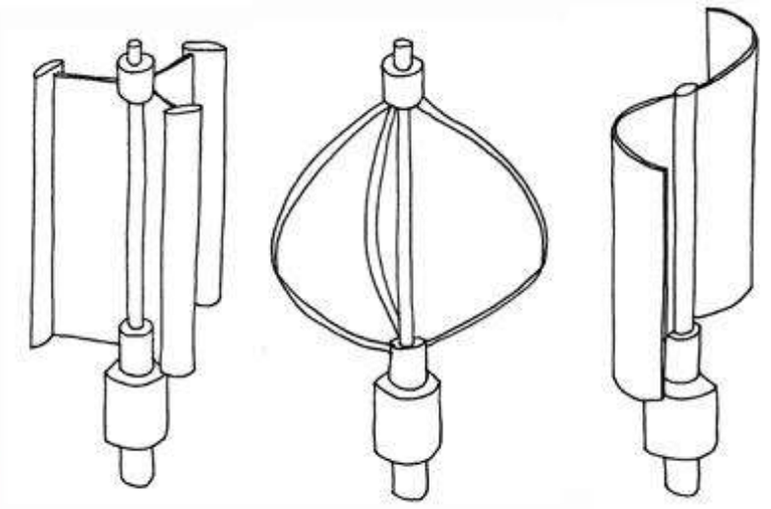
INSTALLING DOMESTIC WIND SYSTEMS

Domestic wind generators (also called turbines) are usually used in stand alone power systems and are designed to charge a battery bank.

Domestic wind generators are usually sized in the range of 300W up to 5kW but in some instances they could include a 10kW or 20kW turbine.

Conventional wind turbines have the turbine axis in the horizontal plane, but a number of innovative designs are being developed employing a vertical axis turbine, and some with more aerodynamic features or shrouded blades to improve the performance of small horizontal axis machines.

These changes are aimed at reducing noise and providing a better output under turbulent wind conditions likely to be experienced around buildings. Test results are promising and some commercial models are making it to the installation stage. The remainder of this fact sheet relates to the commercial horizontal axis wind generation.



New developments in wind turbines include noiseless vertical axis turbines.

The main body of the wind generator comprises a set of blades, the alternator and the tail section. The power of the wind makes the blades turn. The blades are connected to the rotor inside the alternator which turns and generates electrical power. The tail ensures that the wind generator is facing directly into the wind.

Wind speed increases as the height above the ground increases.

Output of a wind generator is dependent on the amount of wind but can also vary from one manufacturer to another.

To help appreciate what you can expect from a wind generator the following table shows the daily AC load in watt hours (Wh) that can be met by a 1000 Watt wind generator at various average wind speeds.

Inverter and battery efficiency have been taken into account in accordance with design guidelines. A household electricity usage of 5,000kWh per year equates to about 13.5kWh per day.

Care should be taken in determining the wind resource of your site.

AVERAGE WIND SPEED METRES/SEC	DAILY AC LOAD THAT CAN BE SUPPLIED BY SOMA 1000 (Wh)
3	690
4	2,142
5	3,060
6	5,585
7	7,650
8	9,180
9	10,863
10	12,470

As a rule of thumb, a wind generator should be installed no closer to an obstacle than at least ten times its height, and on the down wind side. The preferred distance is twenty times the height.

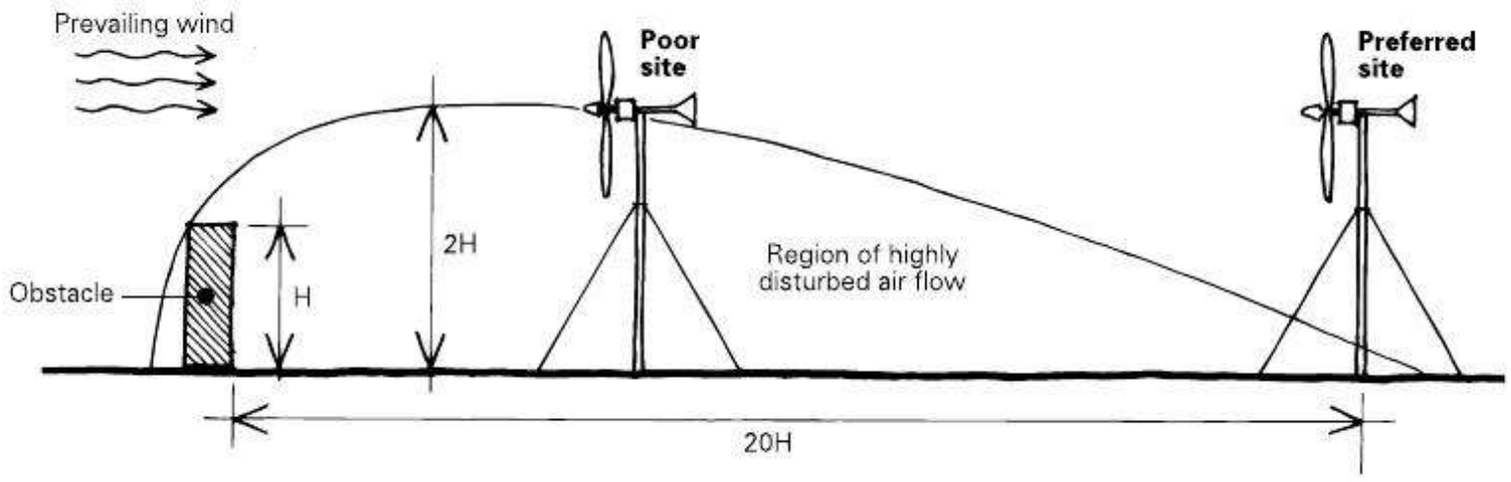
Wind speed increases as the height above the ground increases, so the wind generator should be installed on the highest tower that is practical and cost effective for your site. The typical tower used in domestic wind generator systems is between 10-20m tall.

SITING AND INSTALLATION

Wind generators need 'clean' wind to operate. Clean wind is where the wind is constant from the one direction and is not being made turbulent by near-by obstacles. The clean wind is required to overcome the starting torque (that is the starting resistance) of the wind generator.

Wind can be affected by terrain like hills, trees and nearby buildings or structures. Some areas of Australia receive seasonal wind and may only receive winds in winter while in coastal regions on the east and west coasts the prevailing wind will be summer sea breezes.

Most manufacturers will provide figures on the 'cut-in' wind speed. This is the speed of the wind (generally measured in metres/second) at which the starting torque is overcome and the wind generator begins to turn and generate power. In areas with frequent light winds, a low cut-in speed is an important feature for



maximum output. Manufacturers provide a rated output of a wind generator at a specified wind speed. Not all manufacturers rate their units at the same wind speed.

In Australia there is very little wind monitoring undertaken, so the system designer will have very limited wind data to use to design the system. Designers will use their own experience, knowledge and relevant information obtained from the manufacturer when determining the anticipated output of the wind generator system.

To overcome the power loss in the cables, the wind generator needs to be located as close as possible to the battery bank. If the preferred site is distant from the house, the batteries and inverter could be located near the wind generator and the power transmitted as 240V AC to minimise cable losses. Alternatively the generation voltage can be higher and then transformed down to battery voltage if the batteries are installed near the house. Higher voltage transmission means lower losses.

Wind generators can produce some running noise in high winds. The noise can come from the blades, gear-box, brush gear or wind whistling past the tower, pole or guy wires. The noise may not be loud but may be noticeable to you or close neighbours. The background noise of the wind itself usually covers the sound of the blades. Always ensure that there are no objections to the low level noise produced.

TURBINE CONTROLS

As the wind speed increases the wind generator will spin faster. If wind speed continues to increase the generator may ultimately be destroyed. All wind generators therefore have a wind 'cut out' speed at which the unit will employ some form of overspeed control to either stop the unit generating power or govern the rotational speed to produce constant power.

The two most common forms of overspeed control are mechanical braking and feathering.

In mechanical braking, a brake, similar to those found in many cars, is applied as a result of the centrifugal forces developed when the unit approaches the cut out speed. If the unit is operating in an area where the average speed is close to the cut out speed, braking might happen frequently and the brakes will wear out rapidly.

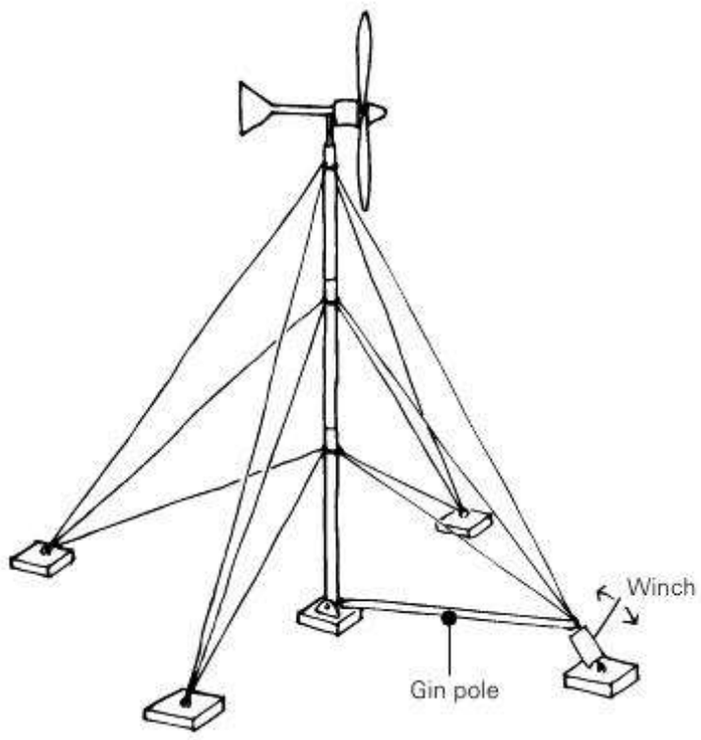
Feathering can occur in two ways: either by rotating the individual blades to reduce their angle into the wind, thereby reducing rotor speed; or turning the whole unit out of the wind.

Wind generators are always producing power when turning. If the batteries are fully charged the excess power is redirected into a dummy load, usually an electrical element. The dummy load can get very hot and should be positioned where it will not be touched accidentally.

TOWER DESIGN AND INSTALLATION

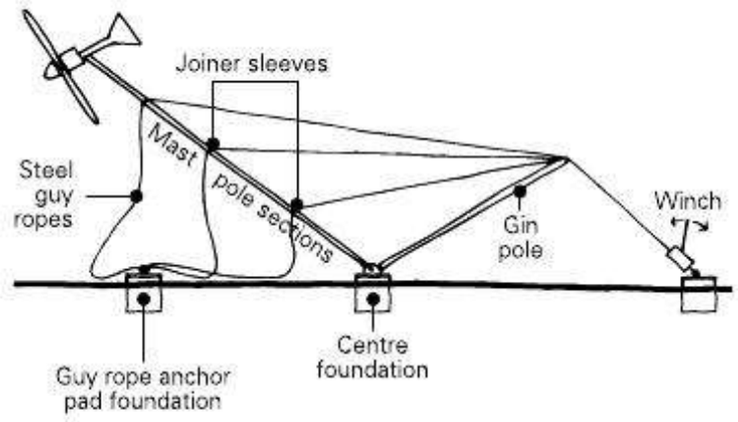
Wind turbines require regular maintenance and the tower needs to be designed to allow access for servicing mechanical components, such as bearings.

The typical tower is designed so that it can be lowered and raised by tilting the tower with a gin pole and winch.



Courtesy of Geoff Stapleton

If a tilt tower and gin pole is used there must be sufficient area around the wind tower for it to be lowered. If it is 20m tall you will need at least 20m area for lowering the tower. If a vehicle is used to raise and lower the tower it also needs room to manoeuvre.



ENERGY USE

Tilt towers are guyed, so although the tower might only be constructed from 100mm pipe, the guying of the tower will have a footprint of 20 x 20m for a 19.5m tower. The guy wire tensions will need to be checked regularly.

The tower and the guy wires will usually require concrete footings. These footings must be designed in accordance with the wind loadings for the particular site.

Wind generators and the accompanying system, being mounted on top of metal towers, are very susceptible to lightning strikes. Lightning arresters should be installed in the system to protect electronic components from the effects of lightning strikes.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on renewable energy, including what rebates are available.
www.gov.au

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www.renew.org.au

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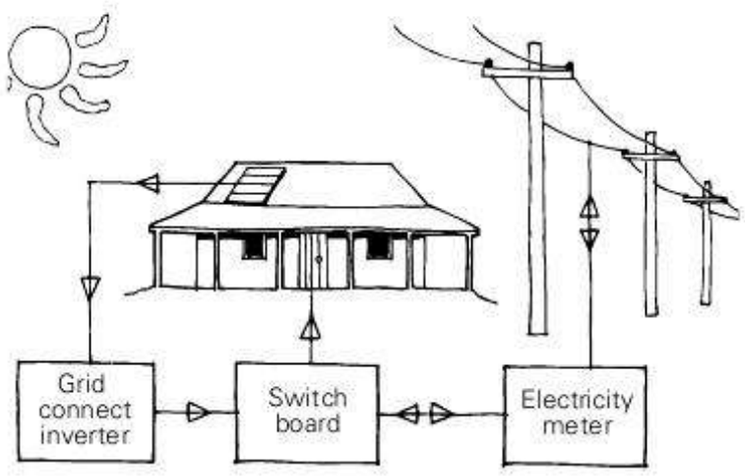
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Batteries and Inverters

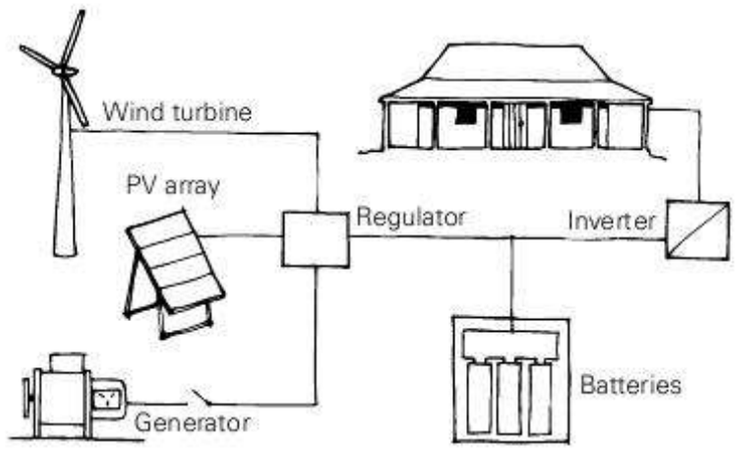
Batteries and inverters store renewable energy turning it into useable electricity. A complete renewable energy system has a number of components, as discussed in this fact sheet.

Grid connected systems require an inverter and metering system. Battery banks can be installed if back up supply is required.



Grid connected system.

Stand-alone systems include a battery bank, inverter, battery charger and a fuel generator set (genset) if required.



Stand alone system.

Each system will require a specific regulator/ controller.

A complete system will include the necessary switches, circuit breakers and fuses to ensure that the system is electrically safe and to allow for major items of equipment to be isolated for maintenance purposes.

Battery banks and inverters are required whether the charging source is photovoltaics, wind, or micro hydro.

The exact layout will vary depending on the equipment configuration and space available.

BATTERY BANKS

Battery types

Lead-acid batteries are used most often in renewable energy systems. Less common are nickel-cadmium batteries which last longer but are much more expensive.

Most batteries are composed of a number of cells. For example a car battery is 12 volt, but is supplied as one unit (monoblock), that comprises 6 x 2 volt cells. In stand-alone power systems the battery banks are supplied as either 12V, 24V, 48V or 120V. These batteries could be supplied as monoblock (12V or 6V) batteries but are generally supplied as individual 2V cells. A 12V battery bank will consist of 6 x 2V cells, and so on.

Battery banks can be designed to provide many days energy requirement with no input from the charging source.

Lead-acid batteries can be supplied as either wet batteries, as used in cars, or valve regulated batteries commonly called 'sealed' or 'gel' batteries. Wet batteries are most commonly used in renewable electricity systems.



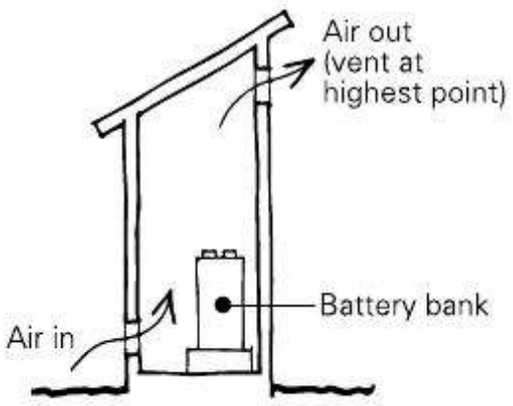
A battery bank.

The life of a battery bank is affected by how regularly it is discharged, and its use. This is referred to as the average daily depth of discharge. If the battery bank capacity is large enough to keep the depth of discharge low, the battery life should be at least ten years. Battery manufacturers will provide information on the cycle life of the battery. Your installer will adjust your system to comply with relevant standards and maximise battery life.

Battery installation

Batteries emit a corrosive and explosive mixture of hydrogen and oxygen gas during the final stages of charging. This can ignite if exposed to a flame or spark.

Batteries must be installed in a well-ventilated environment, preferably in an appropriately designed structure away from the house.



Because the gases rise, ventilation design must permit air to enter below the batteries and exit the room at the highest point.

Ventilation can be achieved naturally or by installing fans and electrical vents. The amount of ventilation required depends on the number of battery cells and the charging current. A large battery bank using large charging currents needs more ventilation.

Your installer will design an appropriate battery storage facility in accordance with relevant standards.

Batteries should be mounted on stands to keep them clear of the ground. If the batteries are ground mounted they should be thermally insulated from the ground temperature. They should not be installed directly onto concrete,

as concrete will cool to ground temperature, causing the electrolyte to stratify. This is detrimental to a battery's long-term life and performance. Low electrolyte temperatures also reduce the capacity of a battery.

Batteries must not be installed where they will be exposed to direct sunlight, as high temperatures may cause electrodes to buckle.

The typical area required for the installation of a battery bank is:

12V	1.4m x 0.3m or 0.7m x 0.6m
24V	1.4m x 0.6m
48V	2.8m x 0.6m

The batteries can be as high as 700mm, and if installed in a box it must have a removable lid or at least 500mm clearance above them to allow access for a hygrometer to check the charge level.

Access to the battery room or container should be limited to responsible people trained in system maintenance and shut down procedures.

Safety signs are required in accordance with Australian Standards.

The installation must include a switch/fuse near the batteries to enable the bank to be electrically isolated from the rest of the system.

Battery maintenance

Battery maintenance includes keeping terminals clean and tight and ensuring the electrolyte is kept above minimum levels. Use only distilled water when topping up the electrolyte level.

Batteries are dangerous items and must be treated cautiously. There are three main dangers with batteries:

> Explosion or fire from the battery gases.

> Short-circuiting the terminals.

> Acid burns from wet, lead-acid batteries.

Ensure that when working with batteries you do not short across the battery terminals. Under Australian Standards the terminals must be covered (shrouded) to prevent accidental shorting.

Wet, lead-acid batteries hold a fluid electrolyte that contains sulphuric acid. This can cause serious burns to the skin and eyes. Always wear protective clothing and eye protection. If 'acid' is spilt on the floor or equipment, it must be diluted with water and neutralised with sodium bi-carbonate. These should be readily accessible and stored near the battery bank.

Batteries need specific charge regimes that include equalisation charging. The system designer will explain this process. The equalisation charge will either be controlled by the system or require the owner to connect a generator and battery charger. Specific gravity readings are the best method to determine the charge level. A safe method for performing this will be explained by the system designer.

System owners should read and fully understand the manufacturer's manual for their battery bank.

Battery disposal

Batteries contain lead and acid that are harmful to the environment. When a battery bank is being replaced the old batteries should be disposed of at a battery recycling station or other suitable site.

INVERTER INSTALLATION

Inverters are commonly a part of battery based stand alone and grid connected systems.



Inverters convert DC power from batteries or solar modules into useable AC, normally 240V AC (single phase) or 415V AC (three phase) power. Inverters are complex electronic devices and must be installed in dust free environments.

Inverters can be either wall or shelf mounted. They are heavy – a 5kW unit could measure 0.6m x 0.6 x 0.4m and weigh 60kg.

Inverters become very warm or hot when operating at large power outputs and need suitable ventilation and cooling air-flow. Insects often like to nest in the heat dissipation vents. To prevent this, inverters should be carefully sited and regularly checked.

Inverters must not be installed in direct sunlight.

Inverters should be readily accessible in case they need to be electrically isolated in an emergency.

Lightning can damage inverters. The risk should be assessed by the designer and appropriate protection installed if required.

Only a suitably trained and qualified person may undertake AC hard wiring to an inverter.

Grid connected systems

Grid connected inverters convert power from solar modules, wind or micro hydro into AC power that feeds into the grid.

On the DC side, the grid inverter is connected directly to the renewable charging source – generally PV.

The AC output of the inverter interconnects with the building switchboard in accordance with regulations.

The inverter can be installed in any suitable location between the renewable energy source and the switchboard.

Battery based systems

The DC currents in the battery leads between the inverter and battery can be very large. To avoid problems due to overheating and voltage drop, these must be sized accordingly and should be kept to a minimum length. Situate the inverter as close as possible to the battery bank.

The battery charger can be a separate unit or be incorporated within a combined inverter/ charger. The inverter supplies 240V AC power from the battery bank. When the generator starts, the inverter passes the load to the generator and becomes a battery charger.

Each battery charging source requires a regulator/ controller to prevent overcharging the batteries. These can be manual or automatic. In automatic controls the generator is started when the batteries reach a low charge level or the load is greater than the maximum power output of the inverter. In manual controls the state of battery charge must be regularly monitored.

Battery charger installation

If the stand alone power system installation includes a separate battery charger, it should be treated in a similar manner to the inverter. Chargers are generally no larger than 0.4m x 0.4 x 0.6m and weigh up to 40kg.

The charger must be installed close to the batteries and can be floor or shelf mounted. The input power to the charger must be a generator-only power point.

GENERATOR INSTALLATION

The generator should be installed in a separate room or enclosure. If installed in the same room as the rest of the system it should be located as far away from other components as possible. This helps prevent excessive heating and contamination from a malfunctioning exhaust.

Sufficient space should be allowed around the generator for maintenance.

Generators can be noisy, so locate and design the enclosure to minimise noise.

The generator fuel must be kept in an approved container in a safe location.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on renewable energy, including what rebates are available.
www.gov.au

ReNew, *Batteries Buyers Guide*, Issue 98 and *Inverters Buyers Guide*, Issue 87.
www.renew.org.au

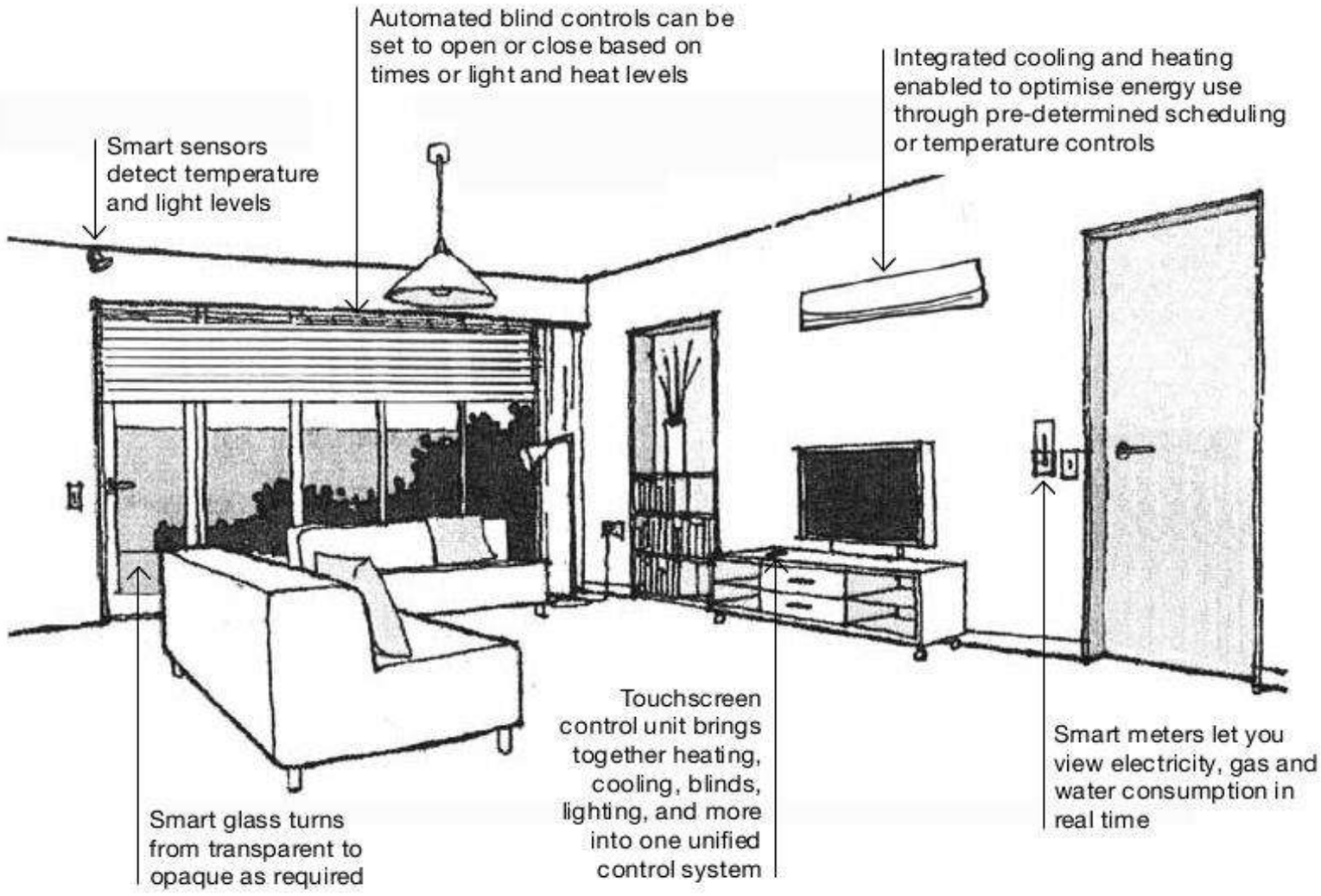
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Home Automation

Home automation is the automated or remote control of appliances and equipment in the home. Automated controls can be used to turn equipment on or off or adjust the operating settings at pre-determined times, on-site or remotely, or can be set to adjust the operation of equipment in response to changes in the home environment, eg. temperature. Homes using these techniques, which may also involve the integration of broadband communications, are sometimes called Smart Homes or Smart Houses.

Home automation can either be centralised and programmable, or consist of decentralised and isolated sensors and controls. It can involve sophisticated electronic programmable controls for lighting, heating, cooling and entertainment devices using a special wiring or wireless controls, or just a few isolated systems being automated, such as motion sensors to control lights.



Home automation systems can only improve the energy efficiency of your home if they are designed for this purpose.

Operating automated systems uses energy, so the automated systems will only lead to energy savings if they save more energy than they use.

Priority should first be given to designing an energy efficient home and installing high energy efficient appliances and lighting. Home automation can save energy if it reduces the time that equipment operates or reduces the need to use equipment, eg. by only switching on lights when they are needed.

Aim to design home automation systems to reduce the need for operating or the time that energy-using equipment operates.

Heating and cooling

A well designed automation system can:

1. Improve passive solar heating and passive cooling through the control of blinds, awnings, windows, vents and fans.
2. Control heaters and air conditioners so they are only used when and where they are needed and are use to achieve a desired temperature.

Design your home to make the best use of solar energy and natural ventilation for passive heating and cooling before you consider your automation options. [See: 4.5 Passive Solar Heating; 4.6 Passive Cooling]

Use temperature sensors in different rooms to control heating and cooling. Appropriate placement of temperature sensors and the use of heating/AC timers can significantly reduce energy use, even if automated systems are not used.

Analyse your heating/cooling needs and how you will manage these. Ask yourself what rooms need to be heated/cooled, when and to what temperature? Aim to heat/cool living areas when people are home but heat/cool bedrooms only at night and the early morning when they occupied. Bedrooms do not need to be made as warm or as cool as living areas, to be comfortable for sleeping. Avoid heating and cooling halls, laundries etc. [See: 4.2 Design for Climate]

Plan your automation system. Consider how opening and closing blinds, awnings, windows and vents can assist passive heating, cooling and natural lighting. Explore how switching on and off of fans and heat shifters might reduce the need for cooling or heating. Consider how better temperature and the timing of use can minimise the energy used in heaters and air conditioners/coolers. Use these answers to decide on your automation needs.

Hot water

Automate the hot water system so it can be switched off when not required, such as when household is absent on holidays. Solar systems can be controlled so they do not require heat boosting during summer months.

Lights

Automate lights so they operated only when needed and switch themselves off when rooms are vacant. This can be done through motion sensors and timers or through more elaborate centralised systems.

Use motion sensors to switch on external lights when needed, or lights when entering the home, rather than leaving lights on.

Use motion sensors, light sensors and timing controls to switch off lights when they are no longer needed, (eg. Room lights may be switched off after 5 minutes if no motion is detected). Give priority to rooms that often have lights left on unnecessarily, like bathrooms, pantries and toilets. However, consider these options carefully as five minutes of inaction in front of a TV is not unusual and you may not want the lights to all go off then!

Appliances and equipment

Use controls to operate appliances and equipment only when they are needed.

Remote control and timer control of appliances, from coffee makers to home theatres to spas, can lead to energy savings if the appliances can be switched off when not required.

Care should be taken not to turn on appliances automatically or at pre-set times as this may lead to additional energy consumption when there is no need for the appliance to operate.

Automating equipment control to reduce operating times is particularly useful if the appliances normally use standby power, even though they are not operating, eg. Stereos, TVs, DVDs and home office equipment. It is also useful when the need for the equipment to operate varies, such as for pool pumps, where daily operating hours can be matched to the season.

Automation equipment, sensors and controls

Home automation systems work by managing the electric power of the equipment being automatically controlled. The degree of 'intelligence' and how it is distributed between the elements of the home automation system varies with the design and with the manufacturer.

Control can be implemented by isolated sensors timers and processors embedded in the switches and relays. Alternatively centralised control can be obtained through networked sensors linked to a controller or computer which then operate the power systems of equipment throughout the house.

The operation of more sophisticated equipment such as central heaters, air conditioners or home theatres, can also be bought under the control of the automation system, but with more intelligent controlled devices, care is needed to ensure that the controller's instructions do not create conflicts.

Automation equipment potentially can include any appliance or machinery in the home, the operation of which is controlled through its electricity supply. This list might include:

> Hot water systems.

> Appliances.

> Home office, home entertainment and other electronic equipment.

> Lighting.

> Heating and cooling/air conditioning systems.

> Fans and air pumps/heat shifters.

> Powered window blinds, shutters and awnings.

> Powered vents and window openings.

> Water pumps, pool pumps and spas.

> Garage doors.

> Security systems.

Sensors that can be integrated into the automation system can include:

> Motion sensors.

> Light sensors.

> Temperature sensors.

Control of the home and its lighting, appliances etc can performed by:

> On-site controllers, which may be special proprietary devices, often activate by touchscreens, or standard computers.

> Remote controllers, allowing equipment to be controlled outside the home or at a distance in the home. Again, these may be proprietary devices, or standard mobile phones or computers.

> Sensors, which operate the home equipment in response to changes in the home environment, such as the presence of occupants or changes in the external temperature.

Automation and electricity demand

In the near future, home automation systems may be linked to the electricity utility in a number of ways. The utility may communicate variations in electricity prices to a 'smart' electricity meter, that will interface with the home automation controller.

Householders can then program appliances to reduce power or switch off altogether during high price periods.

Alternatively householders could enter a supply contract that allows the electricity supplier to signal equipment controlled by the home automation system (such as air conditioners) to turn off certain equipment for short periods. The householder may choose to participate and obtain lower electricity prices or other financial incentives.

ADDITIONAL READING

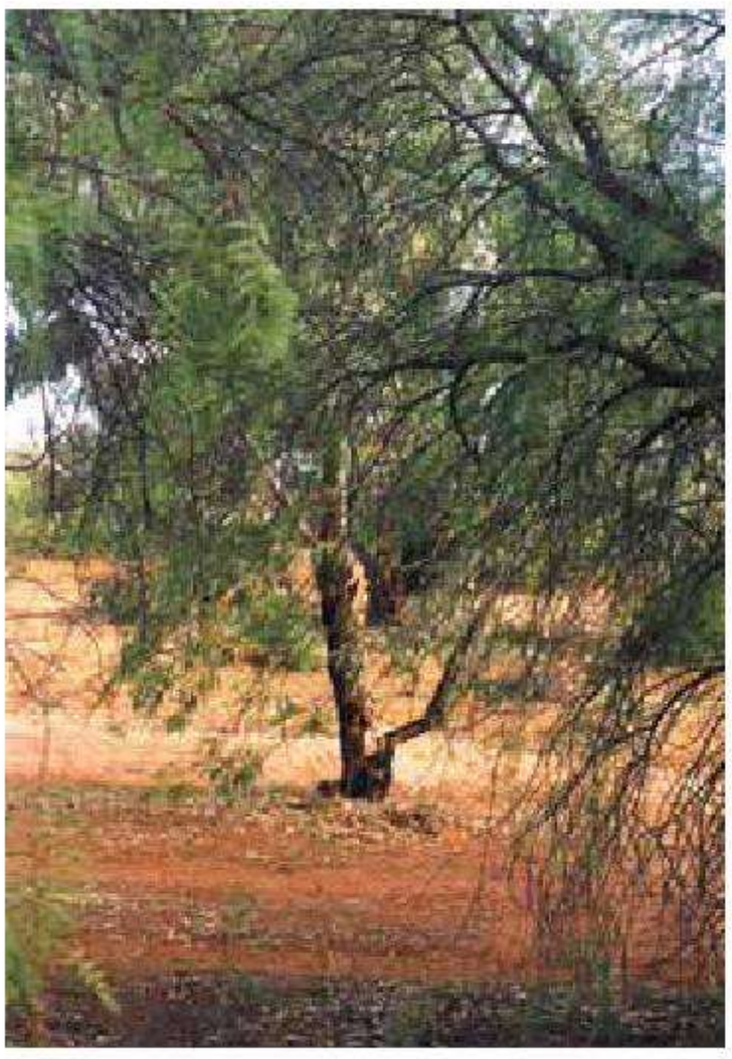
Smart Wired House
www.smartwiredhouse.com.au

Custom Electronic Design and Installation Association
www.cedia.com.au

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Water Use

Australia, the most arid inhabited continent, can provide only a limited amount of fresh water. Available fresh water resources are expected to decline with changes to rainfall patterns accompanying global climate change. As our population grows, so too does the pressure on water use. To ensure future supplies of fresh, clean water we must use it more carefully.



Good building design can greatly reduce the amount of water we use and the degree of contamination we cause. The following fact sheets show you how to use water in a sustainable way:

> **7.2 Reducing Water Demand.**

> **7.3 Rainwater.**

> **7.4 Wastewater Re-use.**

> **7.5 Stormwater.**

> **7.6 Outdoor Water Use.**

> **7.7 Low Impact Toilets.**

> **7.8 Water Case Studies.**

7.1 INTRODUCTION

The application of each of these will depend on whether you live in the city or the country, in the tropics or the warm temperate south. Examine the options presented and decide which design solutions would improve your quality of life and reduce your impact on the environment.



7.2 REDUCING WATER DEMAND

Simple changes can reduce the pressure on reticulated water supplies and reduce your water bills. This fact sheet shows you how.

Choose water efficient products and appliances. Australia now has a Water Efficiency Labelling and Standards (WELS) Scheme, which enables consumers to see the water efficiency rating of new taps, showers, toilets, urinals, clothes washing machines and dishwashers. The blue 6-star arch label shows the relative efficiency and a water consumption or flow figure. The more stars, the more water efficient.

Taps, toilets and showers are key areas where water consumption can be reduced by installing water efficient products.

Fit water efficient showerheads.

Replace your single flush toilet with a WELS 3 or 4 Star rated dual flush model. The 4 Star models are in the 4.5/3 litre category, while 3 Star is the 6/3 litre category. All WELS labelled toilets have an average flush of 5.5L or less.



Fix leaking taps.

Install appropriate taps. Mixer taps in showers can reduce the potential for scalding and save large quantities of hot water. Single lever flick mixer models of mixer taps over basins and sinks, however, waste hot water because they tend to be left in the middle position. Mixer taps with separate controls for hot and cold water are preferable in these locations.

The environmental benefits include:

> Lower water extraction from the environment.

> Decreased sewage volume.

> Reduced CO_2 emissions.

7.3 RAINWATER

Rainwater tanks can provide a useful sole or supplementary water supply in most regions of Australia. These systems are especially recommended in areas where water supplies are limited.

Rainwater can be used for toilet flushing, laundries or for watering the garden. Drinking rainwater is not advised in most areas of Australia with potable supplies. If drinking water is being supplied by the rain tank, the system must be adequately maintained and health guidelines followed.

This fact sheet provides more detail on how to harness rainwater.

7.4 WASTEWATER RE-USE

With appropriate treatment, and if local regulations allow, wastewater can be used to flush toilets, water the garden and even to wash clothes.

Different types of wastewater produced in a household need to be treated differently before they can be re-used.

Greywater is wastewater from non-toilet fixtures such as showers, basins and taps which does not contain human excreta.



On-site sewage treatment system.

Blackwater is wastewater containing human excreta.

Greywater from bathrooms and laundry (but not the kitchen) is the easiest to treat for re-use. Most States permit greywater re-use outdoors as well as indoors for toilet flushing and laundry after appropriate treatment.

Re-use of wastewater containing blackwater may be permissible only outdoors for subsurface irrigation after suitable on-site treatment.

The Wastewater Re-use fact sheet discusses options for wastewater treatment and re-use, including:

> Advantages and disadvantages of wastewater treatment and re-use.

> Estimating wastewater volume.

> Common wastewater system types.

> Reusing wastewater indoors.

> Reusing wastewater outdoors.

7.5 STORMWATER

Stormwater is the term given to pure rainwater, plus anything the flowing rainwater carries along with it. This fact sheet provides information on how to manage stormwater.

Avoid cut and fill on your block when preparing the building foundations. Attempt to maintain the existing topography and drainage pattern. If you do have to cut and fill, stabilise the soil and revegetate as soon as possible.

Retain vegetation, particularly deep-rooted trees that can lower the water table, bind the soil, filter nutrients, decrease run-off velocities, capture sediment and reduce the potential for dryland salinity.

Retain stormwater on your block with permeable paving, pebble paths, infiltration trenches, soakwells, lawn, garden areas and swales.

Minimise impervious surfaces such as paved areas, roofs and concrete driveways.

7.6 OUTDOOR WATER USE

Up to 60 per cent of household water is used outdoors. Using water conservation techniques in the garden will ultimately save you money, time and effort. This fact sheet shows you how.

Minimise lawn areas. In most gardens, lawns consume up to 90 per cent of outdoor water and most of the energy used outdoors. To reduce outdoor water use replace lawns with groundcover plants or mulched garden beds.

Mulching around plants conserves water by preventing evaporation and reducing run-off.

Plant drought tolerant species. Australian natives, succulents, cacti, olive trees and some exotic ornamentals are suitable.

Improve soil. The addition of organic matter, gypsum, sand and other compounds can improve soil condition, water retention and drainage. Hardy, deep-rooted plants can help break up poor soils.

7.7 LOW IMPACT TOILETS

Low impact or low water toilets use no or minimal amounts of water to treat or transport human excreta. If appropriately designed and operated they conserve precious water resources and avoid disposing of effluent and pollutants into waterways and the wider environment.

The best way to simplify wastewater treatment is to avoid mixing it with human excreta. Blackwater is the most difficult form of wastewater to treat due to the presence of pathogens.

The fact sheet describes some common types of low impact toilets and provides advice on choosing these toilets, managing a waterless toilet and how to handle the end products.

7.8 WATER CASE STUDIES

Three case studies show how many of the systems and strategies discussed in the fact sheets have been applied.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on using water wisely, including what rebates are available.
www.gov.au

Water Rating
www.waterrating.gov.au

Water Sensitive Urban Design
www.wsud.org/literature.htm

Windust A (2003), *Waterwise House and Garden – A Guide for Sustainable Living*, Landlinks Press, Victoria.

Woodcock, S. & White, S. (2001), *Sustainable Urban Water Use – An Update Environment Design Guide* General Issues GEN 41 November, RAIA, Canberra,



This vertical greywater filtering system treats water to be re-used in the toilet, washing machine and garden.

Reducing Water Demand

Reducing water consumption in the home is a simple and easy way to decrease water and energy bills and reduce your household's impact on the environment.

Conserving scarce water resources helps reduce the need to dam rivers, reduce wastewater produced and treated at sewage plants, lower energy requirements for treating and transporting water and wastewater, and reduce greenhouse gas emissions.

Low cost water reduction can take place in every household, often with costs recouped through water and energy savings within one year.

FIVE WAYS TO MINIMISE WATER USE

1. Reduce indoor water use by choosing water efficient showers, toilets, taps and appliances.
2. Minimise outdoor water use through reducing grassy areas and planting native species. Minimise paving of outdoor areas as this increases heat radiation and water run-off from the site.
3. Wash cars and bikes on the lawn so that the grass is watered at the same time.
4. Sweep your paths and drives instead of hosing them down.
5. Re-use water where possible.

Fitting a water efficient showerhead takes about five minutes for a plumber or handy person. If you do it yourself, don't forget to use plumber's thread tape.

THE WELS PRODUCT RATING SYSTEM

The national Water Efficiency Labelling and Standards (WELS) *scheme* provides consumers with information about the water efficiency of products.

The WELS scheme requires certain products sold anywhere in Australia to be registered, rated and labelled for their water efficiency in accordance with Australian/New Zealand Standard AS/NZS 6400:2005.

The Standard currently covers showers, dishwashers, clothes washing machines, lavatory equipment, urinal equipment, tap equipment and flow controllers. These products are legally required to display the WELS label. Labelling is voluntary only for flow controllers. Other products may be added to the scheme in the future.

The water efficiency rating is displayed on WELS products in the form of a blue 'star rating label'. Labels for different categories of products differ slightly, but all share two key pieces of information:

> The star rating – the stars indicate water efficiency. The more stars, the more water efficient.

> The water consumption or flow figures.

> The average water consumption per use (dishwashers, washing machines, toilets, urinals).

> The average water flow per minute (taps, showers).



A product search database that enables consumers to compare the water efficiency of products is available at http://search.waterrating.com.au

For further information about the labelling scheme and to search for products, see the WELS web-site at www.waterrating.gov.au

Some council development control plans specify water efficient fixtures in new developments and renovations. Check with your council on its requirements.

SHOWERS

The shower is one of the easiest and most cost effective places to decrease your water use.

An inefficient showerhead can use more than 20L of water every minute while an efficient WELS 4 Star rated one will provide a high quality shower using a maximum of 7L every minute. Depending on the model you choose it is possible to get additional features such as massage, self-cleaning, and flow cut-off control.



Water efficient showerheads can save around $60-$90 annually on household water bills. The reduction in hot water means less energy is needed for water heating, and can save up to $160 on energy bills depending on the sort of water heating system you use.

Many water authorities offer retrofit kits, free showerhead exchange or generous rebates on water efficient showerheads. Check with your local water authority.

The environmental benefits are:

> Lower water use.

> Decreased wastewater volume.

> Reduced CO_2 emissions from reduced hot water use.

TOILETS

There are many ways to reduce the amount of water used by your toilet:

> Use the half-flush button when appropriate.

> If you have a single flush toilet:

– Insert a water displacement device into your tank if you have a single flush toilet. You can purchase these or place a plastic bottle filled with water in the cistern. Make sure it doesn't obstruct the mechanism. Don't use bricks as they can crumble and stop the system working properly; or

– Have a plumber adjust the flush volume of your cistern.

– Even better, replace the toilet with a water efficient dual flush model. This could be one of the common 6/3 litre models with WELS 3 Star rating, or a more modern 4.5/3 litre model with 4 Star rating. You could even fit a 5 star model which re-uses water from hand washing (see below).



This 4.5/3 litre toilet suite re-uses water from the hand basin, and has a WELS 5 Star water efficiency rating.

Replacing a 12 litre single flush toilet with a 4.5/3 litre WELS 4 Star toilet in a household of four people could save more than 60,000L of water per year.

> Fix leaking toilets immediately. A slow, barely visible leak can waste more than 4,000L per year. Visible, constant leaks can waste more than 96,000L.

> Check for leaks by placing a couple of drops of food colouring or dye into the cistern. If colour appears in the bowl within 15 minutes without flushing, then a leak exists and the system should be repaired.

What leaking toilets cost

	LITRES PER HOUR	LITRES PER YEAR	COST PER YEAR (2007)
Slow leak, barely visible	0.5	4,400	$5
Leak visible in bowl, no noise	1.5	13,100	$16
Visible leak, just audible	6	52,600	$63
Visible leak, constant hissing sound	11	96,400	$116

Based on a water price of $1.20 per kL of water.

The most water efficient toilet is a waterless toilet, of which there are a range of models and types available. They work with no odour and little maintenance while providing excellent compost. For more information on waterless toilet systems see 7.7 Low Impact Toilets.

TAPS

There are a number of things you can do to ensure that your taps are not using more water than necessary:

> Fix leaks immediately.

> Don't over tighten taps. This can wear the washer and cause leaks.

A tap leaking at the rate of one drip per second will waste more than 12,000L of water a year.

> Install a flow regulator on kitchen and bathroom sink taps.

> Ensure that all new taps are water efficient. Check the WELS Star rating.

> Install mixer taps in showers. They can reduce the potential for scalding and save large quantities of water wasted through running the shower while trying to get a comfortable water temperature.

> Install separate hot and cold taps or mixer taps that provide cold water only in the middle position over basins and sinks. Mixer type taps are usually left in the middle position. This means that each time the tap is run for a glass of water or to rinse a toothbrush, hot water is drawn off just to cool in the pipe without ever being used.



WASHING MACHINES

The laundry is a great place to reduce your water consumption and is a potential source of water for your garden. There are a number of ways to improve the efficiency of your water use in the laundry:

> Adjust the water level on the machine so it is appropriate for the size of the load. Try to wash only full loads of laundry and use the economy cycle if you have one.

> Use the suds saver function if your machine has one.

> Divert the wash water from your laundry to other uses, such as flushing your toilet or watering your garden. You will need to check with your council to make sure this is allowed and installed to comply with regulations. [See: 7.4 Wastewater Re-use]

> Purchase a water efficient washer. Check the WELS star rating. Most front loaders are efficient, and there are now some efficient top loaders on the market. A 5 star model will save 50L or more per load. Water efficient washers also use less detergent (the big money saver).

DISHWASHING

Dishwashers are also WELS star rated and the most efficient models will use half the water of an older model.

A couple of simple ways to use your water more efficiently when washing dishes are:

Avoid rinsing prior to washing. Scrape food remains off dishes and dispose of them in the compost or garbage bin rather than rinsing them away.

Always use a plug in the sink rather than letting the tap run continuously.

Purchase a water efficient dishwasher. Some newer model dishwashers are very water efficient: WELS 4 Star dishwashers can use less than 1 litre per place setting – that's less water than many people use washing dishes by hand. Look for the WELS label to check the water efficiency.

Always try to fully load the dishwasher before using it and use the economy cycle if you have one.

OTHER WATER SAVING TIPS

In-sink waste disposal units use water when operating and also mix wastewater with food scraps. From an environmental viewpoint well controlled and managed home composting is the most favoured option (CRC Waste Management and Pollution Control, 2000).

Storage water heaters release water through a release valve when they are heating water. Have a professional check the release valves on your water heater. The amount of water used may be minimised by setting the release rate to the minimum recommended by the manufacturer. Turn your heater off when going on holidays so that water is not being heated and wasted while you are away.

Evaporative air conditioners have a bleed valve that releases water while the air conditioner is in use. Ensure that the bleed valve is set to the minimum required for the air conditioner to work with your water supply. Make sure the air conditioner is turned off when you go on holidays.



Reticulated drip fed systems are preferable.

Outdoor water use

See 7.6 Outdoor Water Use fact sheet for tips on:

> Watering gardens and lawns.

> Washing cars, houses, pathways and garden tools.

> Pool filling and maintenance.

> Other recreational uses.

REBATES FOR WATER EFFICIENT PRODUCTS

Depending on where you live, you are likely to be eligible for rebates, subsidies or free offers on some water efficient/water saving products. Check with your council and water utility.

The following website is also useful for identifying rebate offers. http://www.smartwatermark.info/home/rebate_links.asp

ADDITIONAL READING

Contact your State / Territory government or local council for further information on using water wisely, including what rebates are available.
www.gov.au

Australian Consumer Association
www.choice.com.au

Australian Water Conservation Tips
www.savewater.com.au

CRC for Waste and Pollution Control (2000), *Assessment of Food Disposal Options in Multi-Unit Dwellings in Sydney*, Document 2883R.
www.insinkerator.com/environmental.shtml/

Madden C and Carmichael A (2007), *Every Last Drop Counts: The Water Saving Guide*, Random House, Australia.

Mobbs M (1998), *Sustainable House: living for our future*, Choice Magazine, Sydney.

NABERS – water saving tips for your home
www.nabers.gov.au

Water Efficient Labelling and Standards, Australian Government
www.waterrating.gov.au

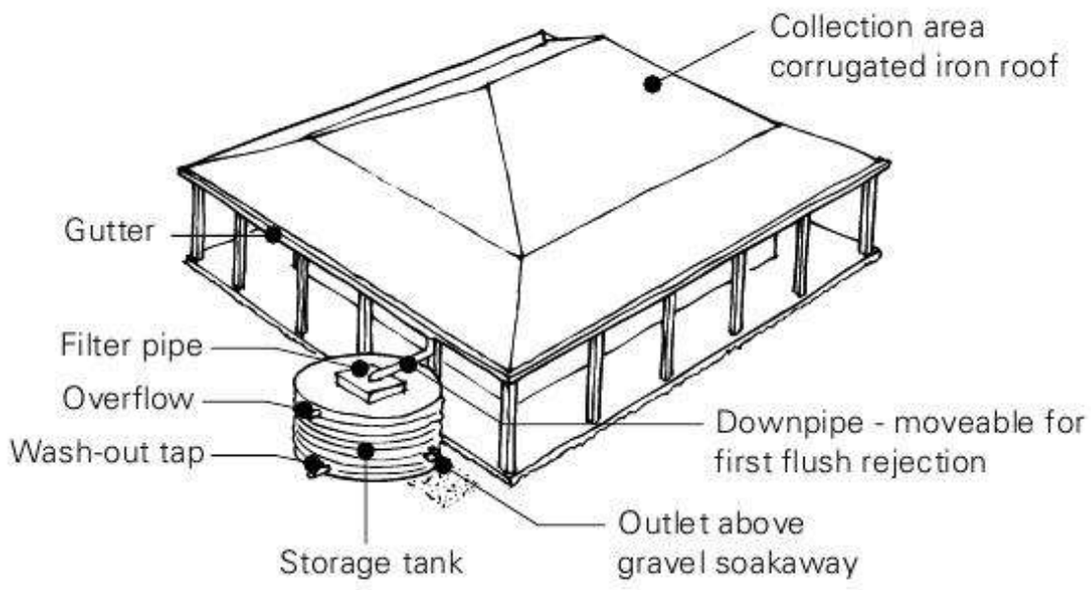
Water Rating
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Rainwater



Rainwater is a valuable natural resource that can be collected for household use. Using rainwater can reduce your water bills, provide a supply of restriction free water, and reduce community infrastructure costs.

Opportunities for rainwater collection and use vary according to where you live. Urban households already have a connection to a centralised, or reticulated, water supply system, whereas rural households typically have to source their water on their property.

Consequently, the regulations and guidelines concerning the collection and use of rainwater vary according to your location. Check with your local council or state health authority for advice on the current regulations and guidelines in your area.



In urban areas water bills will be lowered or eliminated by installing a rainwater tank.

ADVANTAGES

Rainwater can aid self-sufficiency, providing a back-up supply in case of water restrictions.

On rural properties, rainwater can provide a better quality potable supply than river, bore or dam water.

Rainwater tanks can also provide cost-effective on-site detention of stormwater.

Depending on tank size and climate, reticulated water use can be reduced by 50 per cent in urban areas. This can help:

> Reduce the need for new dam construction.

> Protect remaining environmental flows in rivers.

> Reduce infrastructure operating costs.

Tank water rebates are currently available from all state and territory governments, with the exception of Northern Territory which offers plumbing rebates for connecting raintanks to the house. Some rebates are also available from local councils. The rebate amount depends on how the tank is connected to the house and often there are minimum capacity requirements. Contact the relevant government agency to find out more.

DISADVANTAGES

In areas with reticulated water supply the main disadvantage of installing a rainwater tank is the financial cost. This is particularly the case if your water supplier charges a fixed charge for the centralised supply service, regardless of whether or not you use it.

A rainwater tank will cost (in 2007) a minimum of $500 for a small 400L tank to around $8,000 for a 100,000L tank. Costs will vary considerably depending on the tank material, shape and installation and delivery requirements.

Regular maintenance, such as checking and cleaning gutters, is required. See 'System Maintenance' for further details. Health risks can arise if maintenance is not carried out.

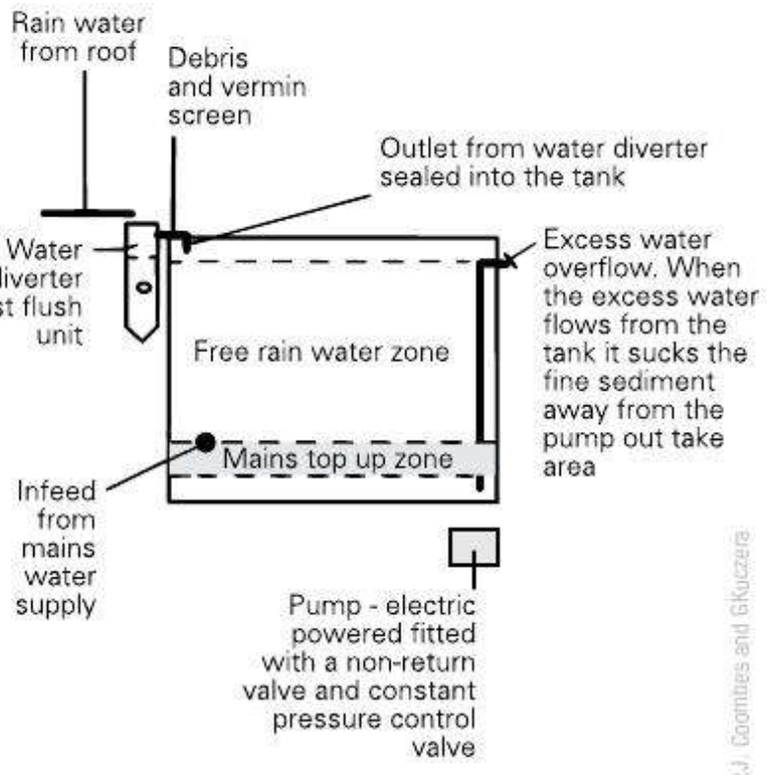
Reliability, ie. small tanks may not have sufficient water available in mid-summer.

HEALTH AND SAFETY

> Cover and thoroughly screen tanks to exclude mosquitoes, birds and animals, especially in areas where mosquito-borne disease is an issue.

> Design tanks to overflow to gardens, infiltration trenches or the stormwater system.

> Desludge your tank periodically with a tap installed at its base.

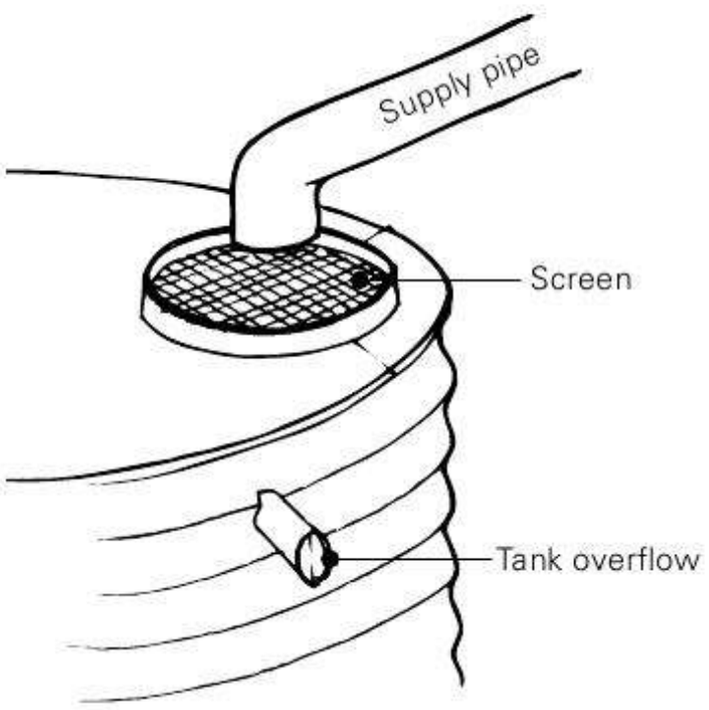


If rainwater and mains supply are both used then mains water must be isolated from the rainwater system by a valve mechanism or tap. Exact specifications vary across Australia. Contact your local council or state health department for advice.

Protect water in tanks from sunlight, which can stimulate algal growth. Plastic tanks may allow light to penetrate so they should be kept out of the sun or painted.

Chemical disinfection or filtration of your rainwater is not necessary if you only use your rainwater for non-potable uses.

Drinking rain water is not advised where potable supplies exist, particularly in urban areas where rainwater can contain higher contaminant levels.



If you drink your rainwater it is recommended that you install a filter. Pathogens such as cryptosporidium and giardia may be present in rainwater, and in urban areas there is a risk of chemical contamination from lead and other compounds. Check with your local council, state health authority or rainwater tank supplier for guidance on the type of filter you should install.

SYSTEM MAINTENANCE

Regular maintenance is very important to ensure that your rainwater will be safe for all requirements around the home, particularly drinking.

One contamination risk comes from animals or birds leaving droppings on the roof and gutters or accidentally entering the tank and becoming trapped. Another potential contaminant is the roofing and roof flashing materials, for example lead flashing on older roofs.

In urban areas there is also a risk of contamination from airborne pollutants. To minimise these risks you should:

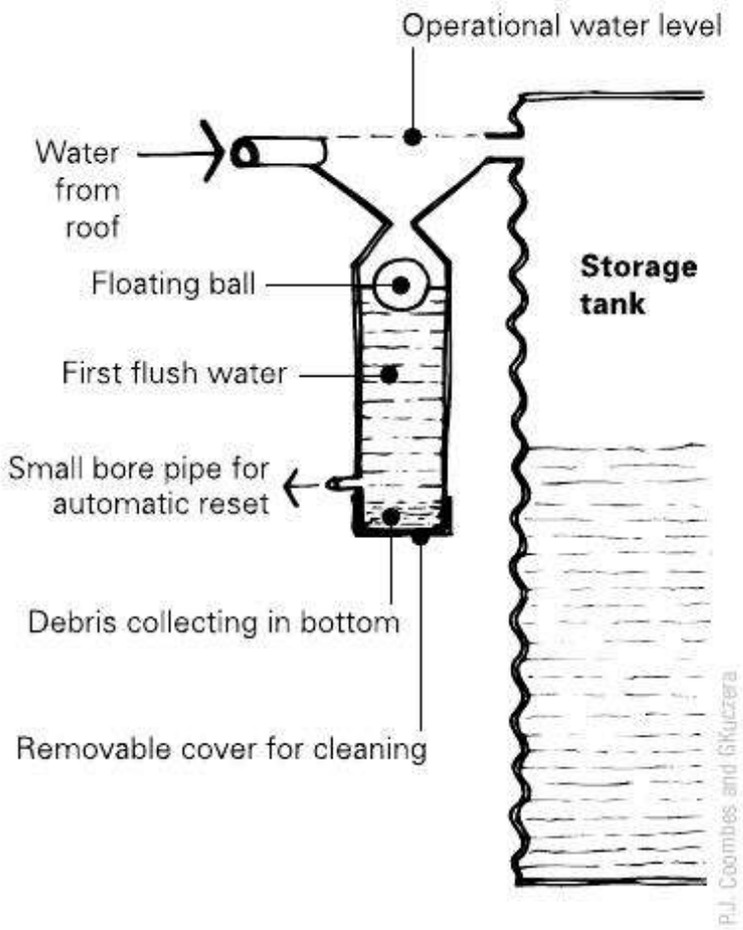
> Check your roofs and gutters for vegetation and debris on at least a weekly basis.

> Keep the roof clear of overhanging vegetation.

> Check and maintain screens around the tank.

> Drain and clean your tank every few years to remove sediment.

> Install a first flush diverter. This device fits onto your tank inlet and prevents the initial flow of contaminant-laden water from the roof entering the tank when it rains.



First flush devices can also be used to reduce the contaminants by preventing the initial roof-cleaning wash of water from entering the tank. It is also important to regularly check the first-flush device and to ensure the catchment area is clean.

BUYING YOUR RAINWATER TANK

One determinant of tank size is whether or not you have access to a centralised water supply system. If not you will need a tank that is sufficient for all your needs throughout the year. The size required will vary depending on the local climate.

If you have access to the internet you can establish the annual rainfall in your area by visiting the Bureau of Meteorology website (see Additional Reading). However, in many areas of Australia the rainfall is highly variable. This can lead to supply security problems.

Other factors that affect the size of your tank include:

> The intended use of the rainwater. You will need to decide if your tank water will be used outdoors only or indoors as well. To use tank water indoors, a plumber will need to connect the mains supply to the tank to ensure minimum water levels. Check with your local council, state health authority or rainwater tank supplier for guidance on connecting your rainwater tank to your home.

> The typical water consumption for these uses. For example, the water used for car washing, washing machines, or toilet flushing. This information should be available from your water supplier.

> The area of your roof. This determines if the water captured would be enough to meet your needs.

> The security of water supply you desire. The bigger the tank, the more water available.

In general, for toilet flushing and use on a small garden, the tank should hold a minimum of 2,000L. For non-potable domestic use and holding stormwater, a minimum of 5,000L is recommended.

Various websites are available to help you calculate a suitable tank size depending on your needs and geographical location see Additional Reading for more information.

TANK MATERIALS

The most common tank materials include plastic (polyethylene), concrete, and galvanised steel. The type of material you select for your tank depends on your budget, the size of tank required and water use.



Galvanised steel is the most common type of tank material in Australia. It is the least expensive, but its lifespan is limited by corrosion.

Concrete tanks are strong and long lasting. They are typically constructed on-site and can therefore be designed to meet specific site and householder requirements.

Plastic tanks are available in a range of sizes and colours. They are tough and durable and relatively lightweight.

In recent years a range of innovative systems have been developed, specifically aimed at providing adequate rainwater storage capacity in situations where space is constrained. These include storage walls, bladders and modular systems.

Storage walls are modular slimline tanks (typically plastic) that fit together and double as a wall system.

Bladders are sealed, flexible sacs that are particularly suitable for tight sub-floor spaces (in areas with as little as 750mm height clearance). Their installation is a little more technically involved than a standard tank, but they can be a especially good for renovations where space is limited.

Modular underground tanks are also available. Some systems are capable of capturing rainwater and stormwater, the latter via infiltration through the lawn or garden. The tanks are covered by a material that filters the stormwater as it enters.

CHOOSING THE RIGHT SYSTEM

There are many shapes and sizes available that can be integrated into walls or underground to economise on space. In general:

> Above ground rainwater tanks are usually the cheapest. Consider slimline and wall line tanks that which can fit tight narrow spaces.



> Underground tanks save on space and have greater catchment potential than above ground tanks. However this option can be more expensive and requires excavation. Some authorities also require annual testing of backflow prevention device. Consider modular systems that capture water via infiltration through the grass lawn or garden.

> Underfloor bladders save on space and may have greater catchment potential than above ground tanks. Installation is also more technically involved. Consider sealed flexible bladders which can be installed side by side or end to end depending on space.



Tanks sizes of 400 to 1000L will cost (in 2007) roughly $500 to $800, including installation. A tank size of 2000L will cost between $1000 and $1400, while a tank size of 5000L can cost around $1500, depending on the tank style and material.

A small pump is usually required to provide pressure. If the house is significantly elevated above the garden then a pump might not be necessary, saving on energy usage.

Install a filter. For advice see ‘Health and Safety’.

Garden watering

Fit a tap directly to the rainwater tank for watering the garden, washing cars and for other outdoor uses.

A sprinkler will require a pressure pump.

While the amount of water required in your garden will vary with climate, the size of the garden and the type of plants it contains, an average household requires a tank with approximately 2000 to 4000L capacity to water their garden year round. This will cost from $1000 to $2000, including installation.

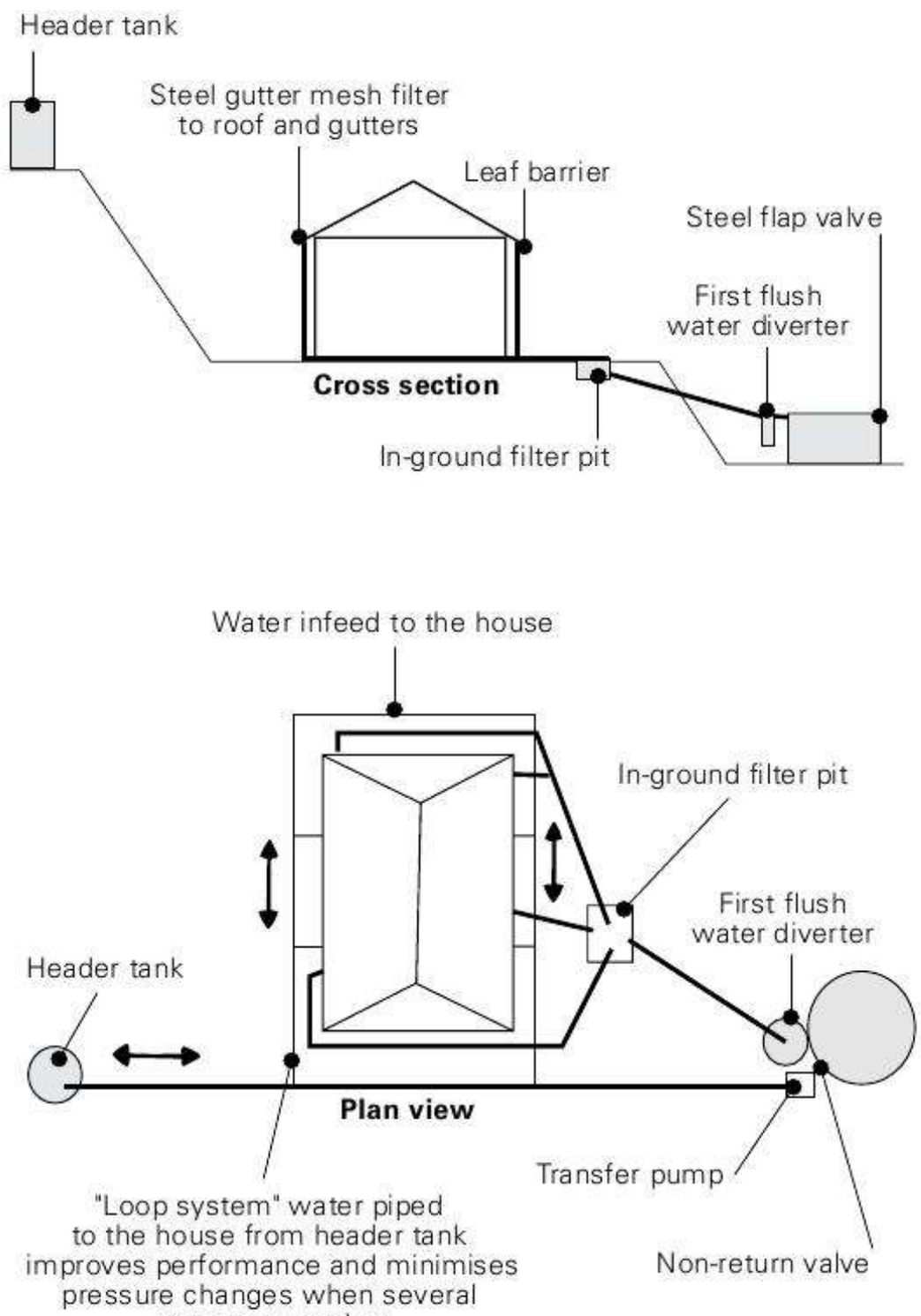
Total household water supply

If rainwater is to be your sole supply you will need a tank with a capacity of 50,000 to 100,000L. This capacity will cost from $6000 to $8000, including installation and delivery.

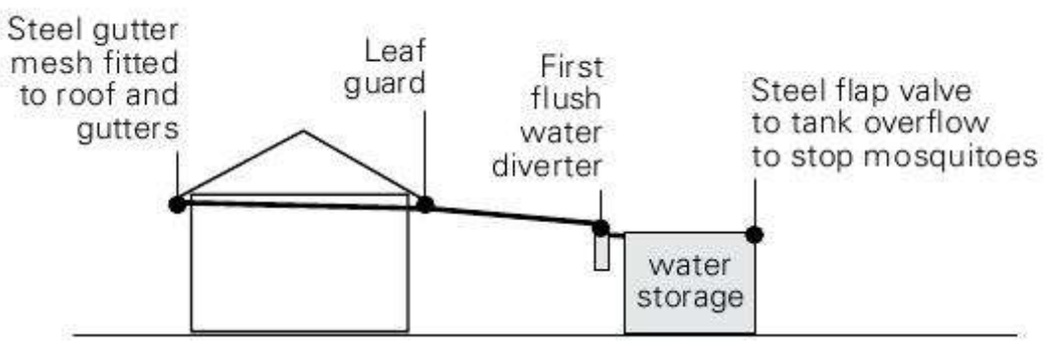
The most economic large tank is normally a concrete tank built in situ.

RAINWATER SYSTEM CONFIGURATIONS

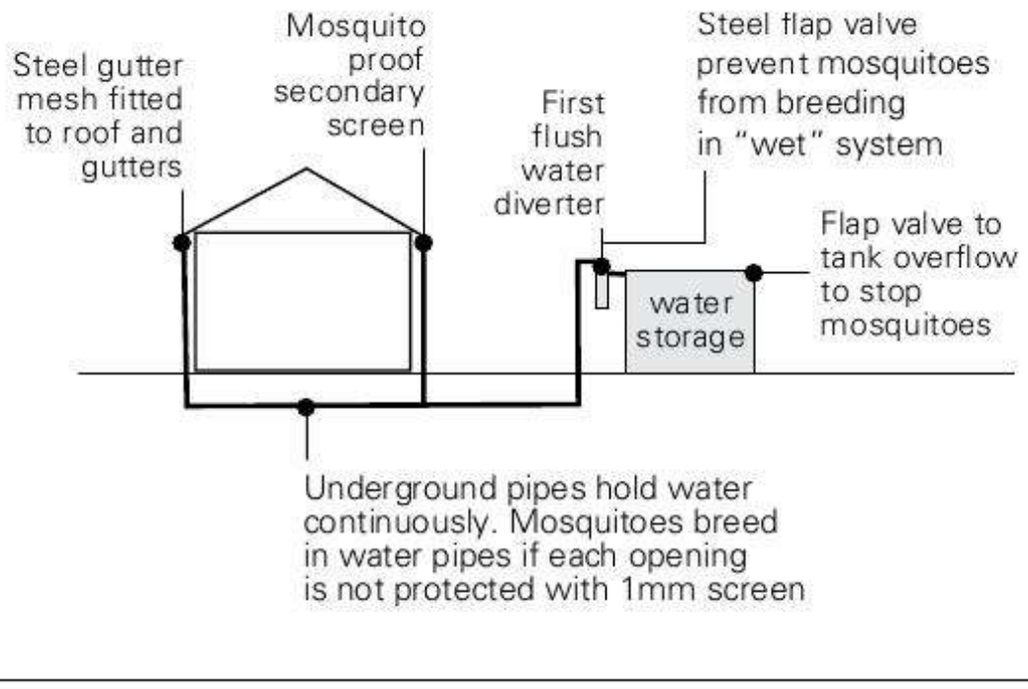
1. Gravity fed system with pump (can be solar)



2. Dry system



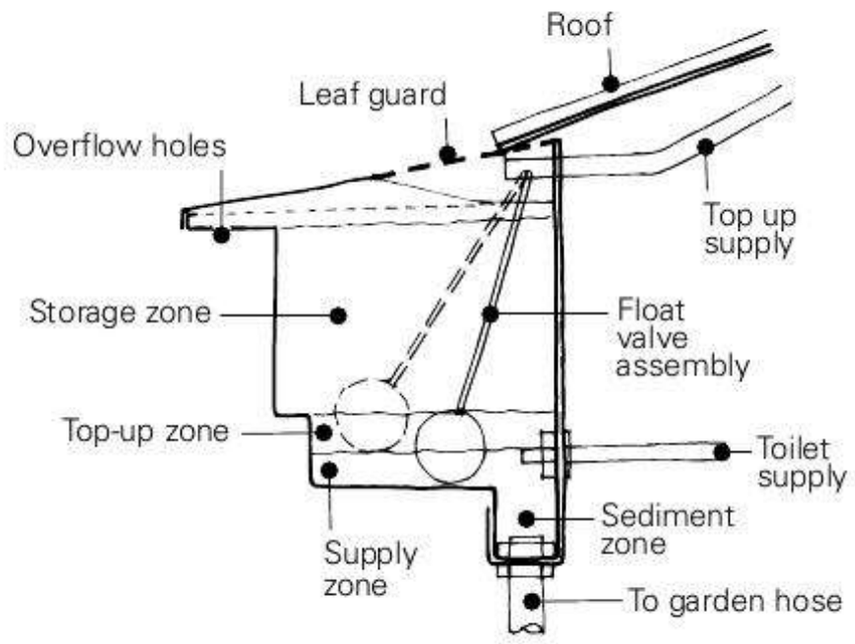
3. Wet system



4. Gutter storage systems

Gutter storage involves directing and storing rainwater in specially constructed large capacity gutters surrounding a house. Gutter storage systems are best suited to new houses, as the cost of the gutters can be offset by savings in building materials.

The system is designed to gravity feed non-potable water for toilet flushing and garden watering.



ADDITIONAL READING

Contact your State / Territory government or local council for further information on rainwater tanks, including what rebates are available. www.gov.au

Australian Government National Health and Medical Research Council, (2004), *Water Made Clear*. www.nhmrc.gov.au/publications/synopses/_files/eh33.pdf

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Mobbs M (1998), *Sustainable House: living for our future*, Choice Magazine, Sydney.

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Stuart McQuire. (2007), *Water Not Down the Drain: A guide to using rainwater and greywater at home*. www.notdownthedrain.org.au

Wade R (1999), *Sustainable Water: How to do it and where to get it*, Choice Magazine, Sydney.

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Principal author: Patrick Dupont

Contributors: Steve Shackel

Wastewater Re-use

This fact sheet provides information on wastewater re-use for both urban and rural households. On-site wastewater re-use provides numerous opportunities to reduce water use within the home. At present, potable (drinkable) water is used for practically everything in the house and garden.

We are literally flushing our drinking water down the toilet!

Wastewater re-use opportunities vary according to where you live. Urban households typically have a connection to a centralised, or reticulated, sewage system, whereas rural households manage their wastewater on-site.

Consequently, the regulations concerning the treatment and re-use of wastewater vary according to your location. Check with your local council or state health authority for advice on the regulations in your area.

ADVANTAGES

Treated wastewater can be used to flush toilets, water gardens and even to wash clothes. By using wastewater as a resource rather than a waste product you can:

> Reduce water bills.

> Use less water resources.

> Irrigate your gardens during drought water restrictions.

> Cut down the amount of pollution going into our waterways.

> Help save money on new infrastructure for water provision and wastewater treatment.

Wastewater re-use decreases the demand on infrastructures for sewage transport, treatment and disposal, allowing the infrastructure to work better and last longer.

DISADVANTAGES

The disadvantages of reusing your wastewater also need to be considered. Currently, one of the main disadvantages for most households is the financial cost of installing and maintaining a re-use system. The attractiveness of the investment would depend on:

> The extent of centralised wastewater treatment services available where you live.

> The price of water in your area (urban) or scarcity of water (rural).

> Whether you are replacing an existing system or starting from scratch.

> The length of time you intend to live in your current house.

> The type of system you install – annual operating and maintenance costs vary between systems.

> Whether a restrictions free, reliable water supply is valuable to you. Wastewater Re-use will provide a much more reliable secondary source of water than common rain tank installations.

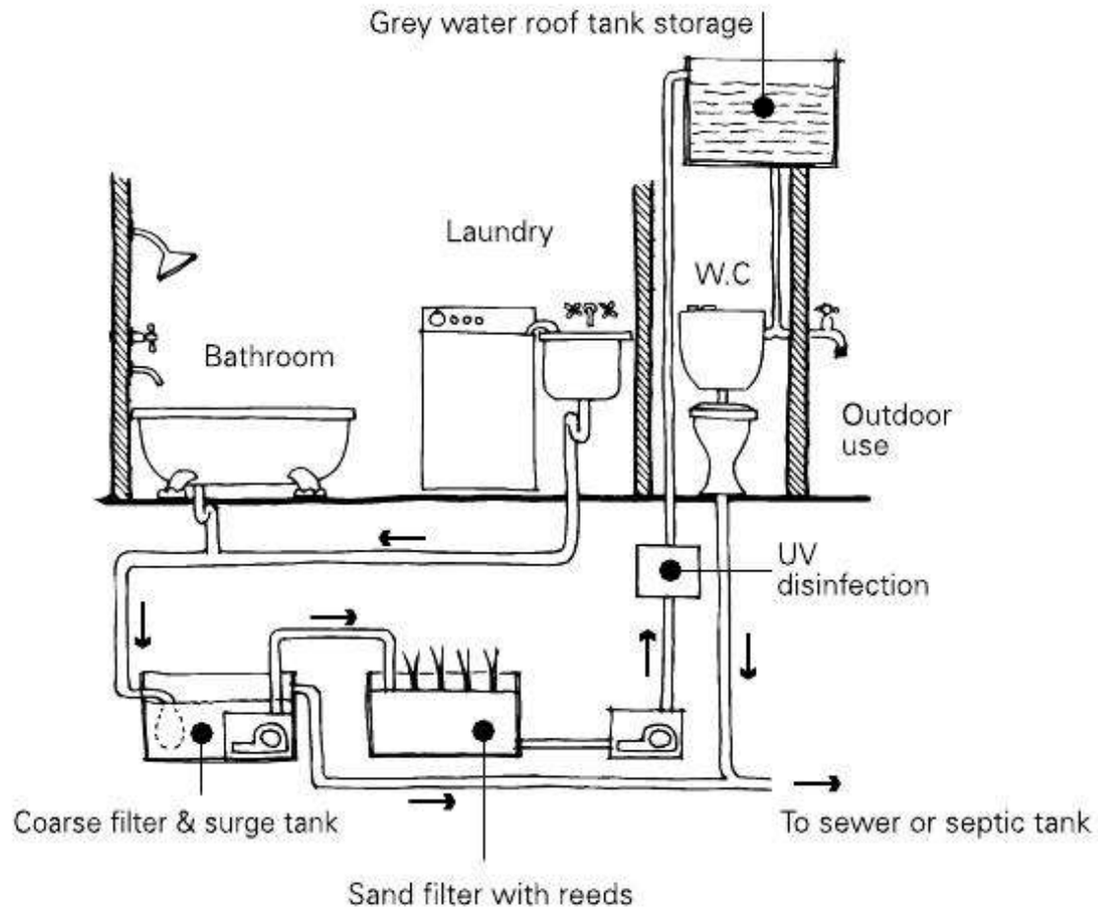
If your house is frequently unoccupied for a fortnight or more, for example a holiday home, then you need to carefully select a re-use system to cope with intermittent use. Most systems that include biological treatment do not function properly if used intermittently.

TYPES OF WASTEWATER

There are two types of wastewater created in a home, each of which can be treated and used in various ways.

Greywater is wastewater from non-toilet plumbing fixtures such as showers, basins and taps. It is advisable to exclude water from kitchens and dishwashers from greywater being recycled, because of the potential for contamination by pathogens. Greywater can be used for garden watering. Appropriately treated greywater can also be re-used indoors for toilet flushing and clothes washing, both of which are significant consumers of water.

Blackwater is water that has been mixed with waste from the toilet. Blackwater requires biological or chemical treatment and disinfection before re-use. For single dwellings, treated black water is suitable only for outdoor re-use.

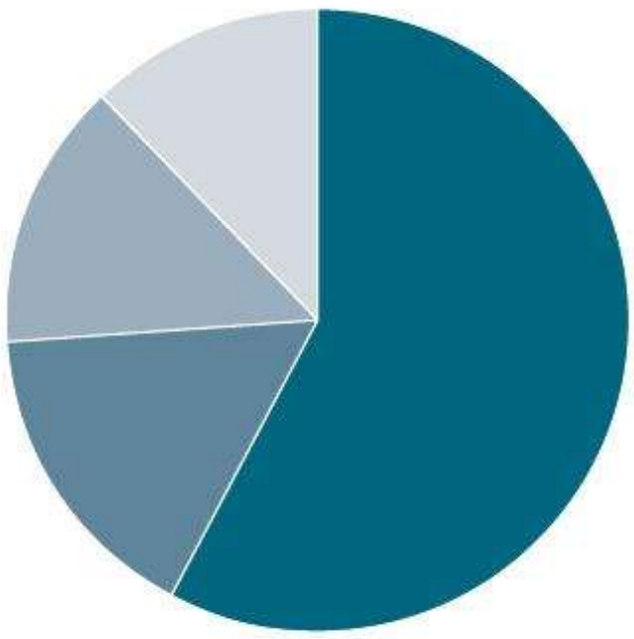


CALCULATING WASTEWATER VOLUME

The table below indicates the approximate amount of wastewater produced per person each day in an average home with WELS 3 Star rated fixtures. [See: 7.2 Reducing Water Demand]

BLACKWATER	LITRES/PERSON/DAY
Toilet	20
GREYWATER	**LITRES/PERSON/DAY**
Shower	63
Hand Basin	6
Washing Machine	13
Laundry tap	2
OTHER WASTEWATER	**LITRES/PERSON/DAY**
Kitchen tap	12
Dishwasher	5
Total Greywater	84
Total Wastewater	120

Wastewater by indoor location



RE-USE WATER QUALITY

The quality of your re-use water depends on your treatment system, the water's first use and which chemicals are used in the home.

To reduce your treatment requirements:

> Minimise use of cleaning chemicals such as coloured toilet dyes. Use natural cleaning products where possible.

> Do not dispose of household chemicals down the sink or toilet. Contact your local council or water authority for information on collection services.

> Use a sink strainer in the kitchen to help prevent food scraps and other solid material from entering your wastewater.

> Use a lint filter on the outlet from your washing machine. A piece of nylon stocking is generally sufficient. Replace as necessary.

WASTEWATER RE-USE IN URBAN AREAS

Consider wastewater re-use if you live in an urban, sewered area and any of the following apply to you:

> You wish to reduce water use further and efficiency measures for indoor and outdoor water use have already been undertaken. [See: 7.2 Reducing Water Demand; 7.6 Outdoor Water Use]

> Water supplies in your area are often limited, eg frequent restrictions or during droughts.

> You have a large garden which needs to be watered regularly or would not survive extended water restrictions.

Remember to check with your local council or water authority before you re-use wastewater, as standards and permission requirements vary.

WASTEWATER RE-USE IN RURAL AREAS

Rural households typically have greater scope for reusing wastewater for the following reasons:

> There is no centralised treatment service, therefore investment in an on-site wastewater treatment system is a necessity.

> Installing a re-use system in a new house, or adapting an existing treatment system to allow re-use, may not incur significant additional expenditure.

> Water supply may be restricted, thus placing a premium on using water resources in the most efficient manner. [See: 7.2 Reducing Water Demand; 7.3 Rainwater]

> Large blocks of land in rural areas allow more scope for on-site disposal of wastewater.

NOTE: that the septic tank system, the most prevalent on-site wastewater treatment system in rural Australia, does not actively treat wastewater to remove disease-causing pathogens. Effluent from a septic tank should be disposed underground at soil depths greater than 300mm.

REUSING GREYWATER INDOORS

Appropriately treated greywater can be re-used indoors for toilet flushing and clothes washing. Toilets and clothes washers are two of the biggest users of water in an average household. [See: 7.2 Reducing Water Demand]

Reusing treated greywater for toilet flushing can save approximately 50L of potable water in an average household every day.

Reusing treated greywater in your clothes washer can save approximately 90L of potable water in an average household every day.

In order to re-use greywater indoors for toilet flushing and clothes washing you will need to firstly:

> Separate greywater and blackwater waste streams.

> Install a greywater treatment and disinfection system that is approved in your State, so it provides a suitable level of treatment and meets local regulations.

NOTE: that while wastewater from the kitchen sink and dishwasher can be classed as greywater, it would require more complex treatment before re-use due to potential contamination by pathogens from food preparation, as well as fats and grease. Many states in Australia do not allow water from kitchens to be included in greywater for re-use, and permit greywater only from showers, (non-kitchen) basins and laundry.

Greywater can be directly diverted from the shower or bathroom sink drains for immediate re-use in the toilet only. However, it should not be stored for more than a couple of hours before re-use or disposal to sewer and will require coarse filtration.

Precautions

Greywater must be treated and disinfected before storage and general re-use because:

> It can contain significant numbers of pathogens which spread disease.

> It cannot be stored for longer than a few hours untreated as it begins to turn septic and smell.

When reusing greywater for clothes washing discoloration of clothing from dissolved organic material may be an issue. This can be avoided by installing an activated carbon filter.

Even after on-site treatment and disinfection, blackwater is not suitable for re-use indoors.

Treatment systems for indoor re-use

A number of package on-site greywater treatment systems are available for purchase in Australia. Check with your council or state health department which systems are accredited for use in your area.

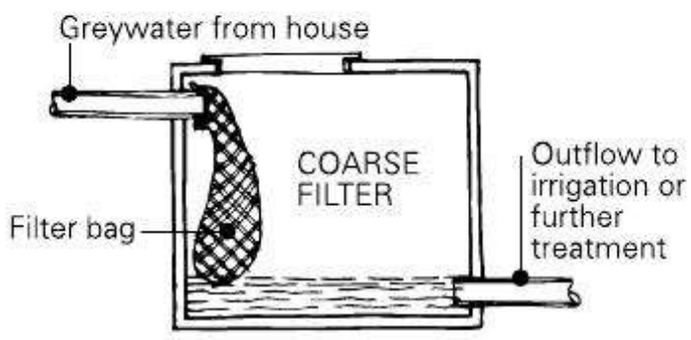
The different treatment systems can vary greatly in terms of the treatment processes used, that may be biological, chemical or mechanical treatment. The qualities of treated water they produce can vary considerably, as well as their energy consumption and initial cost.

With council approval, it is possible to build your own biological treatment system for greywater treatment. See the references list for more details.

Biological greywater treatment generally consists of several steps.

> Coarse filtration to remove large particles, including hair, to prevent clogging. This can be as simple as waterproof box and a filter bag or stocking attached with rubber bands. The stocking or bag must be checked regularly and replaced when full.

> Fine filtration and biological treatment, using a sand filter and reed bed combination. Microbes in the sand break down organic matter in the water while the reeds take up nutrients. The basic structure is a waterproof box filled with coarse sand laid over a gravel bed. Greywater is designed to percolate either vertically or horizontally through the media.



Disinfection

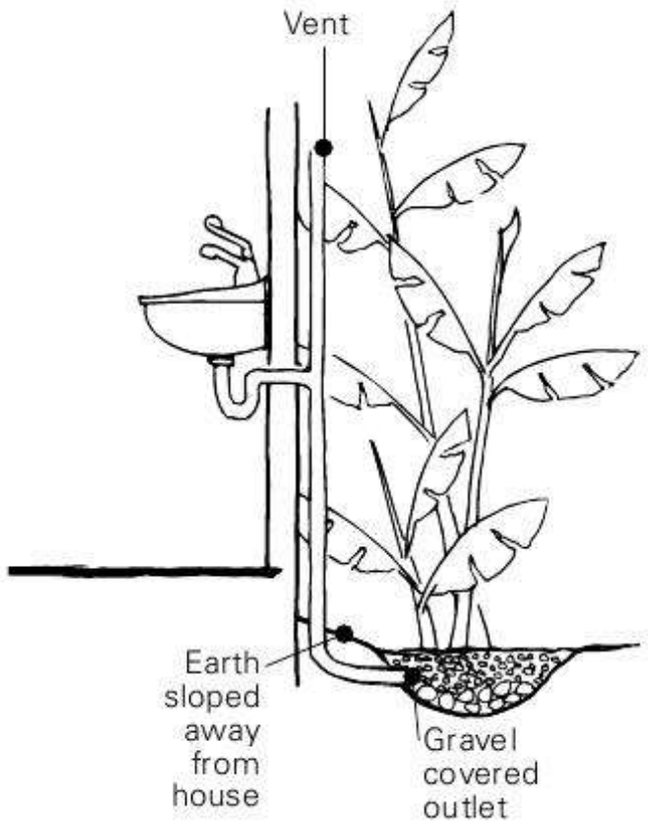
Disinfection is required for indoor re-use of greywater. All disinfection systems require regular maintenance.

Chlorine is most commonly used for disinfection. However, chlorine disinfection has been found to have adverse environmental impacts. Alternatives should be used where possible, such as ultraviolet (UV) or ozone disinfection in place of chlorination.

REUSING WASTEWATER OUTDOORS

Reusing wastewater outdoors can reduce your household's potable water use by 30 to 50 per cent. [See: 7.6 Outdoor Water Use]

Greywater can be re-used in gardens even without treatment. Sub-surface drip irrigation systems spread water evenly around the garden, and are safer for spreading untreated greywater.



Simple greywater sub-surface re-use.

Avoid watering vegetables with re-use water if they will be eaten raw. There is a chance that some pathogenic organisms may still be present even after treatment.

The only place where treated and disinfected blackwater can be safely re-used is outdoors. However, in some states treated blackwater cannot be re-used for above ground irrigation, only in sub-surface irrigation. Check with your local council or state health department.

Precautions

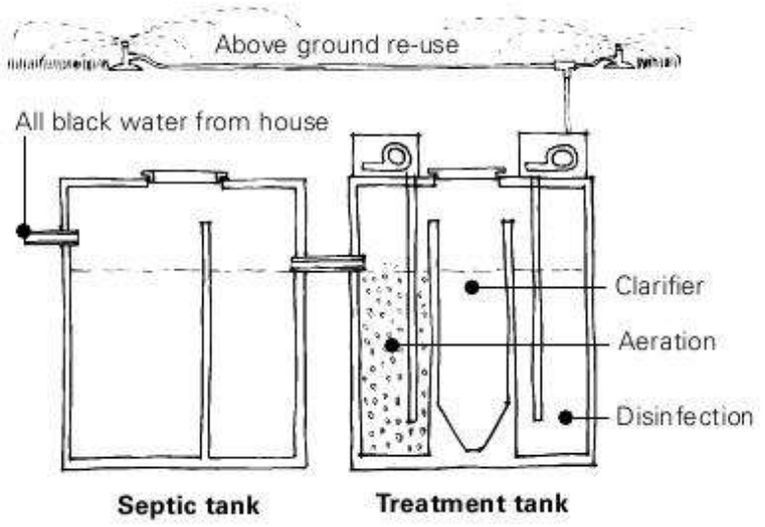
In order to maintain the health of your garden, the level of re-use of wastewater in the garden needs to be balanced with the amount of water, solids and nutrients that the plants and soil in your garden can absorb. If excess wastewater is applied:

> Excess nutrients may run-off or leach through the soil to enter waterways, contributing to algal blooms and other water quality problems.

> Soils and plants may become water logged and inhibit plant growth.

> Soils can become physically clogged with organic and suspended material or damaged by salts in the wastewater.

> Salinity may increase in problem areas when greywater contributes to raising watertables.



In order to avoid these problems:

> Plan your garden carefully. [See: 2.4 Sustainable Landscapes; 7.6 Outdoor Water Use]

> Use Phosphate-free and salt-free liquid or environmentally-friendly detergents.

> Prefilter to remove solids.

Adjust the amount of wastewater re-used to the conditions in the garden. Do not irrigate if the soil is already saturated, see 'Wet Weather Storage'.

Treatment systems for outdoor re-use

There are many different types of treatment systems suitable for outdoor re-use. Contact your local council for a list of treatment systems accredited for use in your area.

The most common wastewater treatment and re-use system currently in Australia is the aerated wastewater treatment system (AWTS). After settling the solid in wastewater, the effluent is aerated to assist bacterial breakdown of organic matter, followed by a further stage of disinfection, usually using chlorine pellets. There are many commercially available models in all states.

Wastewater treatment systems using microfiltration are now available for onsite use at a household scale. These systems use energy but no chemicals, and produce a high quality effluent suitable for indoor use.

Some treatment systems use worms and microbes to treat all household wastewater using little energy and no chemicals. These systems produce effluent suitable for subsurface irrigation, and compost as a by-product.

Wet weather storage

If you are reusing your wastewater in the garden, you will need to have a method of either disposing or storing the wastewater you do not require during periods of high rainfall.

If storage is not an option and you live in an urban area, excess wastewater can be directed to a sewer. In rural areas sub-surface disposal to a trench in the garden is recommended, provided there is enough space.

Storage is recommended as it maximises the usefulness of wastewater.

Wastewater should be treated and disinfected before storage. Storage requirements depend on:

> Climate.

> Household demand for re-use water.

> Presence/size of disposal area.

> Maximum daily wastewater output.

ADDITIONAL READING

Contact your State / Territory government or local council for further information on wastewater re-use. www.gov.au

Brooker, N. (2001) 'Greywater and Blackwater Treatment Strategies' *Environment Design Guide.* Technologies Note No. 11. RAIA, Canberra.

Stuart McQuire. (2007), *Water Not Down the Drain: A guide to using rainwater and greywater at home* www.notdownthedrain.org.au

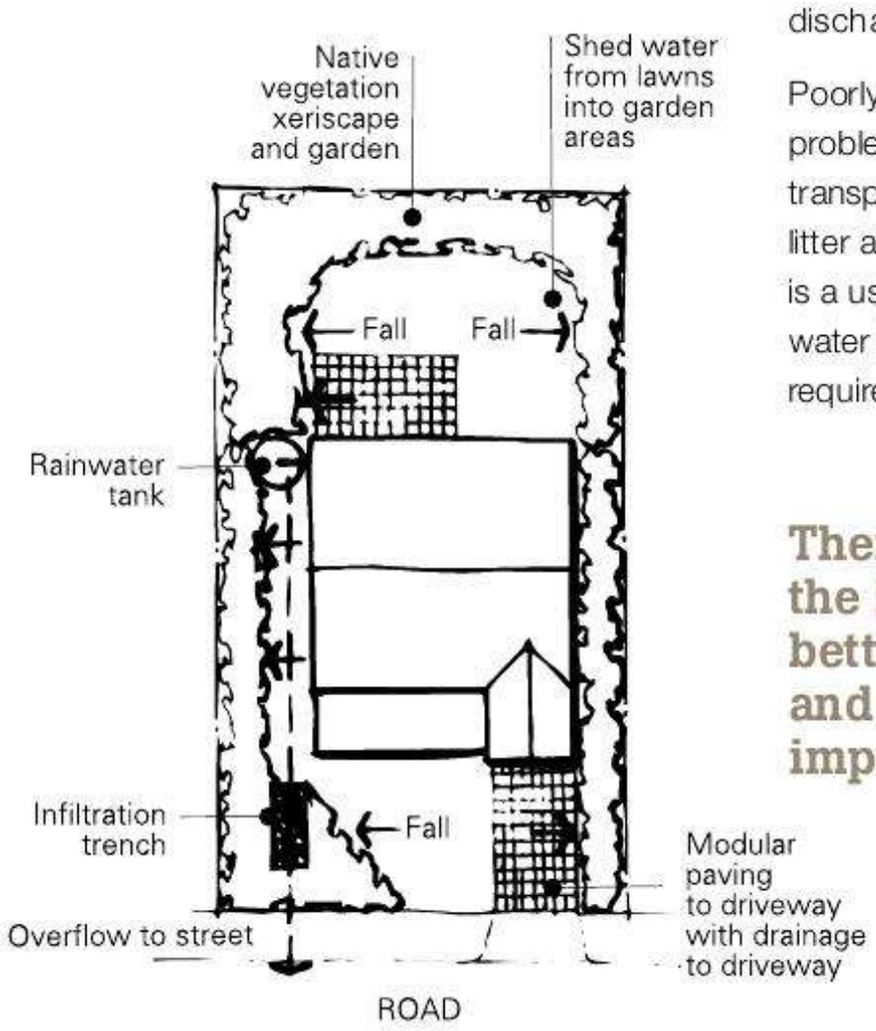
Water Sensitive Urban Design www.wsud.org/literature.htm

Windblad U and Simpson-Hebert M (2004), *Ecological Sanitation*, Stockholm Environment Institute, Sweden. www.ecosanres.org

Principal author:
Simon Fane
Contributing author:
Chris Reardon

Stormwater

Stormwater is rainwater plus anything the rain carries along with it. Stormwater can be considered a valuable resource. Its re-use leads to water savings and reduced environmental impact.



In urban areas stormwater is generated by rain run-off from roof, roads, driveways, footpaths and other impervious or hard surfaces. In Australia the stormwater system is separate from the sewer system. Unlike sewage, stormwater is generally not treated before being discharged to waterways and the sea.

Poorly managed stormwater can cause problems on and offsite through erosion and the transportation of nutrients, chemical pollutants, litter and sediments to waterways. Stormwater is a useful resource that can replace imported water for uses where high quality water is not required, such as garden watering.

There are a number of steps the homeowner can take to better manage stormwater, and reduce the environmental impact of their home.

> Avoid cut and fill on your block when preparing the building foundations. Attempt to maintain the existing topography and drainage pattern.

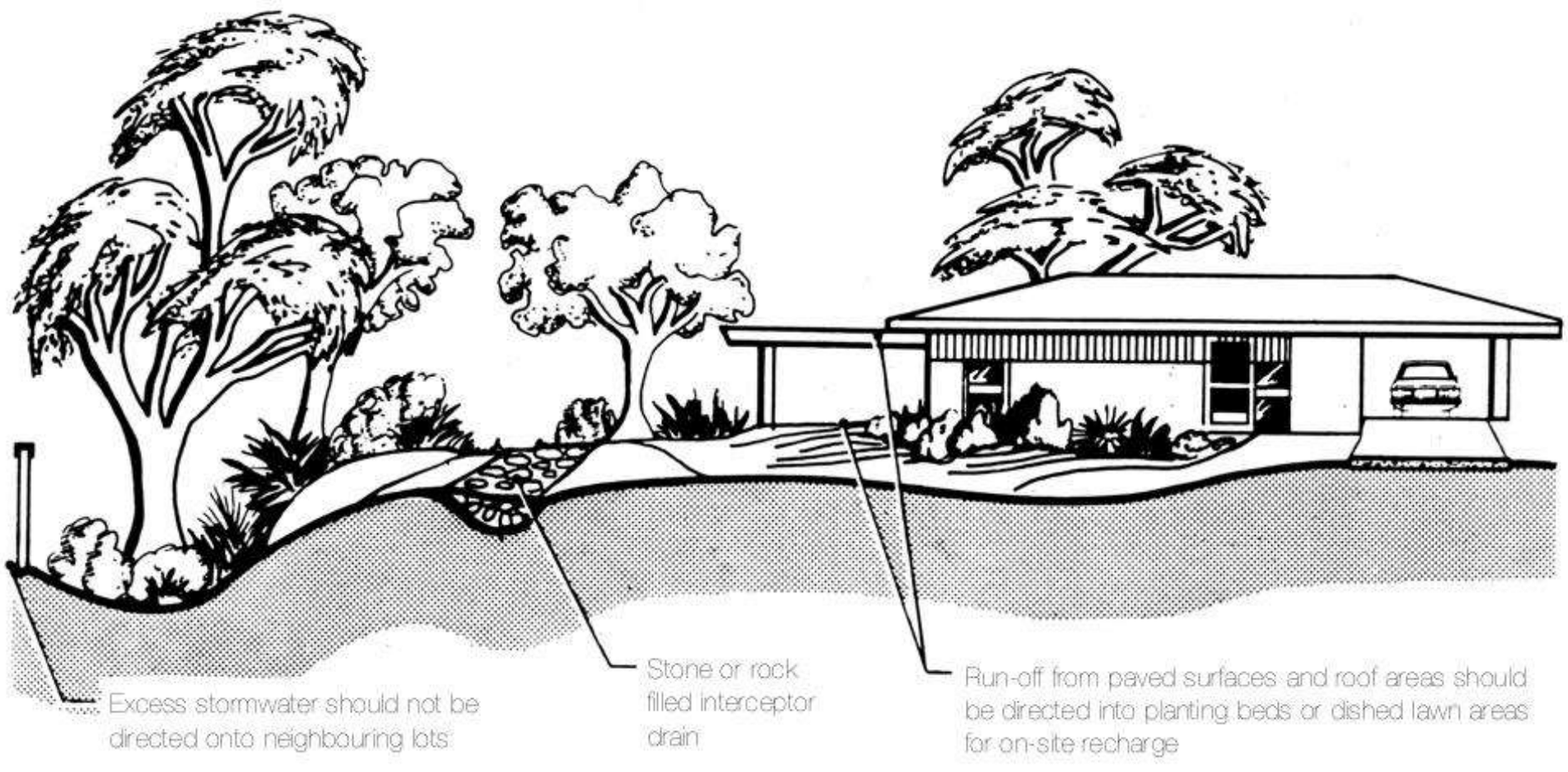
> Retain vegetation, particularly deep-rooted trees. These lower the water table, bind the soil, filter nutrients, decrease run-off velocities, capture sediment and reduce the potential for dryland salinity.

> Detain stormwater on your block where practicable through use of permeable paving, pebble paths, infiltration trenches, soakwells, lawn, garden areas and swales.

> Reduce erosion potential on site during building works by minimising the time that land is left in an exposed, unstable condition. Employ sediment traps and divert 'clean' stormwater around the disturbed site.
[See: 2.8 Sediment Control]

> Minimise the area of impervious surfaces such as paved areas, roofs and concrete driveways.

> Grade impervious surfaces, such as driveways, during construction to drain to vegetated areas.



> Harvest and store roof water for use. [See: 7.3 Rainwater]

> Take care with the substances you use on your land as they can end up in the stormwater. Do not over-use fertilisers, herbicides and pesticides – follow the manufacturer's instructions regarding amount and frequency of application. Look for organic alternatives.

> Avoid the use of solvent based paints. When using water based paints, clean brushes and equipment on a lawn area to trap contaminants before they reach waterways. Plant based paints are the most environmentally benign.

> Visit a car wash that recycles wash water. If this is not an option wash your car on the lawn or on an area that drains to lawn. The nutrients (mostly phosphates and nitrates) in the detergent fertilise the lawn instead of degrading waterways. Note that many native plants do not tolerate detergents.

> Do not build on flood plains as the land may be periodically subject to inundation and may possess a high water table. Councils can advise on the 1 in 100 year flood level.

THE TRADITIONAL APPROACH

Pipes

The traditional stormwater management response relied on conveyancing. Water was conveyed by a pipe or channel from a collection area to a discharge point. The collection area is your house or street and the discharge point is the nearest ocean, creek, river or lake. The conveyancing system sought to remove the most water (high quantity) from a site in the shortest time possible (high velocity). Large, impervious paved areas and big pipes are typical of conveyancing.

The traditional system of conveyancing is highly effective in reducing stormwater nuisance and flooding on site, unless the pipes get blocked. Conveyancing does not solve the problem but merely transfers it to the other end of the pipe and ultimately upsets the local water balance. Stormwater is carried rapidly with its suspended litter, oil, sediment and nutrients and dumped in an ocean, river or lake. The receiving water body then becomes flooded and temporarily polluted because all the stormwater arrives at one time.

WATER SENSITIVE URBAN DESIGN

Water Sensitive Urban Design (WSUD) seeks to approximate the natural water balance on-site prior to the land being built on. It achieves this by slowing the water velocity of stormwater run-off, providing natural filtration, on-site detention and infiltration. The water eventually reaches the river, lake or ocean but has been cleaned and filtered by the soil and used by plants before it gets there.

The objective is to minimise impervious surfaces so that the least amount of water flows off-site into the stormwater system. At the scale of the individual household, options such as permeable paving on driveways and footpaths, garden beds designed for infiltration (raingardens), lawns and vegetation, swales and soakwells can detain stormwater and increase percolation into the soil.

In some cases it may be advisable to place perforated pipes beneath the infiltration areas to direct excess stormwater to the stormwater system. See the references at the end of this fact sheet for more details about options and possible designs.

Water Sensitive Urban Design provides the improved aesthetics and comfort associated with more vegetation. Habitat for native wildlife is improved and the area is cooler in summer. It reduces the need for garden watering and decreases water bills. Erosion and the downstream effects of stormwater pollution on nearby rivers, lakes or ocean are reduced.

THINGS TO CONSIDER

Water Sensitive Urban Design is applicable on all sites but the degree of application will vary according to the site's opportunities and constraints. All sites should be able to maximise permeable surfaces such as garden beds, lawns, porous paving and paths.

When seeking to install sub-surface units such as soakwells and infiltration trenches the following things should be considered.

Site

Soil type – check the soil type. Sandy soils are excellent for infiltration but clay soils tend to become waterlogged. This will affect the efficiency of some of the water sensitive design solutions. For example, water sensitive design in heavy clay soils may need to be supplemented with traditional conveyancing methods.

Soil depth – ensure that you have sufficient soil depth. Areas with shallow soil underlain by impervious rock such as granite, shale or limestone may impede infiltration and may require some stormwater pipes to remove water for discharge off site.

Groundwater – determine the depth to groundwater. A high groundwater table may reduce the effectiveness of infiltration methods during storms.

Slope – ensure that the stormwater design accounts for the terrain as severe slopes increase run-off velocities.

Regulations – check with your local council before employing water sensitive design solutions. Some components of WSUD may conflict with local government drainage regulations.



OTHER DESIGN SUGGESTIONS

Ensure there are no illegal cross connections of sewer and stormwater drains. This is where the stormwater drain discharges into the sewer system and can cause sewage overflows on your property during heavy rain.

Prevent rain from washing sediment (eg sand, soil) into stormwater with a roof, tarpaulin or awning.

Divert stormwater from driveways, paths and other impervious surfaces to vegetated areas to catch, filter and infiltrate water rather than directing water to the stormwater system.

Measures to promote water conservation

> Appropriate landscaping [See: 2.4 Sustainable Landscapes; 7.6 Outdoor Water Use]

> Water harvesting [See: 7.3 Rainwater]

> Stormwater and greywater recycling. [See: 7.4 Wastewater Re-use]

Environmental benefits

Downstream environmental benefits of reduced stormwater pollution:

> Rivers, lakes and beaches will be cleaner and safer for swimming.

> Flooding will be reduced.

> Waterways will look cleaner.

> Councils will need to spend less money emptying stormwater traps.

> The environment will be healthier for plants and animals.

Principal author:
Scott Woodcock

Contributing author:
Steve Shackel

ADDITIONAL READING

Contact your State / Territory government or local council for further information on managing stormwater.
www.gov.au

Argue J (ed) (2004), *Water Sensitive Urban Design: Basic Procedures for Source Control of Stormwater*, University of Adelaide
www.waterbalance.ca/waterbalance/dynamicImages/370_WSUDHandbookPeerReviewMar2005.pdf

Hatt B, Deletic A and Fletcher T (2004), *Integrated Stormwater Treatment and Re-Use Systems*, Monash University

Llyod S, Wong T and Chesterfield C (2002), *Water Sensitive Urban Design – A Stormwater Management Perspective*, CRC for Catchment Hydrology, Industry Report.

Mobbs M (1998), *Sustainable House: living for our future*, Choice Magazine, Sydney.

Stuart McQuire. (2007), *Water Not Down the Drain: A guide to using rainwater and greywater at home*
www.notdownthedrain.org.au

Water Sensitive Urban Design
www.wsud.org/literature.htm

CASE STUDIES

Some recent examples of neighbourhood and sub-division scale water sensitive designs are described below. While the principles of WSUD can be applied at any scale, larger developments can capture some economy of scale benefits.

Kogarah town centre is a multi building high-density development in Sydney. It employs water efficient fixtures indoors, and harvests and treats rainwater from roofs for re-use in toilets and other purposes where drinking-quality water is not required. Stormwater from paved areas is collected to irrigate the landscape which provides biological treatment and filtration. Under-drains collect the filtered irrigation water for further treatment and re-use. A water feature using recycled water creates connection between people and the site's natural water cycle.

Inkerman D'Lux (formerly Inkerman Oasis) is an apartment development in the Melbourne suburb of St. Kilda for 245 dwellings. It recycles all stormwater from roofs and ground flows and sufficient domestic greywater from the residential units to meet the needs for flushing toilets and garden irrigation. On-site wetlands pre-treat the stormwater, while greywater is pre-treated in an aeration balance tank to remove solids. The pre-treated water is combined and treated by a membrane bioreactor and a UV disinfection system, to produce a high quality water for non-potable use.



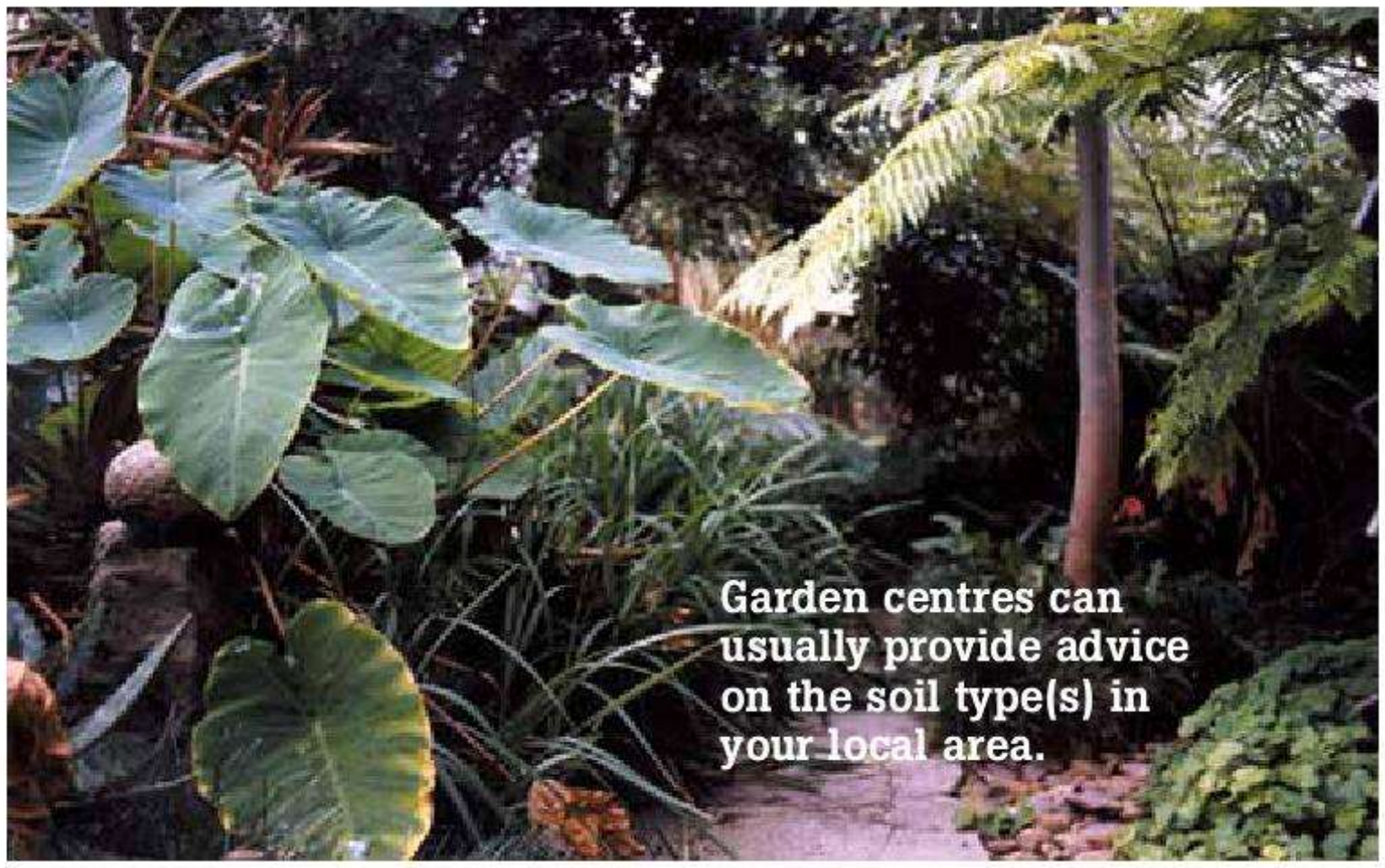
Christie Walk (pictured) is an 'eco-city' development in inner-city Adelaide, with 27 dwellings as a mixture of townhouses, apartments and straw bale cottages. All stormwater from roofs, balconies and impervious surfaces are collected in two underground tanks below the car parking areas, and re-used for toilet flushing and irrigation after filtration and disinfection. [See: 9.2 and 10.1 Case Studies]

599 Payne Road is a growing housing development for 22 large allotments at The Gap near Brisbane. Each new dwelling collects, treats and disinfects rainwater for all indoor uses using individual rain tanks that may be topped up by two large communal rain tanks that have town supply backup for dry periods. Household greywater is treated on-site using Biolytix vermiculture technology, and re-used in subsurface irrigation. Bioretention drains throughout the development increase percolation of stormwater into the ground.

Mawson Lakes is a growing suburb in outer Adelaide, with a planned 4300 dwellings by 2010, as well as retail, commercial, education and recreation facilities. Storm water run-off is treated in natural wetlands and used to fill lakes within the development. Wastewater and stormwater is collected, treated and supplied to all houses, industries and open spaces by dual reticulation for outdoor water use and toilet flushing. Seasonal balancing of non-potable water supplies is achieved using aquifers to store surplus stormwater and treated wastewater, for retrieval during summer and dry seasons.

Outdoor Water Use

Up to 60 per cent of household water is used outdoors, much of which is wasted. Using water conservation techniques in the garden will save you money, time and effort and be a benefit to the natural environment. As this fact sheet outlines, there are many easy ways to reduce outdoor water use. See also 2.1 Sustainable Landscapes.



GARDEN DESIGN

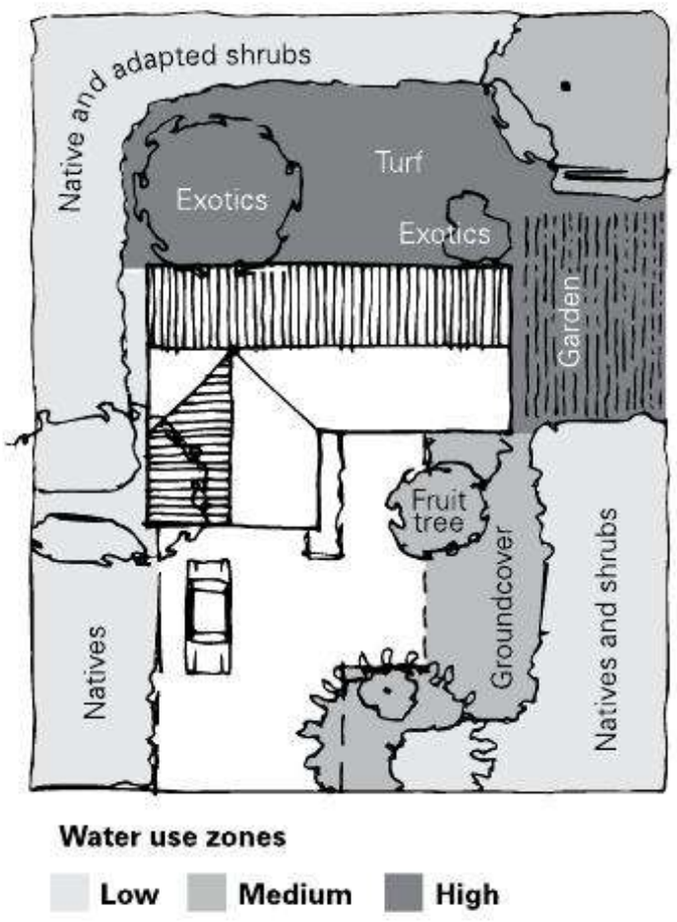
Minimise paving of outdoor areas as paved areas increases heat radiation and water run-off from the site.

Group plants with similar water needs together. Divide plants into high, medium and low water-use zones in your garden. [See: 2.4 Sustainable Landscapes]

Examples of plants for water-use zones

High water-use – Lawns, vegetables, fruit trees, exotic shrubs like azaleas and camellias, flowering herbaceous annuals and many bulbs.

Medium water-use – Hardy vegetables like pumpkins and potatoes, hardy fruit trees and vines like nut trees and grapes, many herbs, some exotic shrubs, most grey or hairy leafed (tomentous) plants, roses and daisies.



Low water-use – Most Australian natives including banksias, grevilleas and eucalypts. Succulents and cacti, olive trees and some exotic ornamentals such as bougainvillea.

Plant trees to create natural shade and windbreaks to reduce evaporation. High water-use plants are best located in areas where they are sheltered from drying winds and strong sunlight.

Where possible, use alternative water source for high water use plants. A simple approach is to direct rainwater run off from downpipes towards high water-use areas.

SOIL IMPROVEMENT

Soil types and water availability

Water holding capacity is determined by the texture of the soil. Finer soils have a greater capacity to hold water due to their greater particle surface area.

There are three main soil types – sand, loam and clay. Sandy soils drain rapidly, clay soils hold water but make it difficult for many plants to grow. A soil with plenty of organic matter and a mixture of fine and coarse particles that form into small composite particles (called 'peds') is ideal.

Hardy, deep rooted plants can help break up poor soils and adding composted organic matter will encourage microbial activity and worms to improve soil condition and moisture retention.

A simple test to identify soil type is to take a handful of soil from the garden and add just enough water to mould it into a ball. Test soil from various sites and from different depths in the garden.

Soil testing

> Sandy soils crumble and will not form a ball. They are light coloured, have little or no smell. Water drains away rapidly and they are low in nutrients.

> Loam soils will form a ball that is friable, usually brown with a pleasantly 'earthy' smell. Holds and drains water well and provides good levels of nutrients. Best for plants.

> Clay soils ball easily and range in colour from white to red or dark brown. Clay has fine, dense particles that do not allow water to soak in easily and which become hard and resist water when dry. They may be high in nutrients that are unavailable to most plants.

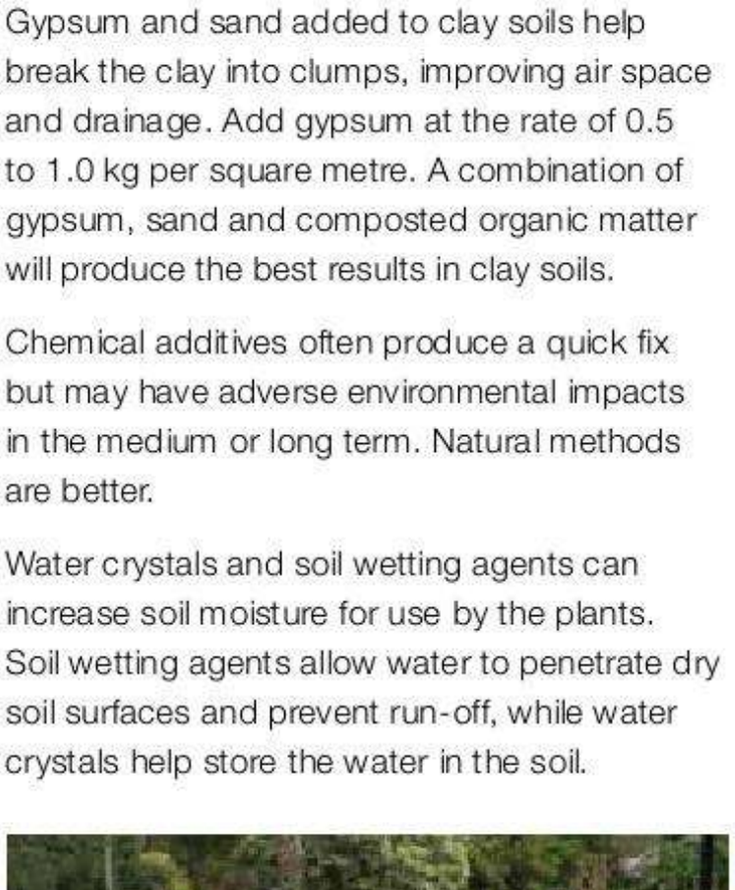
Improving soil

Add organic material. Water and nutrient holding capacity of sand and clay soils can be improved by the addition of organic matter such as manure, leaf mould and compost. Dig in to a depth of 15-20cm.

Gypsum and sand added to clay soils help break the clay into clumps, improving air space and drainage. Add gypsum at the rate of 0.5 to 1.0 kg per square metre. A combination of gypsum, sand and composted organic matter will produce the best results in clay soils.

Chemical additives often produce a quick fix but may have adverse environmental impacts in the medium or long term. Natural methods are better.

Water crystals and soil wetting agents can increase soil moisture for use by the plants. Soil wetting agents allow water to penetrate dry soil surfaces and prevent run-off, while water crystals help store the water in the soil.



REDUCE LAWN AREA

Lawns consume up to 90 per cent of water and most of the energy used in most gardens. They also take the greatest amount of time and money to maintain. Lawns need mowing, weeding, edging and fertilising, and equipment requires fuel and maintenance.

Reducing lawn area is the easiest way to save water. Create garden beds, or mulch areas that are used infrequently or where grass grows poorly.

Replace lawn areas with porous paving, pebbles or drought-tolerant ground covers such as prostrate grevilleas, snake vine (Hibbertia scandens), or myoporum. Seek advice at your local plant nursery.

Ways to reduce water use on lawns

Different grass types have different watering needs. Select a turf that needs less water such as couch, Queensland blue couch, buffalo, Nioaka and Nathus Green (Sporobolous virgincus), tall fescues and carpet grass. Many blends and species are region specific. Ask your local plant nursery for the most suitable low water species for your climate and soil type.

Do not 'scalp' the lawn. Set your mower to cut 4cm or higher. This encourages a deeper root system and the longer grass blades shade the soil, reducing evaporation.

Only water when the lawn is showing signs of stress. Long, slow soakings that allow water to penetrate to a depth of about 15cm will encourage a deeper, more hardy root system.

A lightly fertilised lawn uses up to 30 per cent less water than an unfertilised lawn of the same grass type. A diluted spray of the liquid drained from your composting worm farm (or purchased from a commercial vermiculture operation) is ideal fertiliser. It returns your waste to the soil and plants.

PLANT SELECTION

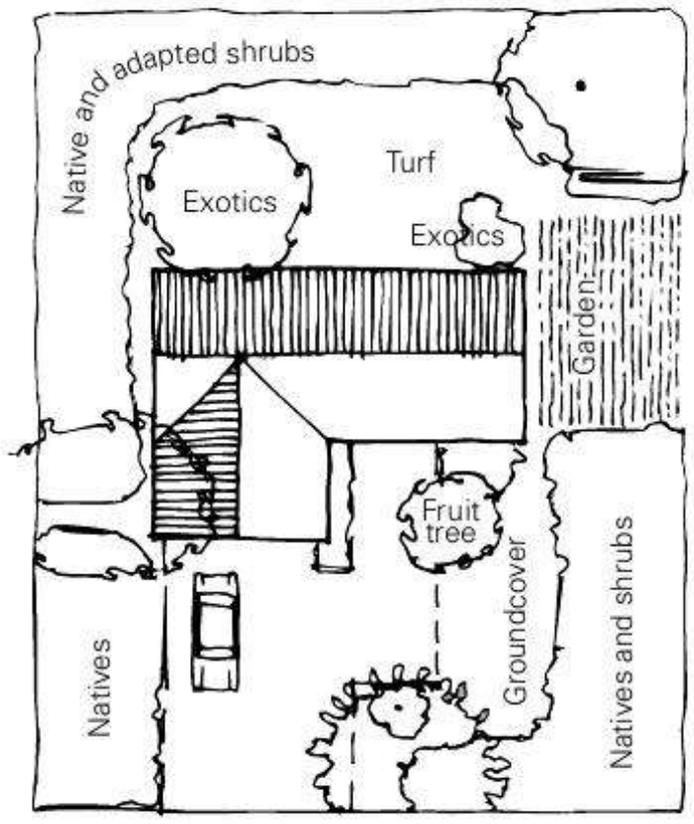
Select plants that suit the soil and garden conditions. Local indigenous plants will have evolved to handle local conditions. Many other Australian native plants have evolved to cope with very little water.

Some exotics from South Africa, California and the Mediterranean also cope well with limited water.

Explore your neighbourhood to discover what appears to grow well in your area. Take note of street trees, which are rarely watered or maintained.

Incorporating native plants into the garden will provide habitat and food for birds and insects. These in turn can aid in pest control and pollination.

Avoid changing gardens during summer as more moisture is lost from disturbed soils and makes it difficult for new plants or lawns to survive.



MULCHING

Mulching is an essential element of a water-efficient garden. Mulching around plants saves water by preventing evaporation and reducing run-off.

Mulching limits weed growth and can improve soil conditions (depending on the type of mulch).



Mulch can be in the form of leaves and grass clippings, sawdust, rocks and gravel, straw and other crop residues, bark and woodchips. Coarse mulch is excellent for reducing weeds and keeping soil cool but it won't improve the soil. Some nitrogen-rich fertilisers may need to be added before the mulch is laid. Medium and fine mulch are also good for limiting weed growth but can wear faster over time. This can be prevented by less frequent watering.

Before mulching, clear weeds, break up the soil crust and water the area. Spread mulch evenly to a depth of 7-10cm. If you are using fine mulch like sawdust then a thin layer of around 2.5cm is sufficient. Re-apply mulch at least once a year, or as it breaks down.

Do not allow organic mulch to touch woody plant stems and trunks or it may cause collar rot and kill the plant.

WATERING

Water early in the morning or evening as this allows water to penetrate before it evaporates. Watering early in the morning allows plants to utilise water throughout the day .

Less frequent, deep soakings train plant roots to grow down into the soil and increase the drought tolerance of plants.

Water the roots, not the leaves. Water on the leaves evaporates easily and can lead to scorching.

Controlling weeds reduces competition for water with your plants.

Ideally, fertilise plants with organic liquid fertiliser or compost. Dry fertilisers take up some water from the soil and can raise salt levels.



Water saving equipment and products

Irrigation equipment

Automatic irrigation systems that are poorly designed and inefficient may use more water than hand-held hoses and sprinklers. Automatic systems set to turn on regardless of weather conditions and soil moisture content will waste water. Systems not adjusted to seasonal needs may deliver water too fast, resulting in run-off, or supply more water than plants require.

Install soil moisture sensors. These trigger cut-off switches when it rains and adjust watering duration according to soil moisture levels.

Drip irrigation is the most efficient system as it delivers water to the roots of individual plants and minimises evaporation and wind drift.



Water-storing crystals can hold hundreds of times their weight in water. When mixed with water they form a soft gel and retain water that provides a reservoir of moisture for plant roots during dry periods. There are also products that can be sprayed on to plants' surfaces to reduce sunburn and water loss.

Soil wetting agents allow water to penetrate deeply into soil.

Humectants, a moistening agent, attract moisture from air spaces in the soil. These are particularly effective in sandy soils.

BEYOND THE GARDEN

Water is used outdoors for activities other than gardening and these also provide opportunities for savings.

Wash your car, or boat at a car wash that recycles water and detergents. If washing the car (or dog) at home, washing it on the lawn prevents water and detergent flowing down the drain. Choose a different place on the lawn each time.



Lawns have a limited ability to uptake the nutrients from detergents. If the lawn becomes water-logged or deteriorates, your car may be compacting the soil or the nutrient levels are too high. Aerate the lawn and switch to the car wash for a few months.

Swimming pool covers significantly reduce evaporative losses and can save between 11,000L and 30,000L of water a year.

Use a broom instead of a hose to clean paths and the outside of buildings.

SMART APPROVED WATER MARK

You can further reduce water use outdoors by choosing products and services labelled with a Smart Approved Water Mark. This label is approved for primarily outdoor goods and services that satisfy a set of criteria as assessed by technical experts, to effectively achieve water savings. Look for the Smart Approved Water Mark on items and services, or check the database of approved products and services at www.smartwatermark.info

It may be possible to obtain rebates on water efficient garden equipment. Your local council should be able to advise you.

ADDITIONAL READING
Contact your State / Territory government or local council for further information on outdoor water use. www.gov.au
Smart Approved Water Mark www.smartwatermark.info
Savewater Alliance www.savewater.com.au

Principal author:
Denise Day

Low Impact Toilets

Toilets that use no water for flushing can have lower environmental impacts even compared to water efficient toilets and recycling wastewater. Waterless toilets or 'dry sanitation' systems are systems that do not use water to treat or transport human excreta. If appropriately designed, they conserve precious water resources and avoid disposal of effluent and pollutants into waterways and the general environment. They can also save you money on your water bill.



Low impact toilets are an important, minimum energy, on-site alternative to centralised reticulated systems that transport the problem downstream. They can also reduce the site restrictions and pollution and nutrient problems that can be encountered in the use of systems such as septic tanks.

Low impact toilets still contain a very small amount of moisture that has to be drained away and council or health department regulations will require appropriate drainage and disposal for this residual moisture. But to all intents and purposes low impact toilets have a lower overall impact and use no additional water to operate.

They are often preferable to conventional toilets in environmentally fragile or water-scarce areas. In the mid-north coast region of New South Wales, Council staff recommend home owners install low impact toilets rather than conventional septic tank systems.

Low impact toilets can produce fertiliser if sufficient time is allowed and correct treatment conditions have been maintained. However advice should be sought as to its use, industrial application such as fruit trees may be ok.

The most common type of low impact toilet is referred to as a 'composting toilet' (CT) although the treatment often involves more than the process that occurs in your garden compost heap.

A composting toilet that is working well and is correctly maintained does not smell. Diverting urine away from the compost can aid the composting process by reducing moisture levels and potential odours.

The original low impact toilet was the pit latrine and sometimes people fear that the composting toilet will look and smell like a pit toilet. But composting toilets can be an elegant addition to a modern bathroom.

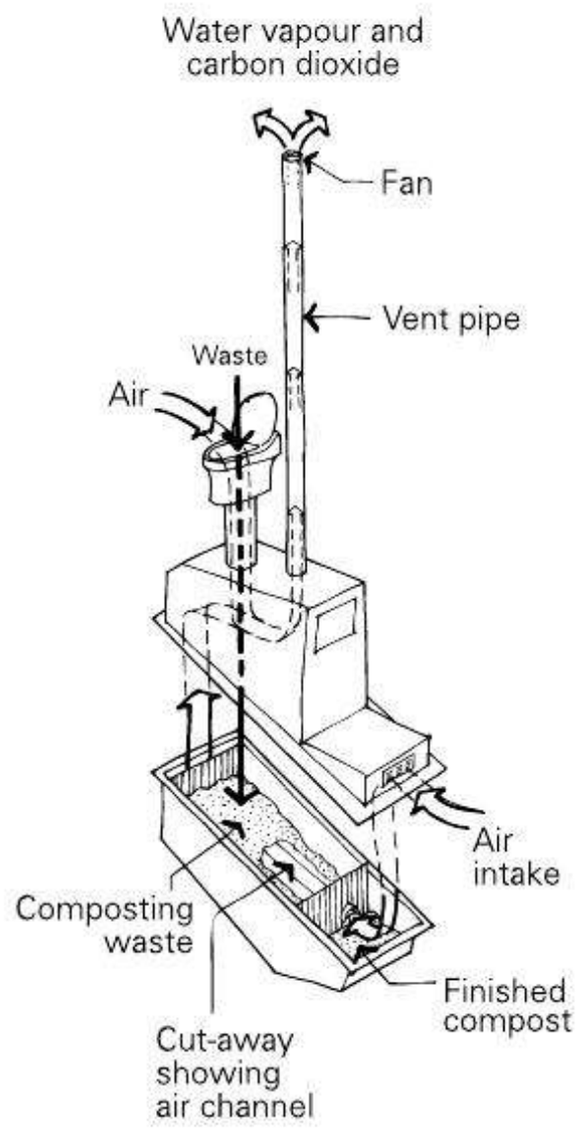
All composting toilets require a volume of space under the toilet floor which may necessitate the construction of either a pit or an elevated platform. Composting toilets generally work best when kept warm so it can be important to locate them in places that do not get too cold, ideally on the solar side of a house.

Decomposition in the holding tank or container of a CT occurs through a complex bio-chemical interaction of factors such as temperature, pH, desiccation, and digestion by invertebrates, all taking place over an extended time period.

There are many designs of CTs but they can be divided into two main types with characteristic advantages and disadvantages. The designs include commercial off-the-shelf units and owner-built systems that can be constructed using readily available materials.

CONTINUOUS COMPOSTING TOILETS

These consist of a single container in which excrement is deposited, and decomposes as it moves slowly through the container. It is then removed as compost from the end-product chamber. There are well known designs with health health department approval in most parts of Australia that consist of prefabricated models available for installation; which may also be constructed by owner-builders.

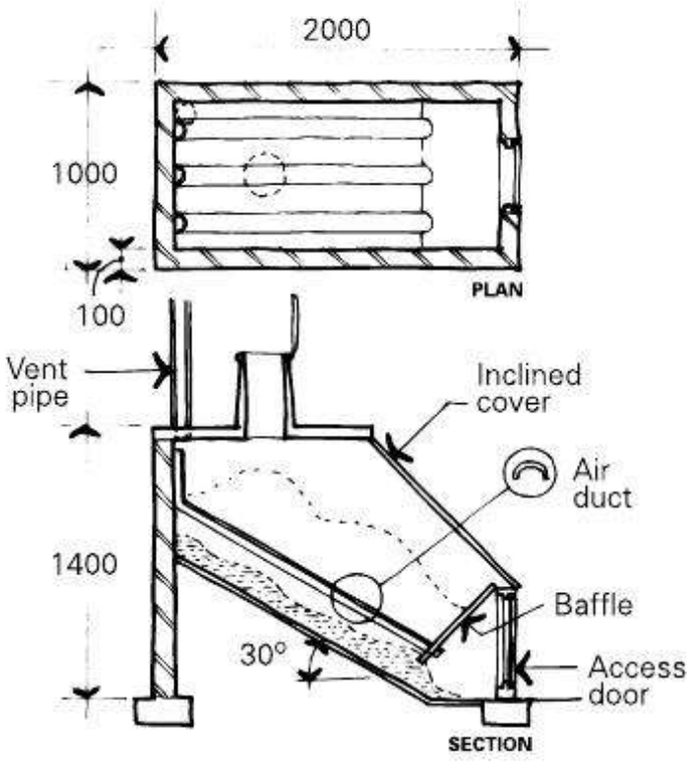


A commercially available continuous composting toilet.

Advantages of continuous CTs

Single containers are fitted under a bathroom and can easily replicate a flush toilet with little physical or social adjustment.

The container is permanently fitted under the toilet seat, and never has to be fully emptied as the compost can be gradually removed when it reaches the end-product chamber.



Measurements are in millimeters

Plans for a small continuous CT.

Disadvantages of continuous CTs

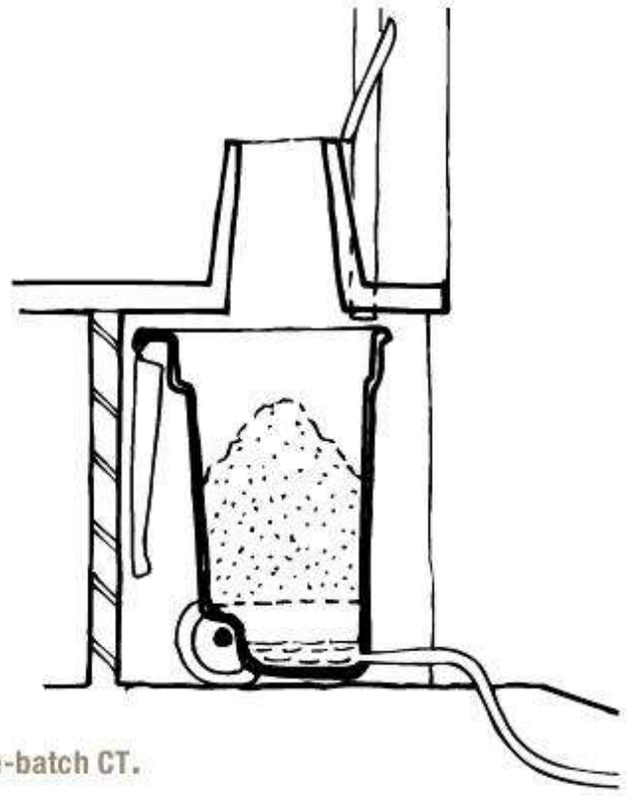
The continuous system may allow fresh material and pathogens (disease causing organisms) deposited on the top of the pile to contaminate the successfully decomposed end-product at the bottom of the pile.

If a problem occurs with the toilet, the system can be out of order until the problem is fixed because there is only one container. Sometimes the pile does not actually move down the slope of the container and can become compacted and very difficult to remove.

BATCH COMPOSTING TOILETS

Batch CTs consist of two or more containers that are alternated so that the active container is being used while the pile in the fallow container has time to compost without the addition of fresh excrement and the potential for re-contamination.

An example of an owner-built batch CT is the 'wheelie-batch' where containers are alternated underneath the toilet seat.



Wheelie-batch CT.

The Fixed Chamber Batch is another example of a batch CT where the two containers are permanently in place and the seat is moved when the time comes to change containers.

The full containers in the batch system need to be replaced by an empty container. This involves disconnecting the container fitted under a toilet seat or moving the seat over a new container. Batch systems can therefore take up more space in the bathroom or under the house.

There are commercially available batch CTs including Australian-made system with approval for use in most parts of Australia. It has six removable containers mounted on a turntable beneath the toilet for collecting waste, which saves space and simplifies changing over to a new container.

MAINTENANCE OF COMPOSTING TOILETS

The composting toilet is relatively simple technically but requires more attention than a flush toilet.

Some carbon based material or bulking agent, such as dry leaves or softwood shavings, should be regularly added to the container, preferably daily or with each use. This provides the proper carbon-nitrogen mix, helps aerate the pile and prevents compacting. Some commercial suppliers say this is not necessary for their design and their directions should be followed, but experience indicates the addition of bulking agent is desirable in most designs to produce good compost.

A CT that is working well does not smell. Offensive odours usually indicate that something is wrong and trouble-shooting directions need to be followed. Often adding bulking agent in greater quantities or more regularly will remove the smell.

The pile in a CT needs to be well drained. The liquid run-off is often treated in a sealed evapotranspiration trench or a solar evaporating tray.

Vent pipes provide aeration to the pile and can work passively using convection. Fans are not essential but are often included in off-the-shelf systems to aid ventilation and minimise odours. Fans should be checked occasionally to ensure they are not choked with dust or insects.

The end-product or compost needs to be removed from the CT container when it is sufficiently decomposed. The frequency of removal depends on the size of container, how often the system is used and local climatic conditions. The minimum 'fallow' period should be six months. Depending on the design and usage, the container usually needs to be emptied every six months to three years.



The compost can be used as fertiliser dug into your garden or disposed of according to local Council regulations.

CTs do not deal with greywater from showers, kitchen and laundry so a separate greywater collection and treatment system needs to be provided. [See: 7.4 Wastewater Re-use]

Some safety precautions

It is safest to assume that the composted end-product contains residual disease-causing pathogens. The degree of decomposition and pathogen destruction is sensitive to a range of ambient conditions in the composting mass (such as temperature, moisture and pH levels) that are difficult for the toilet owner to monitor and control.

> Always use protective clothing such as gloves and mask when handling the composted end-product.

> Bury the compost under at least 10cm of soil.

> Do not use the compost for cultivating vegetables.

CHOOSING A COMPOSTING TOILET

For an off-the-shelf unit contact several suppliers. Tell them about the building, where the toilet will be located, how many people will be using the toilet and whether it will be on a continuous basis or only occasionally, such as in a holiday house. Ask them to recommend a suitable system for your needs and provide a quote. The cost can vary significantly depending on the design and features. Some suppliers will also assist with greywater treatment systems.

Check if the supplier will give you after sales support. Ask if they have any customers with whom you could meet and discuss their experience with the CT. The cycle of usage and production of compost or end-product can take a couple of years. It is important to know that all stages of the process work satisfactorily.

Check with your local council and/or the supplier to confirm that CT design has approval in your area. Council attitudes and regulations vary, but the common off-the-shelf units have Health Department approval. The owner-built designs are usually cheaper to install but often have not gone through the required approval process, even though they have been used widely for many years.

Avoid complicated designs. Simple passive systems with minimum moving parts are usually easier and cheaper to build, monitor and maintain. Some people prefer the designs that have more moving parts because they think it will mean they have less to do with maintaining the system. If the system is working well this can be true, but if there is a problem, the more complicated designs can be more difficult to fix.

There are many types and applications of CTs. Refer to published literature and manufacturers' websites for more information and contacts for commercial units and owner-built designs.

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Del Porto D and Steinfield C (1999), *The Composting Toilet System Book*, The Center for Ecological Pollution Prevention, Massachusetts.

Van der Yn, Sim (1999), *The Toilet Paper*, Chelsea Green, Vermont, USA.

Windblad U and Simpson-Hebert M (2004), *Ecological Sanitation*, Stockholm Environment Institute, Sweden.
www.ecosanres.org

Composting Toilet
www.compostingtoilet.org

Principal author:
Leonie Crennan

Water Case Studies

The following case studies showcase innovative urban water design in single dwellings Australia. The first is an architect-designed major renovation of an existing dwelling, the second is a new house, the third is an owner-built retrofit of an existing dwelling.

CLOVELLY HOUSE, SYDNEY

A major renovation integrating environmentally sustainable strategies with contemporary design.

This case study is of interest for:

> Collecting rainwater.

> Water sensitive urban design.

> Reusing greywater.

> Conserving water.

The Clovelly House is a semi-detached terrace house on a 234m^2 property in Sydney that underwent a major renovation in 2004.

Water quality is matched with its intended use within the house using three sources of water:

> Mains-supply.

> Rainwater.

> Treated greywater.

Only the kitchen uses water supplied by the mains. High efficiency fixtures in showers, baths and hand basins are supplied with rainwater, as is a small swimming pool. The laundry, toilets and garden taps are supplied with treated greywater.

The water saving measures are elegantly integrated into the building. The rainwater from 100m^2 of roof is collected in three specially shaped 1,000L tanks that form a garden wall. Greywater is treated in a lush green-wall that is also an attractive landscape feature. [See: 5.13 Green Roofs and Walls]



The innovative green-wall greywater treatment system treats wastewater from showers, baths and handbasins. The greywater is trickled through three plant boxes placed above each other, where the filtering materials treat and polish the water. The small size and simplicity of the greywater treatment system is made possible by excluding greywater from the washing machine – reducing both the volume and nutrient load of the greywater to be treated.

Monitoring has shown the treated greywater to be of drinking quality, showing that ultra-violet treatment required by specification is unnecessary.

Re-use of greywater from showers, baths and handbasins supplied by rainwater in the washing machine and toilet effectively enables the collected rainwater to be used twice. Wastewater from the laundry, kitchen and toilets are discharged to sewer.

A stormwater infiltration zone in the landscaping, and stormwater absorption tanks at the front and rear of the property are used to manage stormwater including overflows from the raintanks.

Outcomes of the project

> Monitoring shows at least 80 per cent reduction in potable water use compared to the Sydney average.

> Greywater treatment system, possibly the first of its kind in Australia, treats water to high quality with little additional energy beyond small pumps.

> The rain tanks have reliably provided water even during drought.

See 11.4 Clovelly NSW Case Study for more details.



This vertical greywater filtering system treats water to be re-used in the toilet, washing machine and garden.

HEALTHY HOME, GOLD COAST

An advanced water system for a new house.

This case study is of interest for:

> Collecting rainwater.

> Reusing indoor greywater.

> Conserving potable water.

> Minimising wastewater discharge.

The healthy home is an innovative environmentally designed house on a 460m² urban site on the Gold Coast, completed in 2000.

The advanced water system includes rainwater harvesting for potable use, greywater collection and treatment, and solar water heating.

A roof area of 150m² supplies roof run-off via a first flush diverter to a 22KL concrete tank below the house. The water is filtered and disinfected using ultra-violet light to produce high quality drinking water for indoor use. Water pressure is maintained with the aid of a pump and pressure vessel. The water quality meets National Health and Medical Research Council drinking water guidelines. The tank is backed up by mains supply.

A second 1050L tank was added near the carport post occupancy, to collect run-off from the carport roof, to provide water for garden irrigation.

Greywater from the household is treated by a 6,000L aerobic wastewater treatment system (AWTS) with recirculating sand filter also located under the house. Greywater from the bathroom and laundry entering the tank is settled and treated anaerobically in a septic tank and then circulated by pump through an Envirotech sand filter within the tank. The treated water is disinfected with UV light.



Greywater system.

A second pump discharges treated and disinfected greywater to a storage tank for re-use in the garden.

Blackwater and wastewater from the kitchen are discharged straight to the sewer.

Rainfall: the Gold coast averages 1460mm per year.

Outcomes of the project

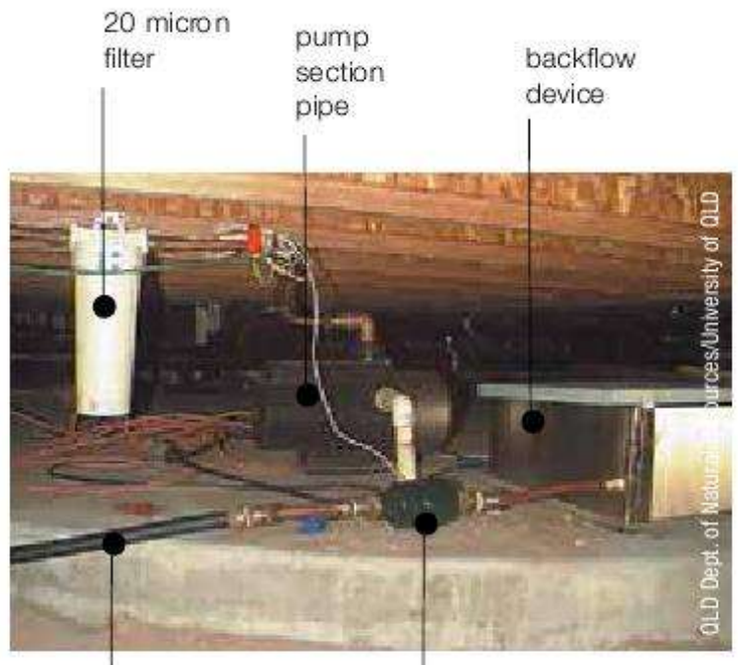
> Town water savings of up to 50 per cent are achieved compared to an average Queensland household.

> Chemical analysis has shown that the AWTS with recirculating sand filter effectively removes organic and suspended solids.

> Disinfection and pumping water for indoor use consumes around 2.6 kWh of energy per day. The requirement for additional electricity for treatment and pumping of rainwater and greywater is a disadvantage of advanced water re-use systems compared with mains supply.

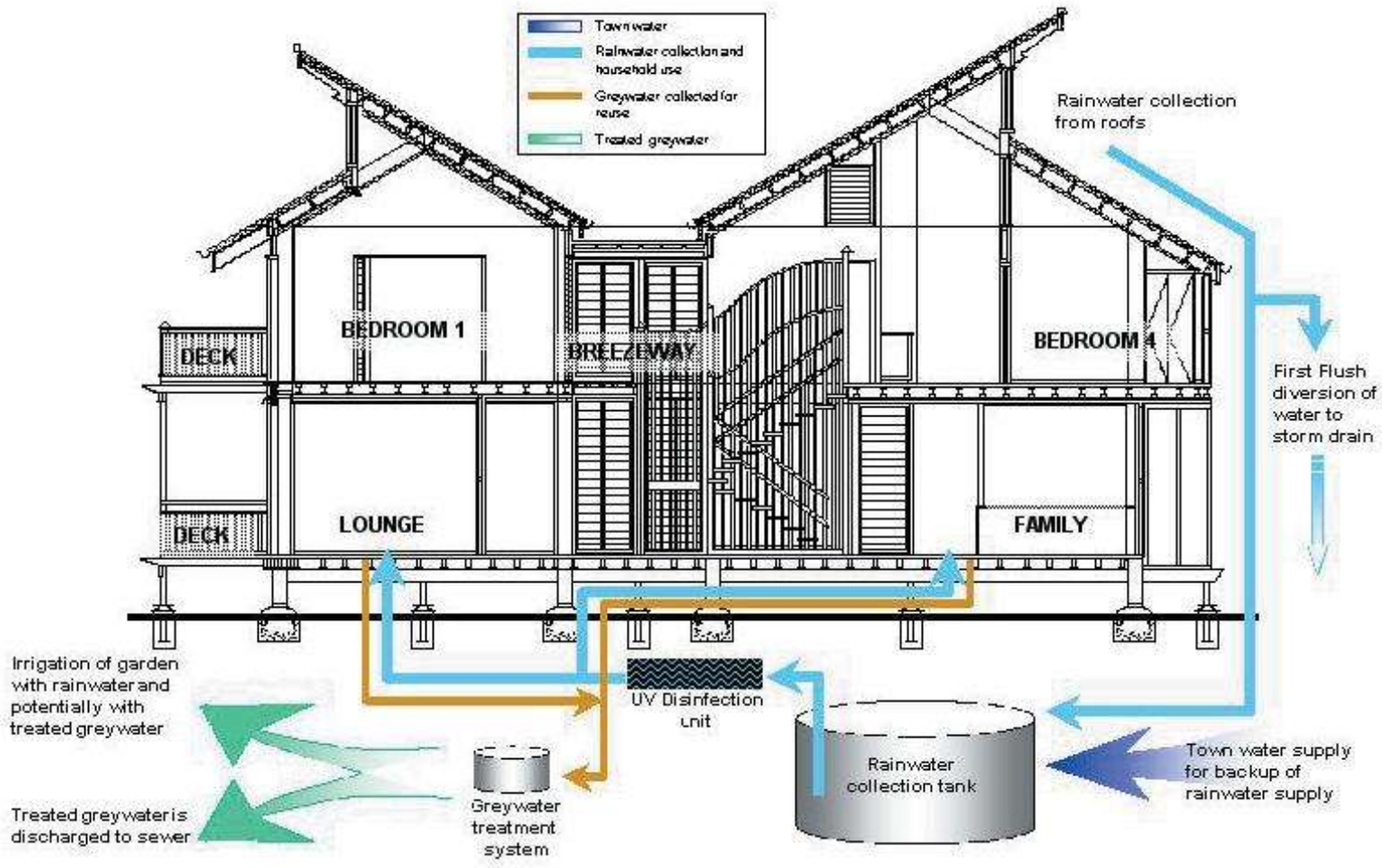
> Significant reductions in potable water usage and stormwater run-off from the site have been shown.

> The rainwater and greywater systems are not currently cost effective on the Gold Coast. Payback periods of 23 and 100 years respectively were calculated on the rain and greywater systems.



Source: QLD Department Natural Resources

www.healthyhomeproject.com



QLD Dept. of Natural Resources/University of QLD

LISMORE RETROFIT, NSW

A single house retrofit for on-site wastewater management.

This case study is of interest for:

> Reusing greywater outdoors.

> Composting toilets.

> Conserving potable water.

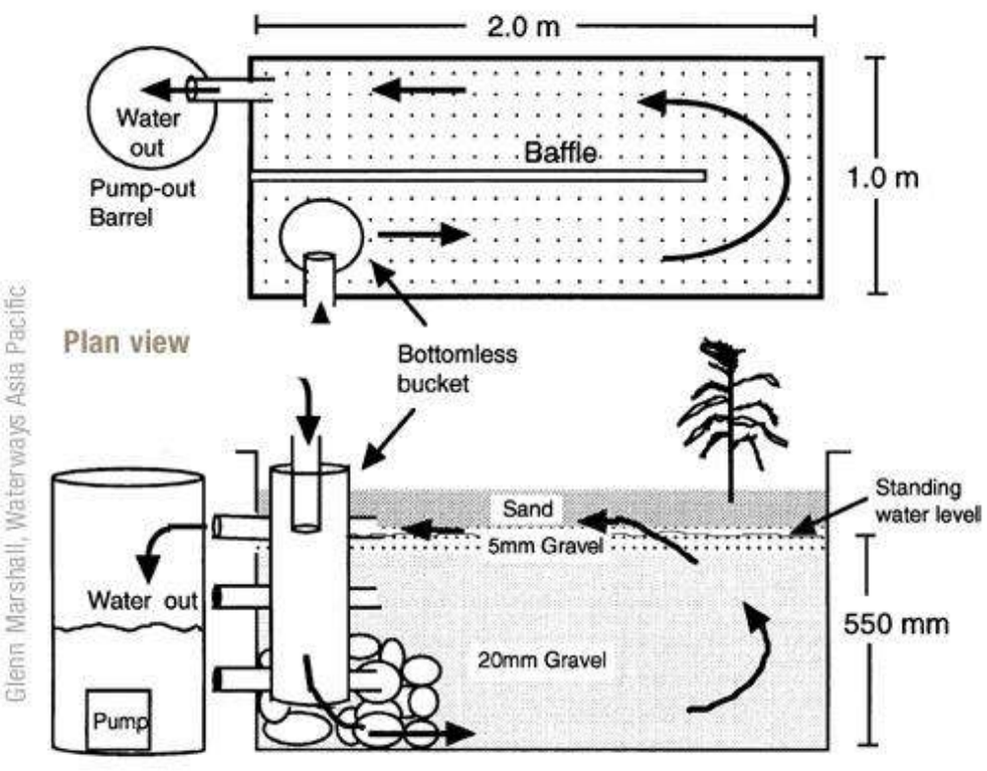
> Minimising wastewater discharge.

This Lismore NSW home was retrofitted over a four year period to demonstrate the potential for on-site wastewater management in the urban environment.

It incorporates dry sanitation and greywater treatment systems.

On the steep 1250m^2 site, the owner-builder constructed a reed bed followed by an intermittent sand filter greywater treatment system that supplied subsurface irrigation for the garden. A 'Wheelibatch' dry toilet was installed with drained liquid (mostly urine) from the toilet directed to the reed bed. The home maintained its mains water supply.

Greywater from the home was diverted through a coarse gravel filter to the small sub-surface constructed wetland. The wetland was planted with Phragmites australis, with greywater passing through the lined basin filled with gravel and sand.



Glenn Marshall, Waterways Asia Pacific

Longitudinal view.

Schematic of wetland

Effluent from the wetland drained to a 4500L storage tank from where it passed through an intermittent sand filter.

The filter was constructed with a 400mm depth of course washed sand above 100mm of gravel. Treated greywater drained to a pump-out barrel and to sub-surface irrigation of a 100m^2 established garden.

The waterless toilet was designed as a batch system using two modified 240L mobile garbage bins. One bin sits under the pedestal while the second lies fallow. The ventilation system covers both bins. Liquid (urine) from the bins is drained to the greywater system.

Outcomes of the project

With two people living in the house, the system avoided an estimated 150kL of sewage and associated treatment and pumping per year.

Chemical analysis showed that with the addition of disinfection, the greywater system should meet NSW greywater guidelines for both indoor and outdoor re-use.

Source: Glen Marshall and Stuart White

ADDITIONAL READING

Veale, J, (2006), *Clovelly House, East Sydney, New South Wales*. The BDP Environment Design Guide August 2006. Royal Australian Institute of Architects.

Gardener T., H. Gibson, G. Carlin and A. Vieritz, (2000), *Water Sensitive Design to reduce the ecological footprint of urban development*, Proceedings of the Water Recycling Australia conference, Adelaide.

Gardner, T. Coombes, P., Marks, R., (2001), *Use of Rainwater at a Range of Scales in Australian Urban Environments*. Paper presented at the 10th International Rainwater Conference, Germany.

Principal author:
Caitlin McGee

Case Studies

These case studies present diverse real life examples of what are currently some of the best sustainable homes in Australia. More economical to run and healthier to live in than many conventional homes, they each demonstrate effective responses to many of the principles of good design detailed in the Your Home fact sheets.

The case studies include new and existing homes ranging from units and apartments to freestanding houses and they are arranged in four categories: New Homes, Medium Density, High Density, and Renovations. Each type is then organised according to the eight climate zones identified by the Building Code of Australia. [See: 4.2 Design for Climate]

NEW HOMES

These examples of new homes are in locations that range from remote islands to the outback, and from the suburbs to the inner-city. Whether the projects are single storey homesteads or multi-storey townhouses, the same basic principles of good design apply. The diversity of these case studies demonstrates that there are no 'cookie-cutter' solutions to sustainability and that commitment to sustainability and comfort can be a powerful stimulant to creative design.

MEDIUM DENSITY

These two case studies include quite different dwelling types that show how even in constrained urban environments it is possible to achieve creative, effective design solutions.

HIGH DENSITY

This case study shows that even the most compact inner-city apartments can deliver high levels of sustainable performance.

RENOVATIONS

Some of the renovations shown here are thorough reworkings of an existing dwelling whereas others are more modest. Together, they demonstrate that almost any existing home can be upgraded to deliver a more sustainable, efficient and comfortable lifestyle.

CASE STUDY CONTENT

The content of each case study follows the same general arrangement – a description of the site and climate is accompanied by information about the design background or brief, then the planning, orientation and passive strategies are described along with an indication of how materials have been used in accordance with good design principles. Different case studies stress different aspects of the design principles.

A map identifies the location of each case study and its climate zone.

Each case study has a text box containing a list of topics where that particular project has performed well. These include:

> Passive design.

> Lifestyle modification.

> Rainwater harvesting.

> Waste reduction.

> Wastewater recycling.

> Greenhouse gas reductions.

> Recycled/renewable material use.

> Reducing transport impacts.

> Embodied energy reduction.

> Renewable energy production.

> Food production.

> Indoor air quality.

> Reducing water use.

At the end of each case study a text box identifies the key experts involved in creating the project.

THERMAL COMFORT (AccuRate)

In order to provide a consistent way of comparing the performance of diverse building designs in various climate zones, all the case studies have been rated using AccuRate which is designed to assess aspects of thermal comfort which are a consequence of the building's design. [See: 1.5 Rating Tools]

Some of the case study projects have relatively low ratings on the AccuRate scale but are reported to perform very well as climate-responsive, passive homes, with high levels of occupant satisfaction. Thermal comfort is only one performance indicator and a lower rating in these case studies does not necessarily mean the house is not environmentally sustainable overall. It reflects the growing complexity and sophistication of sustainable home design and energy rating systems. Ratings for passive design or what some architects and designers refer to as 'free running' performance is still an evolving art, and new tools like AccuRate are providing better quality feedback on particular aspects of thermal comfort.

AccuRate has two modes of operation:

> Regulatory mode that uses the settings needed by building regulatory agencies.

> Full rating mode that takes account of additional design features.

For example, in regulatory mode, building envelope features that are removable, such as curtains, are assumed to be of a minimum standard. In full rating mode the fittings that are actually installed, such as heavy curtains with pelmets would be considered. The case study listings include a mixture of both.

The task of providing representative case studies for each climate zone and building type is on-going – the case studies included here will be added to as resources permit.

Principal author:
Paul Downton

AccuRate Ratings for case studies:
Energy Partners

Little Green Island QLD

NEW HOME

ZONE 1: High humid summer, warm winter



Topics covered
Passive cooling
Orientation and natural ventilation
Rainwater harvesting
Greywater recycling, Compost WC
Design for waste minimisation
Renewable energy generation

AccuRate (thermal comfort)	5.2 (full rating)

This case study is an example of a fully autonomous house that uses no mechanical cooling, generates its own electricity, harvests rainwater and recycles wastewater.

DESIGN BRIEF

The owner (a writer), required a small house that he could use as a retreat to allow time for thinking and writing. The house was to have a large bedroom and living area plus a bathroom, kitchen and a storeroom. Occasionally the owner would do some entertaining so a separate bathroom and multi-purpose, open-plan living area was required.

The house was also to be used periodically for retreats and by guests for meetings. So the building needed a flexible arrangement of spaces. The owner also required that the house should provide maximum comfort but, given its remote location, could not rely on any services from outside the site.

A maximum level of security was essential because of the remote location and the likelihood that the house would be unoccupied for extended periods.

LOCATION AND CLIMATE

The house is located on an island in Queensland. The site is a large area of 30 hectares. It is sited on the only available flat, sheltered area. Existing vegetation filters the extremes of the south easterly winds whilst allowing the elevated design to benefit from controlled cross ventilation.

The climate is highly humid with high rainfall during the three to four month wet season. There are long periods of relatively dry and sunny weather for the remainder of the year. Council required that the house be designed for category 1 cyclone conditions.

Council had no prescriptive planning controls that affected the design due to its remote location. [See: 2.0 Sustainable Communities]

DESIGN RESPONSE

This house has a dominant roof form over open walls that indicates its interaction with the prevailing breezes for cooling. In hot humid climates, wide roof overhangs are required for shading.

The roof is twisted and split open along the long axis of the house to maximise its role in ventilation. Large areas of louvres under the eaves are crucial in providing cross ventilation.

The open plan nature of the house and its flexibility allows the living and bedroom areas to be doubled by the use of adjacent decks. This is important in retaining the feel of the `Queenslander' house style in the tropics.

The design makes maximum use of available breezes to provide year round cooling. Daytime temperatures usually exceed comfort levels.



The cooling design principles were to:

> Elevate the house to increase exposure to cooling breezes filtered through the existing tree cover.

> Provide a large overhanging roof in all directions to minimise direct solar heat gain.

> Ventilate all the eaves edges of the roof to at least one metre high.

> Use a central ventilated ridge that functioned like an aeroplane wing to create uplift and draw cross-draughts of breeze through the house during low breeze conditions and allow convective or stack ventilation.

The house was designed to be built from modular components, fabricated off site and transported to site by barge for erection. A 900mm modular design allowed standard material sizes to be used throughout. This reduced costs and minimised wastage in construction. All plywood and aluminium paneling was made to a 900mm wide grid to minimise any waste at the factory and to ensure that there was no site waste generated from construction.

DESIGN SOLUTIONS

The house has a linear rectangular form with living area and bedroom at each end. The service areas are grouped together either side of a short central corridor.

Decks provide extended living areas on both sides and an extension to the bedroom to the north. In the tradition of the original Queenslander, occupants access rooms via the surrounding verandahs. These external spaces are shaded by wide roof overhangs.

The house has sliding shutters, flyscreens and glass doors, allowing for maximum manipulation of the external envelope. The living area and bedroom have multiple sliding glass doors with matching flyscreen doors. A cyclone proof shutter is fitted in the bulkhead over the doors. This allows equalisation of wind pressure inside and outside the house.

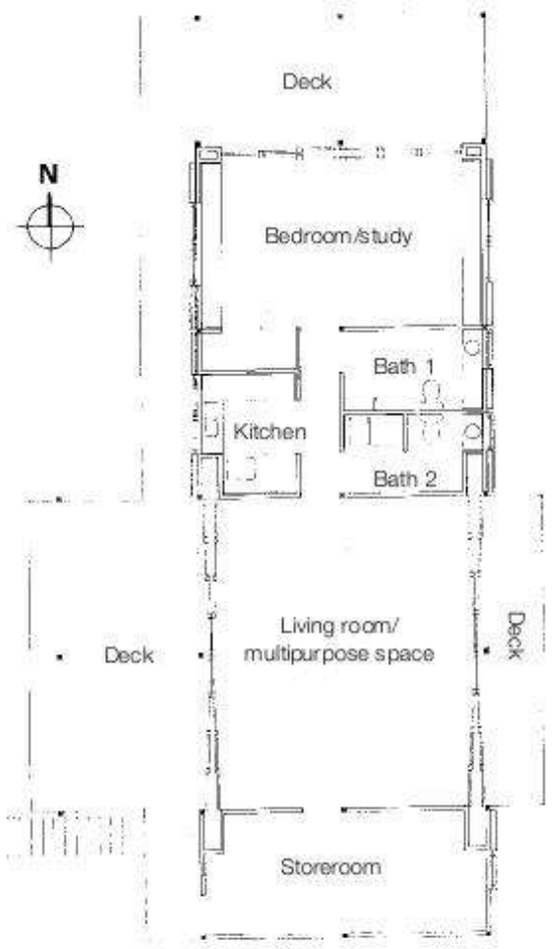
This arrangement allows for four different conditions:

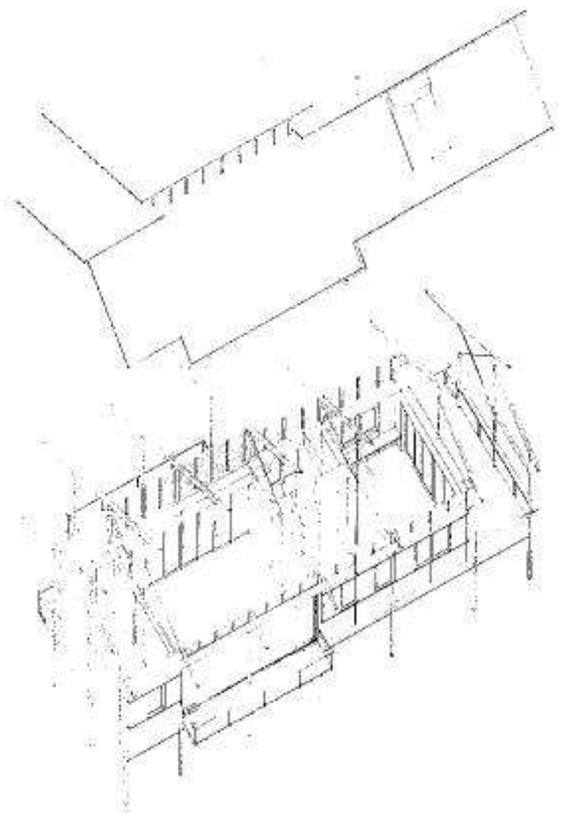
> Shutter closed for cyclone protection.

> Glass doors closed for cooler weather.

> Flyscreened spaces for insect protection.

> All doors open for integration of inside and out.

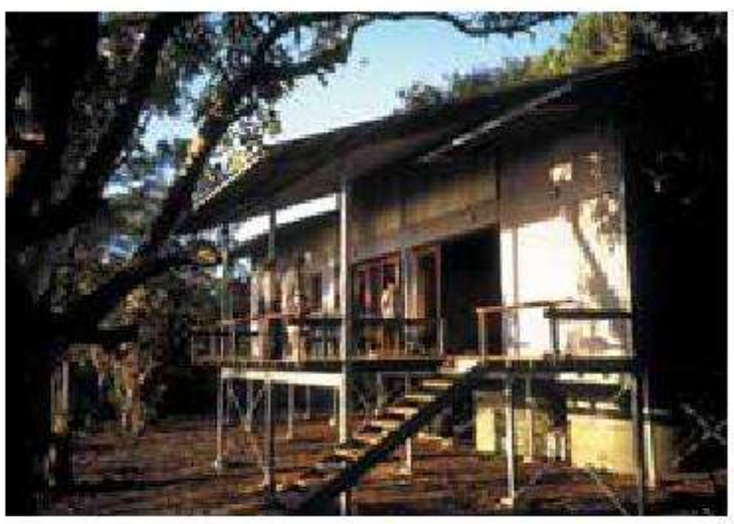






Orientation and windows

The best aspect is to the north and west, looking out over water with spectacular views of another part of the coastline. Given the shape of the site, the house is oriented to those views from both the living and bedroom areas with a substantial overhang to the west. Existing tree cover to the west also shades the house. The bedroom is oriented north since this is the one space that can benefit from some early morning sun penetration in cooler months. [See: 4.3 Orientation]



Structure and envelope

The main structure of the house comprises steel column and beam sections that provide efficient strength and rigidity against cyclonic conditions. As the site has a high termite content, no timber structure contacts the ground and a large undercroft area allows inspection for termite activity.

Roofing and ceilings are in corrugated steel sheet on steel purlins.

Flooring is sustainably logged local hardwood joists with hardwood floors.

Walls are lightweight modular panels which reduced transport costs. The design was based on a series of panels and structures to allow offsite prefabrication.

Thermal mass and insulation

The house requires cross ventilation in order to attain thermal comfort. The walls are insulated and two layers of insulation in the roof system reflect radiant heat and prevent heat loads from reaching the structure. Convection and cross ventilation remove heat from the building.

In high humid climates with high humidity and low diurnal temperature ranges; thermal mass is of little benefit. Low mass construction responds rapidly to the effects of cooling breezes and has lower embodied energy – particularly on a remote site. [See: 4.7 Insulation; 4.6 Passive Cooling]

Cladding and lining

The external walls are lined with lightweight, high strength, aluminium sandwich panel modules. They provide substantial protection from cyclones and security risks, transport easily and are highly durable in a marine environment. The interior is lined with plantation grown, hoop pine plywood.

Ventilation

Cross ventilation is encouraged through the use of adjustable sliding doors and the permanent louvering system above the doors and at the ridge vent.

Sliding doors are standard sashes fitted to custom designed heads and sills that allow for multiple stacking of the doors, allowing rooms to be completely opened. The windows are also made from standard sliding sash sections with customised heads and sills. They have flyscreens with sliding aluminium screens for external security.

Services

The house has no heating or cooling systems other than the designed, natural systems.

Rainwater / stormwater

Gutters fitted with leaf guard drain to two rainwater tanks beneath the house. Water is sand filtered and drinking water is reverse osmosis filtered. The tanks are sized to allow for collection of the whole year's rainwater supply during the monsoon season.
[See: 7.3 Rainwater]

Lighting and daylighting

The house has compact fluorescent fittings installed throughout to reduce energy demand. Using one fitting type on a remote site simplifies maintenance. Waterproof fittings used inside and out keep insects away from the light fittings, extending their life and reducing maintenance.

Uplights are mounted on the wall and use reflectors and the ceilings to distribute the light throughout the house. There are lowered ceilings in the bathroom and kitchen areas to provide lower reflection levels and increase light levels in the service areas. [See: 6.3 Lighting]

Water heating

The house is fitted with a solar hot water system.

All shower and tap fittings are WELS 3 Star rated to limit water wastage. [See: 7.1 Water Use Introduction;]

Energy and appliances

A Remote Area Power Supply system is installed. The system used is a commercially available system (Pyramid Power). This includes a solar tracking array of Photovoltaic



cells, an inverter, a battery bank and a backup generator. The batteries and control system are mounted in a pyramid shaped storage box underneath the panels. The backup generator is rarely required.

Energy from the PV cells is stored in batteries with 12 volt DC output and is converted to 240 volt AC by the inverter to supply the house. This allows use of conventional lights, stereo, computers, etc. The fridge and small cooktop run on imported LP gas to reduce electricity demand. Even the most energy efficient fridge in the tropics would require an excessive number of PV panels, beyond the financial resources of the owner. [See: 6.6 Renewable Energy]

Black / greywater systems

The house is fitted with a single composting toilet system (Rotaloo) that has two pans arranged back to back in the two bathrooms. The system is commercially available and allows for up to two pans and provides a system of composting bins that may be rotated when full to allow full composting before it is removed for use in the garden.

The dry residue has nil health risk if composted properly. The system has Australia wide health department approval. [See: 7.7 Low Impact Toilets]

The waterless toilets reduce water demand by up to one third, reduce the volume of wastewater that must be dealt with and simplify the wastewater treatment system by not mixing pathogens with wastewater. Greywater from the basin, shower and sink is treated in a reed bed system before being used to water non-edible plants. [See: 7.4 Wastewater Re-use]

Landscape

The immediate site area around the house is kept clear of vegetation with a gravel bed. The original mango trees and surrounding tropical forest is maintained in all directions.

Siting the house to have a view of a Hoop pine tree directly outside the kitchen has provided a curiosity as this tree species was used in all the plywood panels lining the internal walls of the house.



EVALUATION

The house has worked as designed for several years. The thorough application of passive cooling principles maintains acceptable levels of thermal comfort year round.

The owner is extremely pleased with the design solutions and said that the house worked well.

The mechanical tracking system on the PV panels failed but the falloff in output was negligible.

Better leaf guard systems combined with a first flush diverter system would reduce water contamination.[See: 2.0 Sustainable Communities]

PROJECT DETAILS	
Architect:	Tone Wheeler, Environa Studio
Builder:	Planet Build P/L
Engineer:	Randall Jones

Principal author:
Tone Wheeler

Contributing authors:
Steve Shackel
Chris Reardon

Rockhampton QLD

NEW HOME

ZONE 2: Warm humid summer, mild winter



Topics covered
Passive design
Daylighting
Reducing water use
Rainwater
Reducing embodied energy
Greenhouse gas reductions
Sustainable materials use
Renewable energy generation
Indoor air quality
Adaptability

AccuRate (thermal comfort)	6.7 (regulatory)

Waste flyash is used in the innovative wall construction of this passive solar house. Designed to show community and industry that sustainable development and commercial marketability can be successfully combined, this house presents an attractive and familiar appearance whilst reducing embodied and operational energy use. Indoor thermal comfort is achieved without supplementary heating or cooling.



DESCRIPTION

Brief

Triple bottom line requirements of social, economic and environmental sustainability were set by the client (QLD Department of Housing) and the house had to be fully accessible for the widest possible range of users with varying abilities whilst providing a safe, secure and cost-efficient environment. Within the habitable area of 180m² one of the four bedrooms had to be usable as a home office.

Site

The site is on the corner of a main road, Campbell Street, running northwest-southeast and a minor street (see plan). Access was allowed only from the minor street and this determined the position of the garage.

The corner of the house presents the glazed doors of the dining room and projecting patio roof towards the road junction. The inherent difficulties of the site were accepted as part of the strategy of demonstrating the flexibility of a sustainable design approach. [See: 2.2 Choosing a Site; 4.3 Orientation]



During the hottest months the prevailing wind is easterly and in January there are north-easterly winds for about 30 per cent of the time. This suggested an 'L'-shaped plan to funnel the breezes through the house for natural cross-ventilation, primarily through the verandah, family room, dining room and patio but also through all other rooms.

Climatic design strategy

The mean temperature of the coldest month of July is 16°C and almost every day the daytime temperature reaches 22°C so winter comfort conditions are relatively easy to achieve. Summer overheating is controlled by reducing solar gain, maximising natural ventilation and using thermal mass to even out temperature extremes. Because the daily range of temperatures is quite high (mean maximum to mean minimum is around 10-14°C) thermal mass is beneficial. The concrete slab-on-ground floor serves this purpose assisted by the medium-mass masonry walls. [See: 4.2 Design for Climate]



Entrance, facing N/W, well shaded.

At Rockhampton's latitude of 23.5° the roof is the element most exposed to solar radiation. An off-white 'Colorbond' surface has been chosen to minimise solar heat input. This lightweight roof is heavily insulated with a layer of foil-faced glass fibre batts under the roof skin (face downwards) giving R1.5 and another layer of R2.5 on top of the plasterboard ceiling giving an overall resistance over R4.5.

Ceiling fans are installed in all rooms as well as over the verandah. Safety is assisted by having 2.7m room heights that also assist cross-ventilation.

The attic space is ventilated through the two gambrel ends at the front patio and slotted sheeting to the eaves soffit.

Walls

The external load-bearing masonry walls of hollow blocks (400 x 200 x 200mm) contribute to the sustainability of the house being made by Ultimate Masonry from waste flyash from a nearby power station with the addition of some cement. The wall is externally rendered with an off-white finish to reduce solar heat input and internally lined with foil-backed plasterboard on battens. The overall R-value of the wall is 0.88.

Almost half of the block cavities are reinforced and core-filled at corners, window and door-jambs with a bond-beam along the top. Overall average thermal properties have been calculated as providing an R-value of 0.85m²kW and a time-lag of 5.3 hours.

A side-benefit of the lightweight blocks is in handling, which is much easier than for heavy conventional concrete blocks.
[See: 5.5 Construction Systems]

Solar control

All roof and wall surfaces are an off-white colour with a low solar absorbance. All eaves are 900mm wide to exclude high-angle sun. Projecting roofs over the verandah, entry porch and corner patio provide full shading to the glazed doors. Vegetation and other obstructions provide shading from early morning and late afternoon sun. Bedrooms 1 and 2 have been strategically placed to utilise the shading effect of the existing large Poinciana tree. Because the windows of the living room may be exposed to the sun after 3:30 p.m. at mid-summer, some solar control 3-star 'OptLight' low-e glass is being used for comparative testing of its effect.
[See: 4.6 Passive Cooling; 4.10 Glazing]

Water

Dual flush (3/6 litre) toilet cisterns and flow control taps with a WELS 3 Star rating are used, except for the kitchen sink and laundry tub where WELS 2 star rating is appropriate. The washbasin in the 'powder room' is fitted with an automatic, infrared controlled tap. The washing machine and the dishwasher are WELS 3 Star rated.

The 'Hydrotap' unit installed in the kitchen provides instant boiling or chilled water and is claimed to result in significant water savings.



The 5kL rainwater tank.

Roof rainwater collection is into two tanks of 2 and 5 kilolitres respectively, and is used for garden watering. There are plans to introduce a dual plumbing system to allow use of rainwater and greywater for other purposes. [See: 7.3 Rainwater]



The 2kL rainwater tank at the S/E corner.

Energy

Two photovoltaic arrays of twelve BP/Solarex 984Wp polycrystalline silicon modules are installed on the roof facing northeast. These are grid-connected through a Sunrise inverter with two-way metering. A Clipsal 'C-bus' energy management system is integrated with the power supply. [See: 6.7 Photovoltaic Systems]



Two arrays of PV cells and the solar H/W unit.

As part of the project three water heating systems are being compared. The system originally installed was a Quantum heat pump unit and then this was replaced by a Solahart solar panel system with an integral hot water cylinder. After one year of operation this was replaced by a Bosch instantaneous gas heater.

Passive controls

Site conditions dictated a sub-optimal solar orientation but associated problems are resolved by making good use of the prevailing breezes. On summer afternoons the east-facing verandah provides a good, well covered outdoor living space useable even during rain.

The 'thermal flywheel' effect of building mass is well utilised. The tiled concrete slab-on-ground is thermally well coupled to room air (only the bedrooms have carpet). The masonry walls provide useful thermal capacity. [See: 4.9 Thermal Mass]

One of the best features of the house is the roof insulation with its overall R-value more than double the BCA requirement of the time 2.2m²K/W.

Insulation of the masonry wall is not quite as good but the average R-value of 0.85 is almost twice as good as current practice (brick-veneer walls provide an R-value of 0.46). It is well shaded with a time-lag of 5.3 hours and its performance is quite good. [See: 4.7 Insulation]

Cross-ventilation is excellent through the central part of the house across the family living/dining room. Provisions for capturing the breezes from the dominantly northeast and easterly directions are excellent although different window patterns and openings might have helped and the fanlight openings with drop-in hopper type sashes are obstructed by the eaves and direct the air flow up to the ceiling. Metal louvres down to floor level (in bedrooms 3 and 4) provide some additional openings.



View from verandah through the house to the patio.

Embodied energy

The embodied energy content of materials used is low and their sustainability rating is high. Wall blocks incorporate a waste material and the roof framing is made of plantation timber. Windows and door frames are made of aluminium, which is a high energy material but long lasting and fully recyclable. [See: 5.2 Embodied Energy]



Roof framing: plantation softwood. Note the skylight shaft to the family room.

Maintenance requirements are minimised; materials selection has been based on LCA (life-cycle cost analysis). Only materials with nil or very low VOC (volatile organic compounds) content were selected. The bedrooms are carpeted with wool. All other rooms have ceramic tile floors which are not only easy to maintain, but also thermally advantageous. All paints used internally are water-based.

Lighting and daylighting

The fenestration (windows and window fittings) is adequate for all rooms, except the quite deep family living/dining room where a large roof light ('SkyDome') has been installed with a rectangular shaft through the attic space and a large ceiling diffuser panel.

Two small domed skylights are installed over the corridor. One of these, as well as the main skylight, is fitted with laser-cut angularly selective acrylic panels to admit low angle sunbeams, but reflect high sun to reduce solar heat gain during the hottest part of summer days.

The house mostly uses fluorescent, or compact fluorescent lamps. [See: 6.3 Lighting; 4.11 Skylights]



Accessibility

All of the elements of the house had to be useable for people with a range of abilities including people temporarily or permanently on crutches or with walking sticks, parents with prams, older and younger people who cannot lift their feet high when they walk. It also had to be able to be cheaply and easily modified to accommodate people's changing needs.

There are no steps or thresholds and doorways and corridors are of appropriate width. Bathrooms and the kitchen provide full access, complying with Australian standards. All handles, taps and electrical switches have been selected and located for easy use by people with varying abilities.

The kitchen roll-out bench is the lowest of three benches set at different heights to accommodate a wider range of users and is an excellent example of 'universal design'. [See: 3.2 The Adaptable House]

EVALUATION

People in the tropics and sub-tropics prefer an open-air life style most of the year, with open doors and windows and no sharp boundaries between indoors and outdoors. The house facilitates this very well, obviating the need for mechanical air conditioning.

The mean temperature of the hottest month, January, is 26.9°C and the comfort range with still air is 23.4 to 28.4°C. With air movement of 1.5m per second this upper limit would extend to 33.4°C. The highest recorded indoor temperature is only slightly above this limit at 35°C. In bedroom 1 on Dec.1, 2002, whilst the outside temperature varied between 24 and 39°C the inside remained between 29 and 34°C.

Annual operational energy use has been measured at 9748 kWh, of which 2813 kWh was contributed by the PV system, thus the net use of 6935kWh is 28 per cent less than that of the average Queensland household. This is a comparative saving of 2,900kg of CO_2 emissions. The recently installed solar hot water system is expected to give a further reduction of 400kg CO_2.

Although they face northeast and not due north and the inverter is undersized the photovoltaic arrays contribute about 29 per cent of the total electricity use.

Water consumption was measured at 1150L of water per day average compared with average Queensland use of 1455L. Even with rainwater collection over half of this was due to the sprinkler system and with improved management this could be substantially reduced.

Interior spaces are well lit and a light, airy atmosphere is created. Good indoor air quality is achieved by a combination of excellent ventilation and only using materials with low VOC content.

Residents were initially worried that the tiled floors may be slippery, but the non-slip tiles proved to be satisfactory.

Adaptability is well demonstrated. It can be a major headache and cost to remove a section of fixed cupboards and find matching floor tiles to create a section of bench to sit under. In this house it is already done, at minimal cost and effort.

A two year case study was carried out based on in-depth interviewing of occupants that found the residents had no difficulty in adapting to life in a house that it was socially sustainable, ie. designed to minimise energy consumption but also to maximise living comfort. Initially there was some worry about leaving the doors and windows open overnight but a trust in the security screens soon developed and the benefit of night ventilation was realised. An initial perception of lack of privacy has disappeared as the vegetation has grown.

An exceptionally high rate of satisfaction with the building and its equipment was reported with the residents saying that they would use many of the design features in their next house.



Patio at the dining room (W) with through-view to the verandah (E). Note the ventilation louvres above, to the attic space.

PROJECT DETAILS	
Designer:	QLD Department of Public Works and QLD Department of Housing
Builder:	Q Build, Department of Public Works
Engineer:	Project Services, Department of Public Works

ADDITIONAL READING

Szokolay, S.V. (1987), *Thermal Design of Buildings* RAIA Education Division, Red Hill.

Further information and a virtual tour of the house are available at the web-sites:

www.build.qld.gov.au/research

www.housing.qld.gov.au/researchhouse

Principal author:
Assoc Prof Steven Szokolay

Photos courtesy of:
Assoc Prof Steven Szokolay and QLD Dept of Public Works

The Gap QLD

NEW HOME

ZONE 2: Warm humid summer, mild winter



Topics covered
Orientation
Design for climate
Passive heating
Passive cooling
Insulation
Thermal mass
Glazing
Shading
Reduced water demand
Water harvesting
Water re-use
Material selection
Renewable energy
Solar hot water
Electric lighting

AccuRate (thermal comfort)	7.7 (regulatory)

BLAKELY RESIDENCE

Conventional techniques and materials were used in the construction of this Brisbane house. It constitutes a low cost solution to the requirement for an environmentally friendly house that uses minimal heating and cooling equipment and is both pleasant to inhabit and normal in appearance.

THE BRIEF

The requirement was for a family home with four bedrooms and an open kitchen/living/dining space with a large deck.

The family have an interest in, and knowledge of, passive thermal design principles. They wanted a thermally modelled house that made good use of natural daylight. They also wished to take advantage of the available views across a valley to hills that lay to the north-east and east of the site.

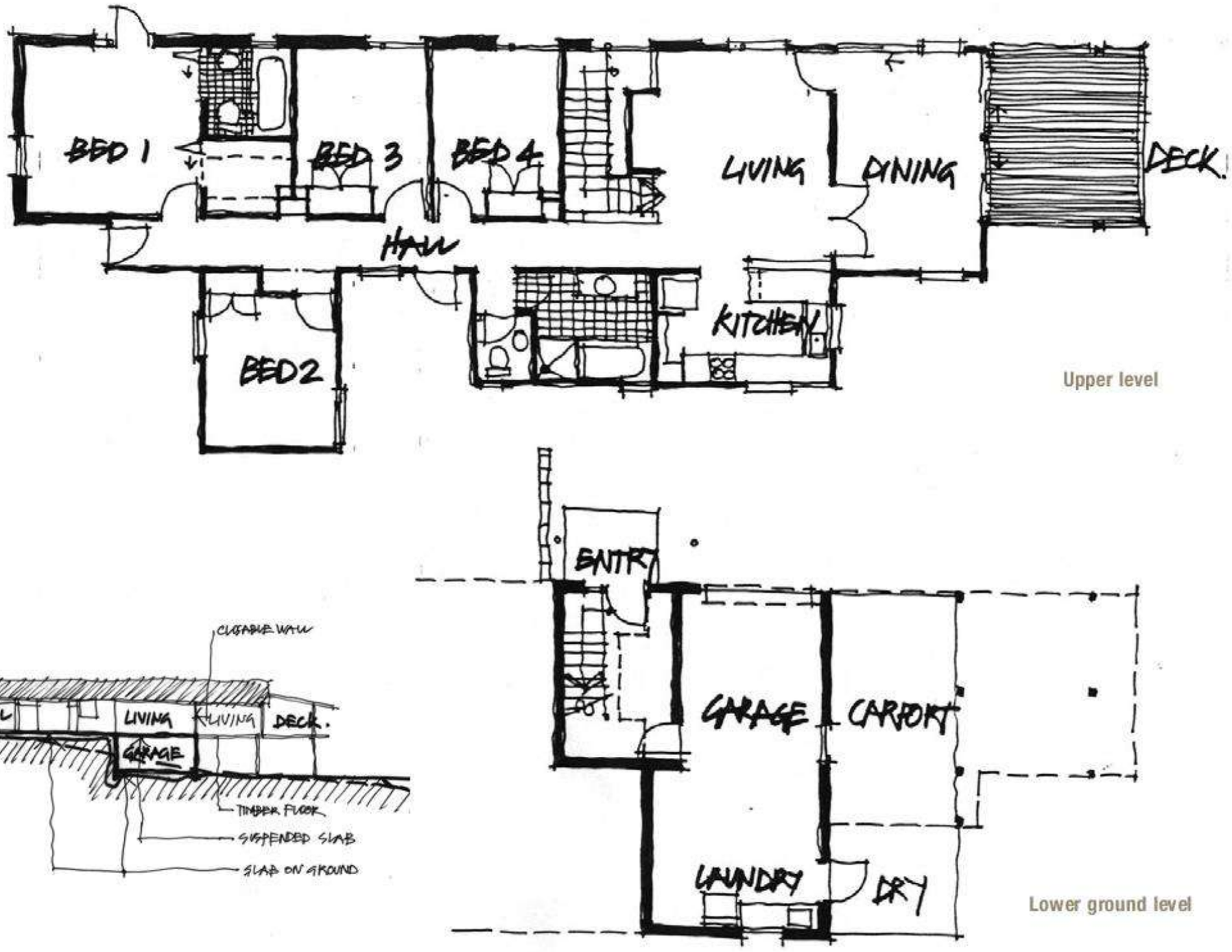
There was one key conflict in the design requirement. The clients wanted an open (floor to ceiling glass) light, timber feel to the house. However, they also wanted a heavy weight approach to controlling thermal comfort.

The plan of the house reflects the living habits of the family. It is essentially a long pavilion containing a row of rooms off one side of a hallway axis. The bathroom and kitchen are lean-to pavilions off the other side of the hall.

Being environmentally aware people, the owners wanted to explore a range of environmental design issues (such as choice of construction materials and stormwater/water use) which would not result in an unconventional home.

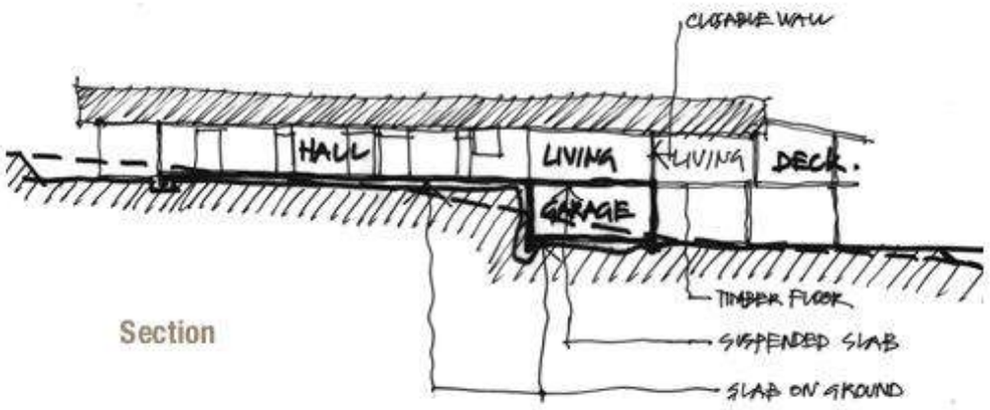
In the end, the design of the house was an exercise in implementing sustainable practices and technologies within the cost and familiarity constraints of a fairly normal home in the suburbs, site and climate.





Upper level

Lower ground level



Section

SITE AND CLIMATE

The site is located at The Gap, a north-western suburb of Brisbane. The area is characterised by a valley running west to east with a microclimate slightly different to the typical Brisbane climate. Brisbane is hot and usually humid in summer and cool, sometimes cold and dry, in winter. For at least 5 months of the year the climate is very pleasant.

The site is above a secondary valley that runs southeast allowing access to cooling breezes. Hills to the north and east restrict the usual cooling afternoon breezes from the north-east.

The site falls fairly steeply (4m in 30m) from west to east. It is located behind and above a house dug into its site at the street. Access is via a long narrow drive. This means that stormwater (run-off and seepage) was an important issue. The site had been completely cleared of trees and the density of the estate meant little overshadowing. [See: 4.2 Design for Climate; 2.2 Choosing a Site]

DESIGN CONTROLS

While the site has no special development controls, it was covered, like the surrounding estates, by a brick veneer covenant. This is greatly at odds with the basic concepts of more sustainable design. Interestingly, this is seen as a way of controlling quality. The issue was dealt with by partly cladding the house in lightly rendered block veneer although some minor legal sparring did occur.

BROAD DESIGN RESPONSES

In the design, special materials, construction details and technologies were kept to a minimum.

Energy efficiency measures included orientation of the house (long side to the north), controlling solar access, the use of thermal mass and good insulation.

Issues of stormwater control and water use efficiency were resolved comparatively simply using an agricultural system.

While the house is designed in detail for the specific site, context and people, the principles behind it (practices and technologies) are applicable for any house design.



SPECIFIC DESIGN SOLUTIONS

Orientation

The site and its context allowed a simple orientation solution: a rectangle with long sides to the north and south.

Orientation to the north is preferred because for a good part of the day, especially during summer, the sun is at a reasonably constant height above the horizon. This means that solar access can be easily controlled with simple fixed shading devices such as eaves and window hoods.

The western end of the house is tucked into the side of the slope to the west, providing good protection from the low hot western sun.

The east end of the house rises out of the ground, giving a lot of access to east and north-east sun. This will need more control in summer although bedrooms are protected by the verandah and living areas.

This orientation not only suits the sun but also suits the direction of prevailing breezes/ winds in Brisbane. [See: 4.3 Orientation]



Ventilation

For passive thermal performance to work, ventilation needs to be tightly controlled. In summer there must be enough ventilation to cool the structure (especially at night) and to provide fresh air and air movement. However, there must not be too much, or excessive warm outside air may be brought inside.

The rooms of the house drain to a corridor that has doors at both ends and in the middle. The windows in the bedrooms are relatively small to minimise conductive heat loss and gain. Awning windows can be opened to allow good air flow through the hall when needed.

A roof ventilator (closable) is located near the refrigerator in the kitchen. This helps vent excess heat from the kitchen area in summer. The hall opens to the living areas which can be opened up, allowing breezes to be funnelled down the hall past the rooms.

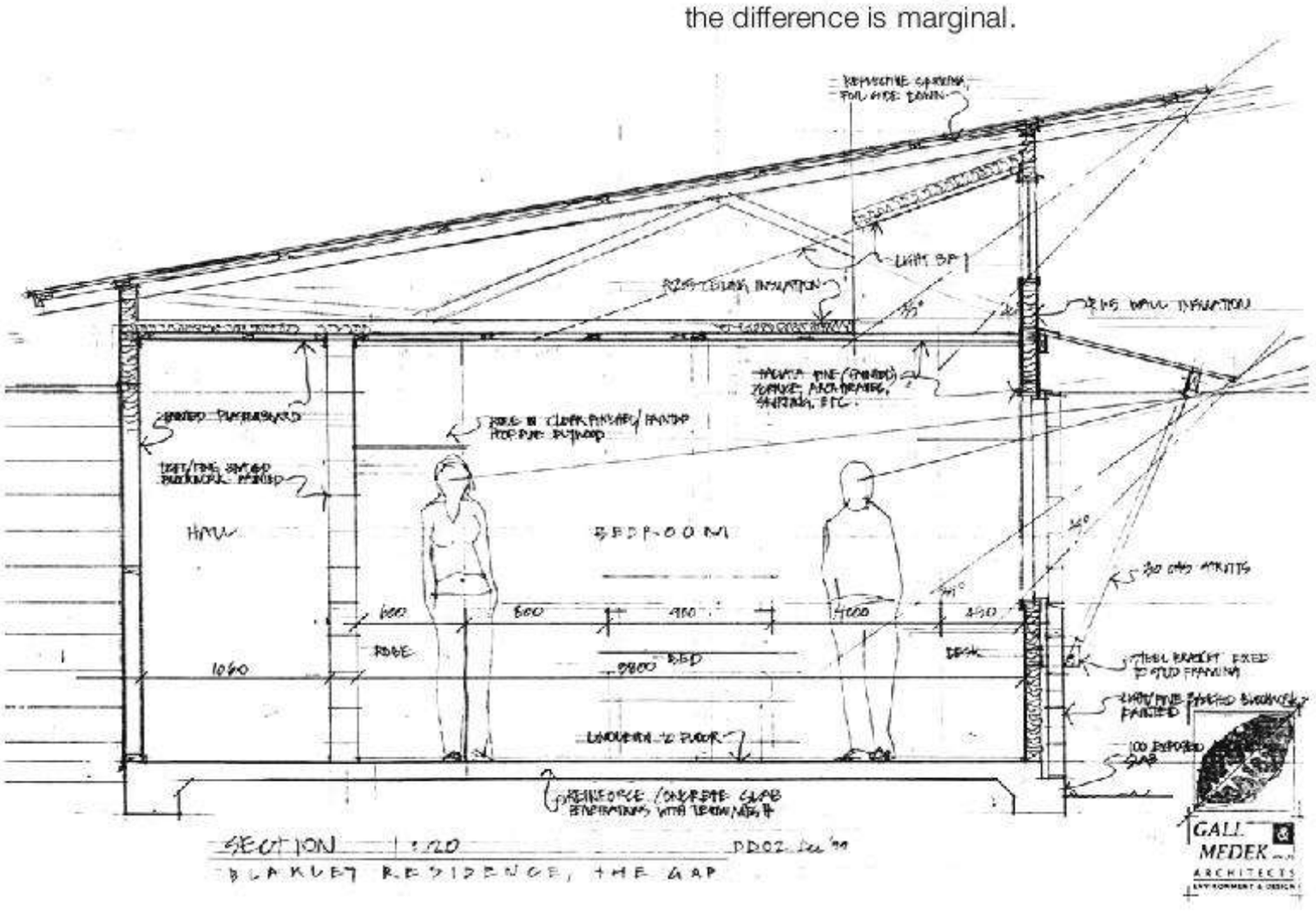
The thermal mass part of the house can be separated from the tropical/lightweight part of the house by sets of sealed doors, to separate the air masses. [See: 4.6 Passive Cooling]

Thermal mass and insulation

To resolve the conflict in the client's brief (mentioned earlier) the house was designed with two zones. There is a thermal mass section, incorporating bedrooms, bathrooms, living/dining areas, the kitchen and downstairs area, the entry and garage/laundry. There is also a tropical room extension to the living/ dining/kitchen area that can be closed off from the rest of the house.

The heavy end of the house is naturally connected to the ground using an uninsulated concrete slab. As the ground drops away, the upper level, entry/living/kitchen becomes a suspended slab (uninsulated) over an enclosed garage on a slab on the ground. The heat/cool storage of the house is carried out by these slabs and the ground under them.

The use of linoleum on the floors is critical. Carpets insulate the slab and so waste its thermal potential. Linoleum avoids the insulating effect of carpet and the perceptual coldness of tiling or stone. A dark colour would have been best thermally but the clients wanted a lighter, brighter feel to the house and the difference is marginal.



The external walls of the house are insulated, using a polyester/cotton material to R1.5. The comparatively small window/door glazed area ensures maximum possible wall insulation. This is cheaper than double glazing.

The ceiling is insulated to R2.5 with a similar material. Insulation is placed above the bottom chords of the roof trusses. A reflective foil sarking is placed over the roof battens, under the tin.

External glazed doors have wide timber frames, reducing the glazing area but retaining the perception of large openings.

A few insulation values were tested with thermal modelling to find a cost effective optimum. [See: 4.7 Insulation; 4.9 Thermal Mass]



Shading

Shading is provided to the north (less to the south) by the overhanging eaves and a long window hood that runs the length of the northern face of the house. Both windows and walls are shaded to control heat gain from the sun.

The width of the shading is determined by the angle of the sun and the orientation of the house. The shading devices also allow windows to be kept open when it rains.

As mentioned before, western shading is provided by the site but there is only one opening at the western end of the house – a deeply recessed door.

The eastern end of the house is very open and extensively glazed. The verandah roof provides a lot of shading from high morning summer sun. The tropical living area also protects the rest of the house with the separating doors providing additional shading.

Landscaping using locally endemic rainforest species is proposed to further moderate and fine-tune solar access. [See: 4.4 Shading]

Lighting

Day light in all rooms was an important requirement, especially for bedrooms.

Small, high clerestory glazed panels are used. Raised parts of the ceiling, framed between the roof trusses, bring the light into the backs of the rooms (the walk in robe is lit over the ensuite). These high windows, mounted in walls, allow mostly reflected ambient light into the rooms, which is softer and carries less heat. The solution is simple, cheap and very effective.

Due to the clerestory panels, artificial light use is reduced. Lights that will be run for long periods of time are fluorescent. [See: 6.3 Lighting]



Structure and envelope

In keeping with the basic principles of the house, its plan, form and structure are simple, cost effective and material efficient.

The house has a simple geometrical and modular layout. The ceiling is mostly flat. The roof and walls are prefabricated radiata pine, treated where exposed.

Due to careful design and planning of internal spaces, the overall size of the house was kept to a minimum.

Secondary structures, such as boxed-in eaves or bulkheads were avoided. These take time to construct, require more materials and tend to dull down the expression of the house.

The architects attempted to construct a building that says something about the issues to which it responds and the resources that have gone into making it.

Health and materials

A few simple choices of materials were made that make the house a healthier place in which to live.

Linoleum was used on the floors and kitchen bench tops. It is inexpensive and does not give off volatile organic compounds (VOCs). It smells nice and has antibacterial and antifungal properties. It is very durable, non-combustible and comparatively, easily repaired. It is made of natural materials and so has less environmental impact in its manufacture.

Raw, high moisture resistant, hoop pine plywood was used for cabinet joinery in conjunction with solid hoop pine. This again reduces VOCs and the pine is from sustainably managed plantations in Queensland. The pine is finished in almost natural tung oil.

Water

The broad aim was for the surface and ground hydrology of the site to not be greatly affected by the placing of the house on the site. The roof form allows most rainwater falling on the roof to be collected.

It was proposed to take this water to a soakage system with a stationary overflow to the kerb and channel system. This proved too difficult for a number of reasons.

It is possible to retain some roofwater in small tanks for drinking and watering the garden. These have not yet been installed.

Because the site is steep and above other properties, there was some risk and concern about the proposed site drainage system. [See: 7.5 Stormwater]

Water heating

An electric back-up solar hot water heater was installed. The cost of this was off-set by the state government's assistance.

EVALUATION

The house was given a 7.7 star rating for a passive thermal (heating and cooling) performance using the AccuRate software.

The house has been temperature tested by the previous occupants. Three thermometers were placed on the verandah, in the tropical room and in the thermal mass area. During a cold snap in winter, the interior of the house stayed above 17°C when it was about 1°C outside on the verandah. In a recent heat wave, while the outside of the house was above 40°C, the interior of the house stayed below 30°C. No controlled management of the house was carried out.

In the end it is important to note that it is not the house that uses energy, but the people who live in it. The house provides an opportunity to easily reduce energy bills without suffering to do so.

After a period of occupation, the house appears to be a fairly successful attempt to implement some key sustainable development practices and technologies in a cost effective way.

Regardless of the theory behind the design and construction, the house is very pleasant to live in. Everyone who visits it (not just designers or clients) expresses this.

TEMPERATURE °C RANGE AND AVERAGE FOR MAY 7AM READINGS		
ROOM	RANGE	AVERAGE
Deck	4-15 (11)	11
Sunroom	6-16 (10)	12
Bedroom 1	16-22 (6)	20
Bedroom 2	16-24 (8)	21

TEMPERATURE °C RANGE AND AVERAGE FOR MAY 7PM READINGS		
ROOM	RANGE	AVERAGE
Deck	12-18 (6)	15
Sunroom	14-20 (6)	17
Bedroom 1	20-24 (4)	22
Bedroom 2	23-26 (3)	23

PROJECT DETAILS	
Architect:	Jim Gall, Gall and Medek Architects
Builder:	Mark Kennedy
Engineer:	John Batterham
Thermal modelling	Holga Willrath, Solar Logic

Principal author:
Jim Gall

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.

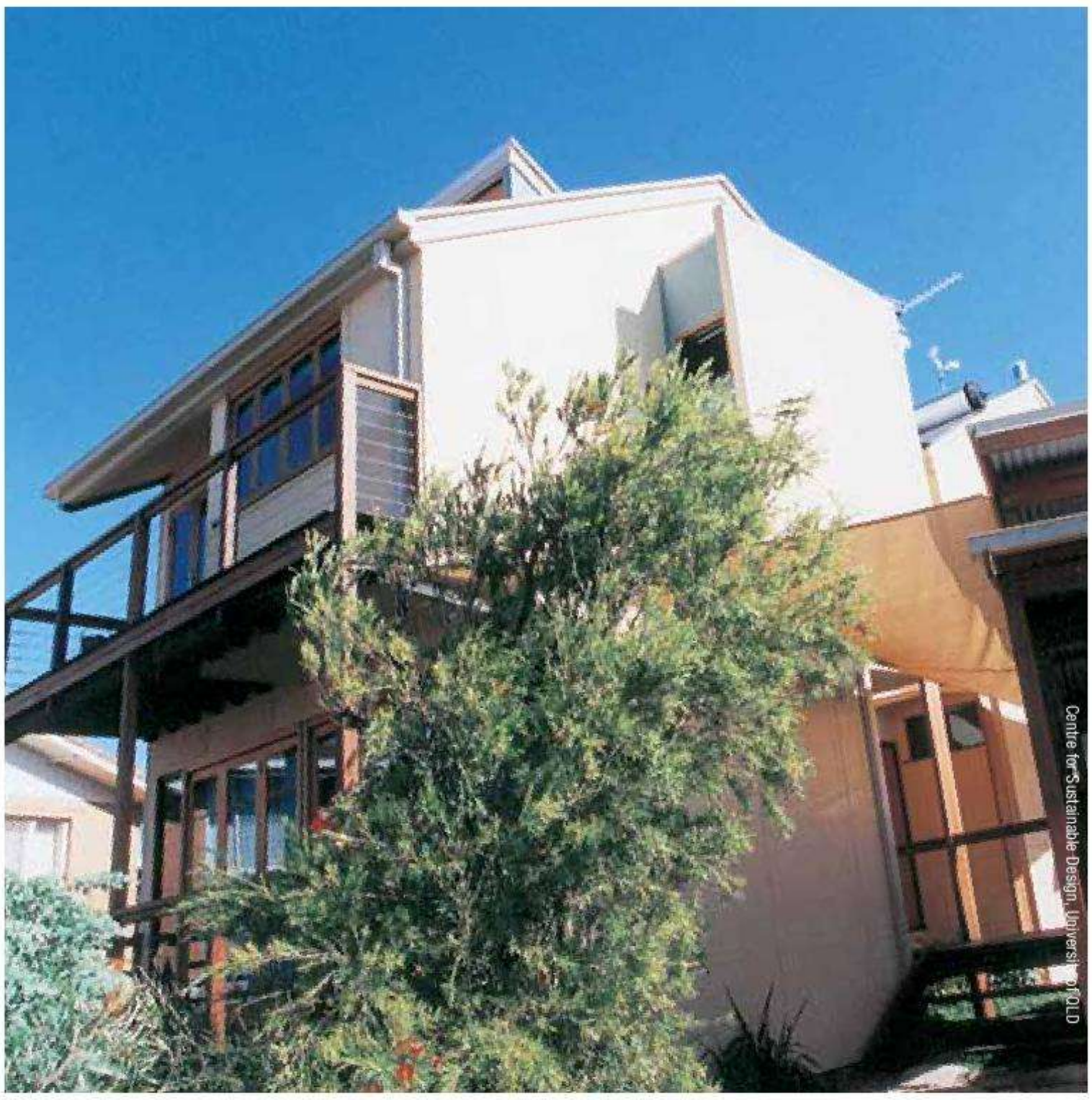
The Healthy Home Project brought together Queensland's leading Universities and Government Departments in a joint venture with industry partners. For more information see www.healthyhome.com.au

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.

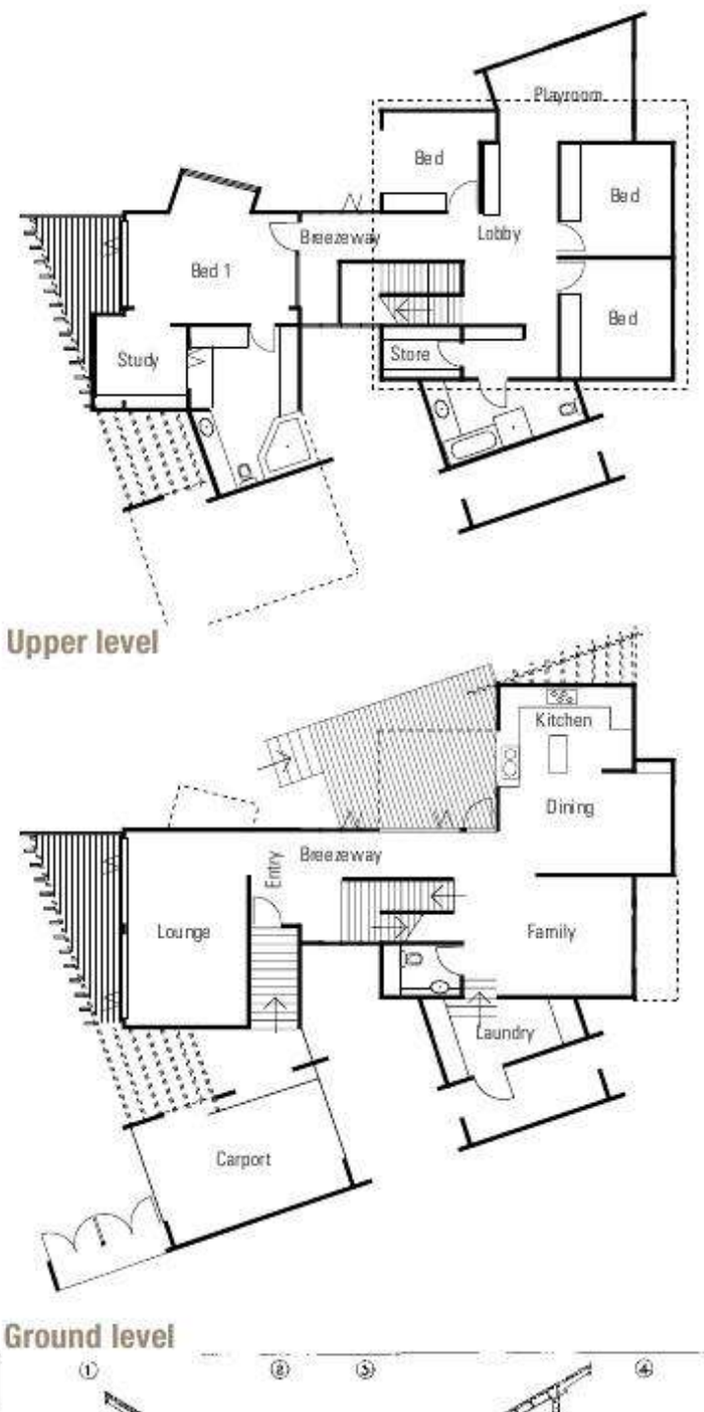
The house is designed to significantly reduce impacts on resources, both in construction and during the life cycle of the building.



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.



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

East Perth WA

NEW HOME

ZONE 5: Warm temperate



Topics covered
Passive design
Reducing embodied energy
Greenhouse gas reductions
Sustainable materials use
Renewable energy generation

AccuRate (thermal comfort)	4.9 (regulatory)

This passive solar home was designed to operate with minimal energy consumption. It demonstrates how high mass construction, good orientation and the very reliable 'Freemantle Doctor' are a simple recipe for increasing comfort and reducing operating costs in a Perth home. Low embodied energy materials were used throughout the house and its compact design reduces demand for resources.

A solar hot water service and photovoltaic array significantly reduce greenhouse gas emissions.

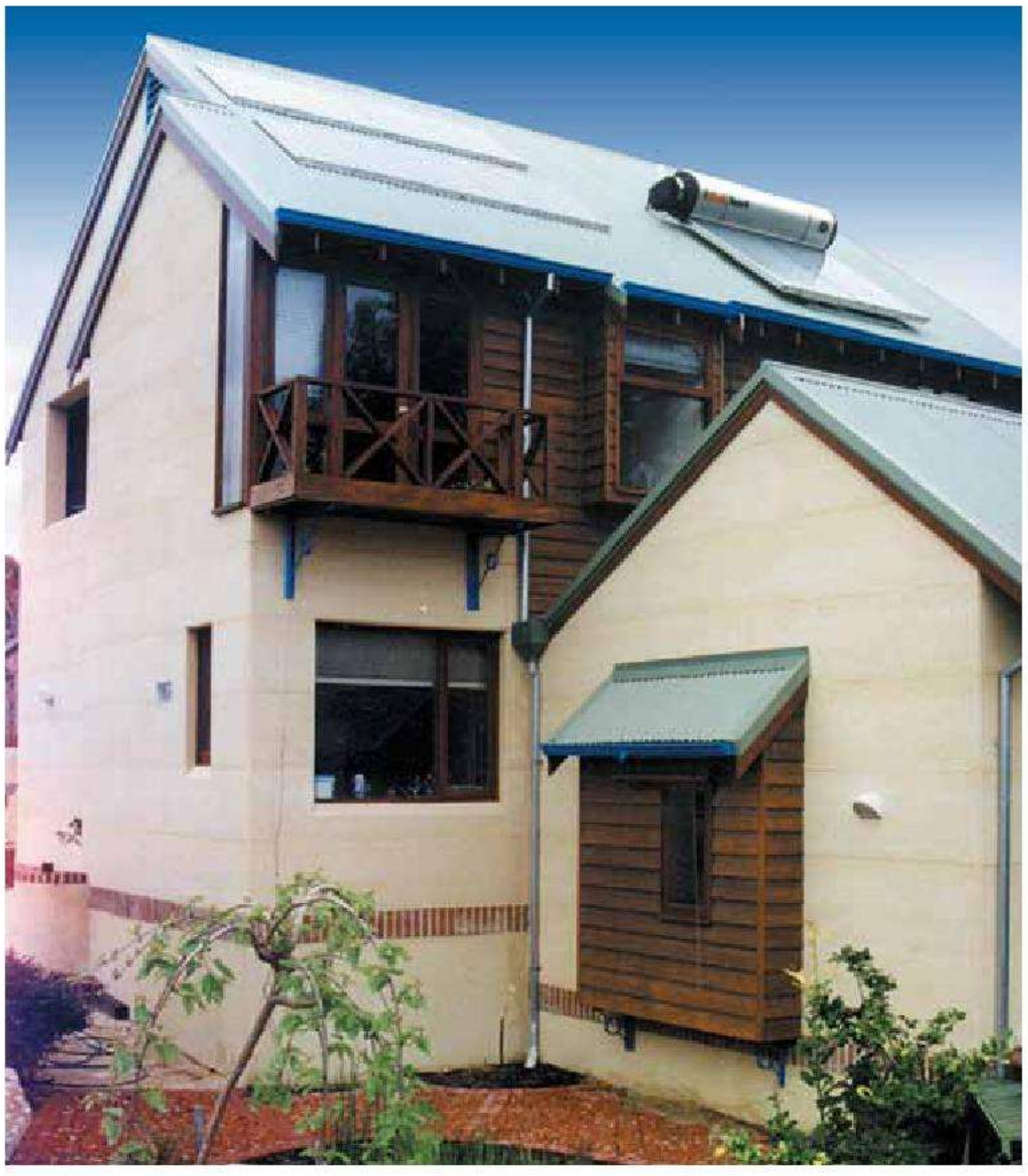
WHY BUILD THE HOUSE?

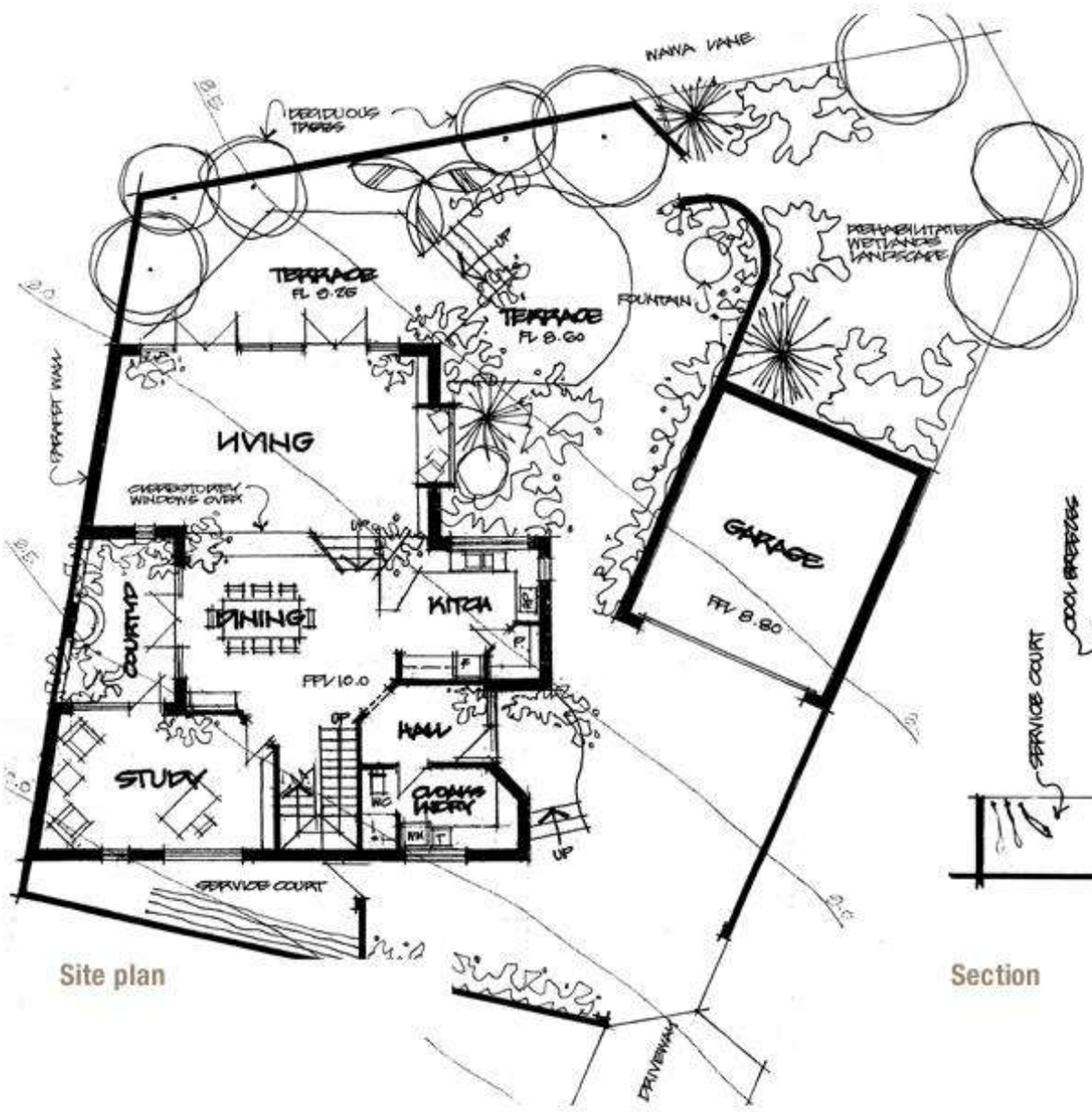
The home is a part two storey with a lower single storey pavilion, built on a slope in the inner city suburb of East Perth, Western Australia. The house is located on a 600 square metre block. The subject land was once a wetland that drained into the Swan River at Banks Reserve. The main reason for selecting this site was its inner city location and its uninterrupted solar access.

The owners wanted to create a living demonstration of passive solar design. One owner Bill Parker (editor – Solar Energy Progress journal) previously found himself in the somewhat ironic situation of talking and writing about passive solar design yet living in a house that was elegant but thermally inefficient. Building a new house was an opportunity to put his words into action.

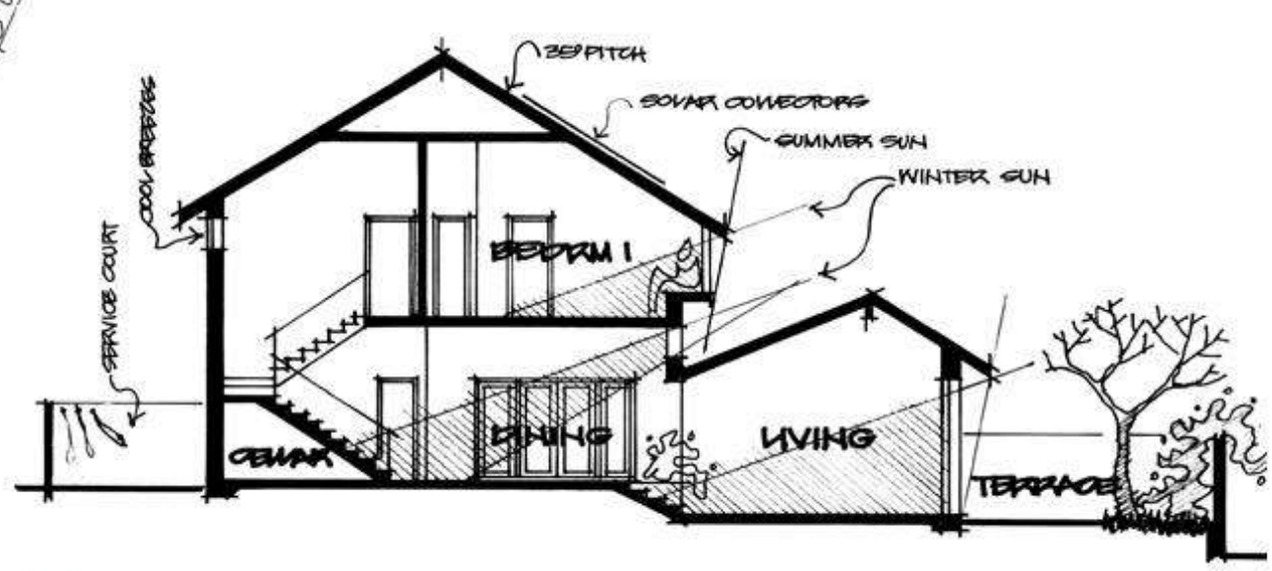
SITE SELECTION

Finding a north-facing block in the general inner city area proved to be a challenge. The decision to buy this particular block in East Perth was made in consultation with the architect who thought there was potential for solar gain from the natural slope of the block.





Site plan



Section

THE BRIEF

The owners briefed the architect and specified a simple concept that would include two bedrooms, an office and a large open living area with an integrated kitchen.

The living area and the kitchen were faced north in accordance with principles of passive solar design. The kitchen's northerly aspect also meant that cooking odours could be exhausted naturally using the prevalent south-westerly breeze.

Winter heating is achieved without the use of purchased energy. Energy requirements for summer cooling have also been minimised. Air-conditioning was not considered necessary.

DESIGN SOLUTIONS

The slope of about 1.5m from south to north has been exploited, allowing further solar gain through windows situated above the lower pavilion. This provides natural lighting during the day and only task-oriented lighting is required in the office.

In winter, the sun can penetrate to the rear of the lower floor to provide adequate warmth. The mass of the upper floor provides a good sink for bedroom and bathroom warmth. This means that the entire house is always warm in winter.

In summer, the house is comfortable, but the design does depend on the strong afternoon sea breeze. The house uses four bladed ceiling fans for comfort in summer in combination with the strategic placement of windows and openings for breeze entrapment.

The 'Fremantle Doctor' can be captured and warmth flushed out of the building from the south-west to north-east. If the breeze is mild or fails (which is rare), the upper floor can become hot but by using the low noise fans, sleeping is still comfortable with flyscreened full length opening doors and open windows.

With predictions of higher climatic temperatures in future due to climate change, it is possible that additional adjustable external blinds might be required, especially in March when daytime temperatures are still high and the sun is lower in the sky. [See: 4.3 Orientation; 4.6 Passive Cooling]

ENERGY CONSUMPTION

Electricity is supplied by a 1kW array of solar panels. The house is connected through an inverter and excess electricity is sold to the grid. A refrigerator rated at 2kWh/day uses the most electricity. All other uses are minimised by either using efficient appliances or by using gas (cooking and boosting solar hot water). Some of the lighting is low wattage compact fluorescent (CFL). [See: 6.0 Energy Use]

EMBODIED ENERGY

Although the owners were well aware of what could be achieved in terms of low energy construction, they had not paid much attention to embodied energy data and its environmental impact.

As the designs were finalised and the task of specifying was closed off, considerable information about material selection was revealed by investigation or by chance. For example, the roof is supported by engineered trusses made from local plantation timber, which is claimed to consume 25 per cent less timber and is cheaper to install.





All buildings consume energy in construction. The major wall construction is locally derived rammed limestone. The embodied energy is much lower than for fired clay bricks.

Some clay bricks have been used in retaining walls and for some internal walls, for space and load bearing reasons.

External paving uses bricks fired by landfill gas.

[See: 5.2 Embodied Energy]

EVALUATION

There are two major benefits of living in the home. Firstly, the house maintains an even, natural temperature throughout in winter. Secondly, the home consumes very little energy and consequently has comparatively low running costs.

The owners firmly believe that the benefits of winter warmth from the sun can be enjoyed for the life of the house at no cost.

High thermal mass construction is ideal in Perth's climate. The 'Freemantle Doctor' is the most reliable cooling breeze in Australia. However, on the rare days the breeze does not arrive, un-insulated, high thermal mass construction (particularly first floor) can cause overheating.

The rammed earth walls have only R 0.5 insulation value which is quite low. Thermal lag can slow the transfer of heat through the walls but solar exposed walls will still overheat in no breeze periods and they are a source of heat loss during a Perth winter.

At design stage, the house was modelled on NatHERS. It was also modelled on the 'Tecto' program (Garry Baverstock, WA).

On the first pass NatHERS rating, the building easily reached 161MJ/m^2, a 4 star rating in the inner Perth climate. The Tecto rating gave a very similar result to NatHERS. This was:

> Heating required 66MJ/m^2/annum.

> Cooling required 95MJ/m^2/annum.

The design data entered had to be adapted to accommodate NatHERS limitations (two storey convective ventilation). Modelling of the cooling energy was complicated by the large retractable blind that shades a west facing courtyard. This was not recognised in the assessment and the window was counted as unshaded glazing. (The blind is removed in mid May and re-erected in early November).

Alterations were made to the glazing as a result of recommendations from the rating. In this example, HERS software was used to good effect as a design tool.

PROJECT DETAILS	
Architect:	Zdenka Underwood Architect
Owner Builder:	Bill Parker
Engineer:	Garry Maroochi, Maroochi Engineering Group

Principal author:
Bill Parker

Contributing author:
Chris Reardon

Subiaco WA

NEW HOME

ZONE 5: Warm temperate



Topics covered
Reduce energy use
Passive design
Indoor air quality
Waste minimisation and recycling
Water use / treatment
Reducing transport impacts
Greenhouse gas reduction
Reducing embodied energy
Sustainable materials used

AccuRate (thermal comfort)	6.1 (full rating)

This two-storey house is located in the western suburbs of Perth, Western Australia. It was instigated and developed by the local city council as a collaborative project to demonstrate an energy efficient, passive solar home design.

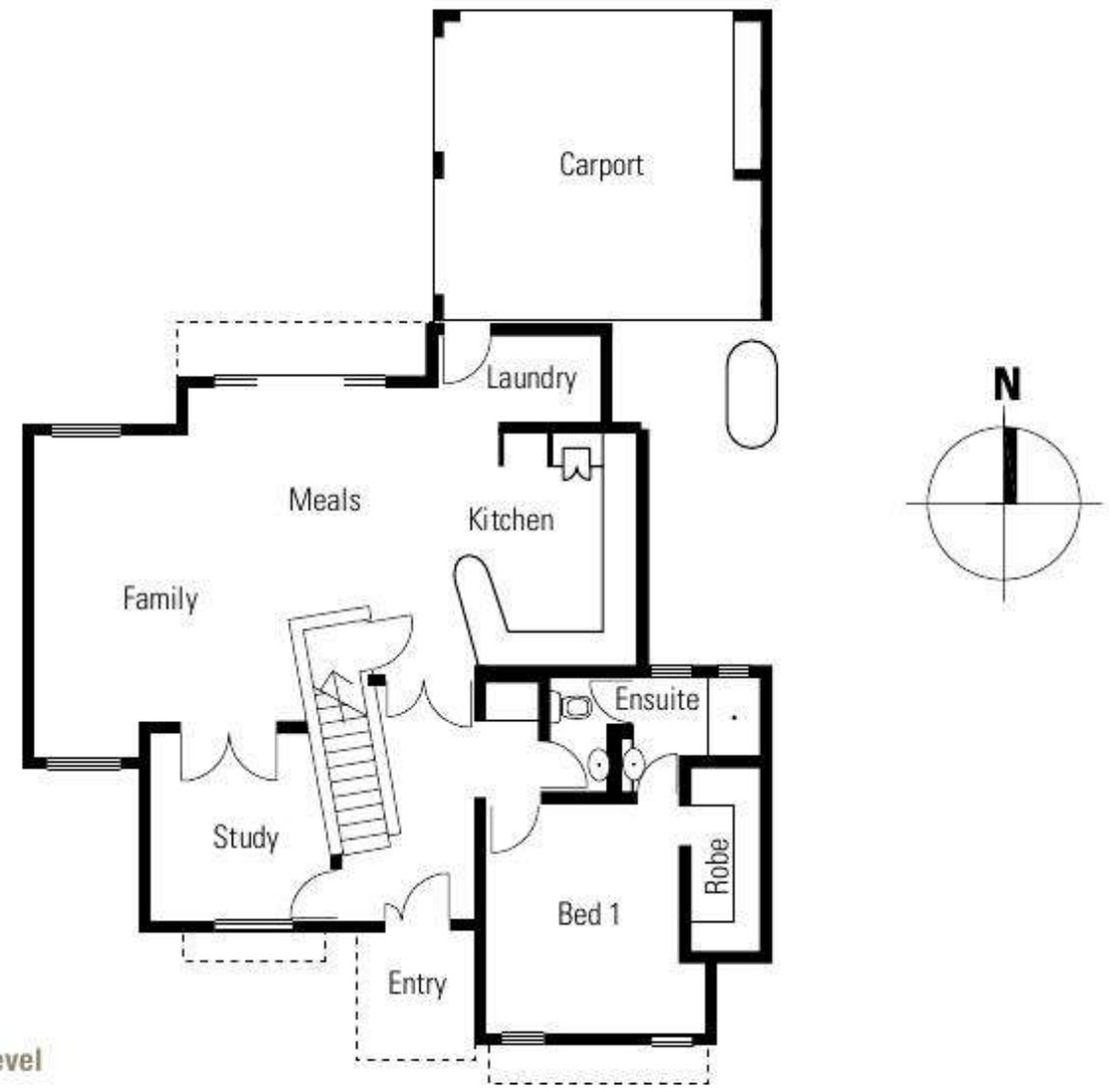
The Subiaco Sustainable Demonstration Home was open for public inspection until May 2006 after which it has sold. It represents a unique collaboration of the wider community with local government departments, universities and businesses sponsoring the project.

Issues addressed through the design and construction process included cost efficiency, passive solar principles, energy efficiency, low allergenic design, water efficiency, and adaptability for universal access. In responding to these requirements, various products and techniques have been used to demonstrate alternative solutions to traditional approaches.

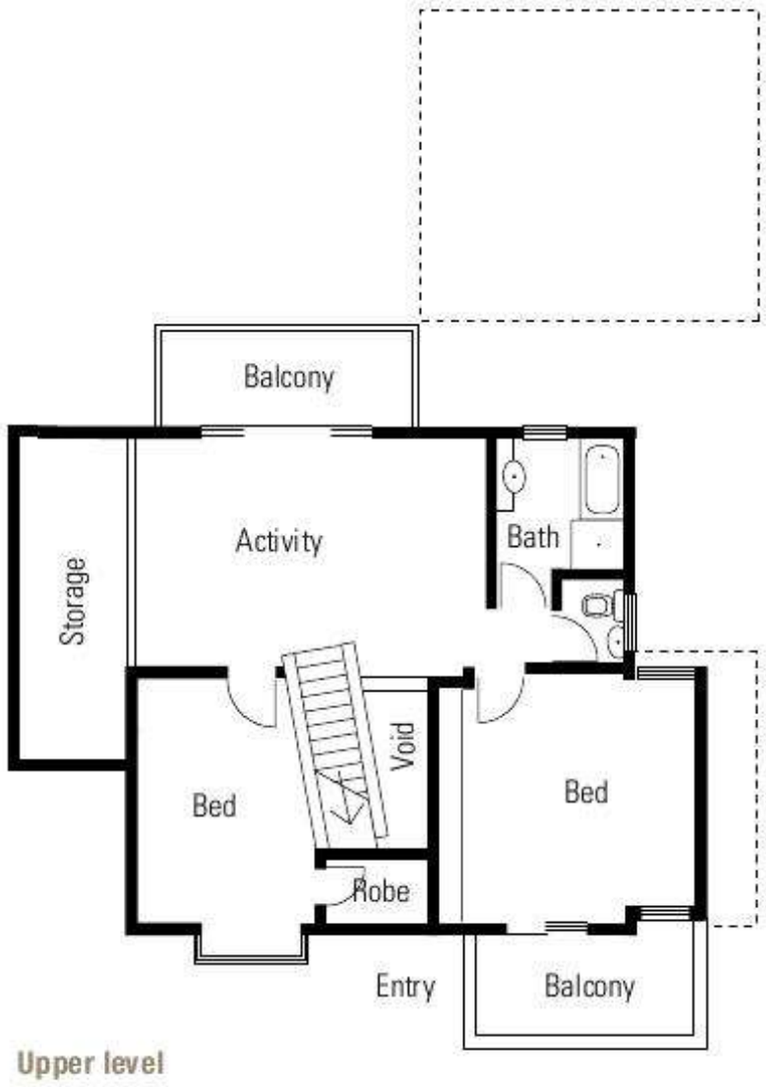
The house is designed to suit diverse occupants and lifestyles. The bedrooms are of a similar size to that of a master room, allowing the possibility of two couples living in the house, each with their own bathroom. Living areas are located for solar access while bedrooms face south. The kitchen, laundry and bathrooms are located in one area of the house to minimise plumbing for cost efficiency, and there is little wastage of space.

Wall construction is a combination of double brick cavity and reverse brick veneer on concrete slabs. The suspended slab for the upper floor was built using a process called 'quickfloor',





Ground level



Upper level

giving an 80-90mm concrete slab on a permanent steel frame. Harditex cladding is used to the exterior of the reverse brick veneer on a timber frame, and the roof is Colorbond metal on a timber frame.

The timber frame provides less opportunity for heat transfer and condensation compared to a metal frame. The timber is plantation pine, a renewable resource. It is untreated in the roof.

The site

The site is a corner suburban lot with the southern and western boundaries facing onto the main streets, with a side street to the northern boundary. The long axis of the site is north-south which is not ideal for a passive solar design. A requirement by the local redevelopment authority was that access to the carport had to be from the northern side street, reducing the potential for northern exposure to the house.

The neighbouring block to the north was undeveloped at the design stage of this house, and design guidelines had originally stipulated that there could only be a two-storey building on that lot to protect solar access. There is now a three-storey building under construction there that may impact on desirable solar exposure.
[See: 2.2 Choosing a Site; 4.3 Orientation]

A brick and tile factory existed on the block originally. Its material has been recycled and re-used in this house as 'rammed rubble'. The crushing process occurred off site, because environmental considerations such as the impact of noise to neighbouring properties prohibited it from taking place close to site. Although not a financially viable solution for this project due to its small scale, it demonstrates an option that, on larger projects, may be environmentally and financially viable. [See: 5.3 Waste Minimisation]

The climate

The climate in Perth is temperate. Winter mean temperatures range from a minimum of 8.6°C to a maximum of 17.9°C. Summer mean temperatures range from 18.6°C to 33.2°C. There is a cool afternoon south-westerly breeze and a cooling easterly breeze from across the land that occurs late evening/early morning; both are common. [See: 4.2 Design for Climate]

Heating

Horizontal and vertical mass has been utilised for heat absorption, with consideration to location, volume and thickness. Solar access is primarily to the upper floor in winter. The reduced suspended slab thickness heats up and transfers heat through conduction to its surroundings quickly. More heat is stored in this area by a central core of thermal mass surrounding the stairwell. The mass absorbs heat in winter and then transfers it back into the room as the air cools.

An initial study indicates that the minimum internal air temperature achieved is 16°C in winter with summer internal air temperatures generally falling within the comfort range of 18-28°C and a maximum peaking in excess of 32°C. [See: 4.6 Passive Solar Heating]



Cooling

Night ventilation is required to cool the house in summer. The house is designed and oriented to trap and redirect air flow. The southern facade 'steps out' in three locations and channels the afternoon, south-westerly breeze through the house. A vent near the entrance door catches this cool breeze which passes by the thermal mass, absorbing its heat, before exiting via

high-light windows on the northern side of the upper floor. Manual opening of windows at night and closing them during the day is essential to achieve the best comfort levels.

Ceiling fans in the bedrooms and living areas contribute to the movement of air over the body and provide a cooling effect to a person in summer.

Cross ventilation has been addressed in the wet areas to reduce the opportunity for mould or mildew and assist in achieving a low allergenic home. Where possible the wet areas have an opening facing north for direct sunlight and assistance in airflow.

No auxiliary heating or cooling has been installed in the house.[See: 4.6 Passive Cooling]



Shading

There are various methods of shading.

The building form provides shade with the upstairs, northern balcony shading the windows below.

A light-weight horizontal structure of fixed metal louvres protects both the glazing and the mass of the northern balcony to minimise heat build up and transfer into the home. These louvres are angled to Perth's sun to allow maximum sunlight through in winter and to omit it in summer. Vertical solar louvres provide shading to the gable window.

A deciduous tree has been planted in the northern courtyard to provide shade in summer. This is environmentally friendly, low maintenance and more cost efficient than building a permanent structure.

Other methods of providing shade include removable fabric sails and stainless steel cables for creepers to grow along. [See: 4.4 Shading]

Insulation

Reverse brick veneer has been used on a portion of the western walls, with R1.5 batts between timber stud frames. 'Aircell' insulation has been fixed to the internal leaf of all western and eastern walls to address the issue of ambient heat build-up.

Blinds or lined 'block-out' drapes insulate the windows with the gap between drapes and glass maintaining the surface air resistance of still air. Instead of using pelmets, drapes have been located in the recess of the window, to reduce the potential of dust collection for this low allergenic home whilst minimising heat transfer.

The roof is insulated with R2.5 batts at the ceiling level and 'Aircell' insulation is placed between the rafters and battens to the Colorbond metal roof sheeting to maintain a 50mm air gap between insulation and roof sheeting. To allow for continuous airflow in the ceiling space, a raised central portion supported on punched purlins with fly mesh vents the roof. [See: 4.7 Insulation]

Solar hot water system

To fit the limited roof surface the solar hot water system has been split into two panels – one to the western side of the roof and the other to the east. One panel faces north with the water storage tank located mid-way in the ceiling space, the other faces west. The roof and ceiling insulation assist the tank in achieving a higher performance by a reduced heat loss. The tank is located over the wet areas to minimise pipe runs.



Windows

Windows have been designed and located to promote cross ventilation. They take advantage of the afternoon south-westerly sea breeze. Airflow obstruction is minimised as the air is channelled through a depth of only two rooms.

Standard, single glazed, aluminium framed windows are used to maintain cost efficiency. Glazing to the north is maximised (50-60 per cent) to allow sun penetration to the thermal mass of the house.

The west facade was required to have a window by the local redevelopment authority as it addressed a main street. It is the only window facing west and the only window to be double glazed. A frame of vertical solar louvres has been fixed to the outside of the wall to assist in shading the glass. The performance is not optimal, which reinforces the need for appropriate window design for western facades. [See: 4.10 Glazing]



Colours and textures

Colour is important in realising the full potential of a passive solar design. Light, smooth finishes will reflect some of the sun's radiation, while dark, rough surfaces will mostly absorb it. Light colours such as cream-beige face brick, off-white render, and grey steel roof sheeting have been used externally, while dark, rough floor tiles have been laid in the northern living spaces to absorb winter sun.

Energy use and efficiency

The passive solar design reduces the need for auxiliary heating and cooling.

Photovoltaic cells (1.5kW) are grid-connected to allow import (purchase) and export (sale) of electricity.

Lighting is energy efficient with the use of compact florescent and 12V pan lights. There are low energy ceiling fans and a conduction cook-top. [See: 6.3 Lighting; 6.8 Photovoltaics]

Water use and recycling

The house is connected to the main city water supply. It recycles greywater from the bathrooms and laundry through an underground 'Galvan' system for pumped distribution to the gardens. Because greywater from the kitchen contains a high percentage of organic waste it is not recycled. All black water is directly plumbed to the main sewer. [See: 7.4 Wastewater Re-use]

Low flow plumbing fixtures have been installed to reduce water use.

A compact 4,000L rainwater tank collects water off the roof but is not plumbed into the house. A carbon filter makes the water drinkable but the water is primarily used on the gardens. The tank shows rainwater can be captured without detracting from the home's aesthetics. [See: 7.3 Rainwater]

Low allergen and universal access

Special consideration was given to the kitchen design. It is structured on a 'flow system' with the fridge and pantry being at the threshold of the kitchen to be most accessible. The sink and preparation area follow so that the 'danger' zone of the stove top and oven is only occupied by those using them.

Cabinetry is of standard materials for cost efficiency. Cut ends and penetrations have been sealed to try and prevent any leakage of toxins from the MDF board.

Design features for universal access include door clearances of 850mm, light switches at 1,000mm and power points at 600mm above the floor level, lever style door handles and a straight staircase to allow for a future stair lift if necessary. [See: 3.2 The Adaptable House]

Materials used

Costs were kept down and construction was builder-friendly. Standard building materials and construction methods were predominately used to make the process accessible to the mainstream market. These included concrete for the slabs, bricks for the walls, Colorbond metal sheeting for the roof and plantation pine for the framing. Predominantly, double brick construction is used, with a portion of reverse brick veneer on the western walls. [See: 5.5 Construction Systems]



Landscaping

The vegetation and planting is water-wise and low allergen. There is a raised garden bed that is wheelchair accessible.

Leaves from the deciduous tree are used for mulch on the garden beds. There is a compost bin and worm farm in the courtyard. [See: 2.4 Sustainable Landscapes]

EVALUATION

The design might have benefited from greater northern exposure at the lower level by creating a solar access court or by redesigning the carport as a solar-type verandah. The upper floor may be over glazed on the north adding to the upper level heat loads. An evaluation of in-use performance of the house would be valuable. However, computer models indicate that overall a very good performance can be expected.

PROJECT DETAILS	
Designer:	Solar Dwellings in conjunction with Dr Elizabeth Karol
Builder:	Glenway Homes
Engineer:	Structerre

ADDITIONAL READING

Baverstock, G.F. and Paolino, S. (1986), *Low Energy Buildings in Australia: a design manual for architects and builders*. Volume 1 – Residential Buildings. Graphic Systems.

Sustainable Energy Development Office website for Western Australia: www.sedo.energy.wa.gov.au

House website: www.subiacosustainable.com.au

Principal author:
Garry Baverstock

Perth Hills WA

NEW HOME

ZONE 5: Warm temperate



Topics covered

Reduce energy use
Passive design
Indoor air quality
Waste minimisation and recycling
Water use / treatment
Reducing transport impacts
Greenhouse gas reduction
Reducing embodied energy
Sustainable materials used

AccuRate (thermal comfort)	5.3 (regulatory)

This is a simple and inexpensive home which uses passive solar design techniques, and is situated in bushland near Perth, Western Australia. The design aims for the house were to minimise electricity use, and harness solar and wind energy to regulate the internal climate while staying within a strict budget.

INTRODUCTION

This energy efficient home is located in a secluded bush setting north-east of Perth, Western Australia, in the hills above the Swan Valley.

The owners commissioned the house for use as a retirement retreat. Having a keen environmental awareness and genuine intention to live an environmentally low impact lifestyle, the owners opted for a simple, contemporary concept which maximises passive solar advantages throughout the year. The house is run using very little energy. The two occupants have installed efficient lighting and appliances, and spend a lot of time outdoors, even during winter. The booster switch for the solar hot water heater is easily accessible (in the kitchen), allowing precise control over the power used. Because the house has only two adult occupants, expensive technologies like solar power and gas boosted hot water were considered unnecessary, and would have resulted in a very small reduction in greenhouse gas emissions.

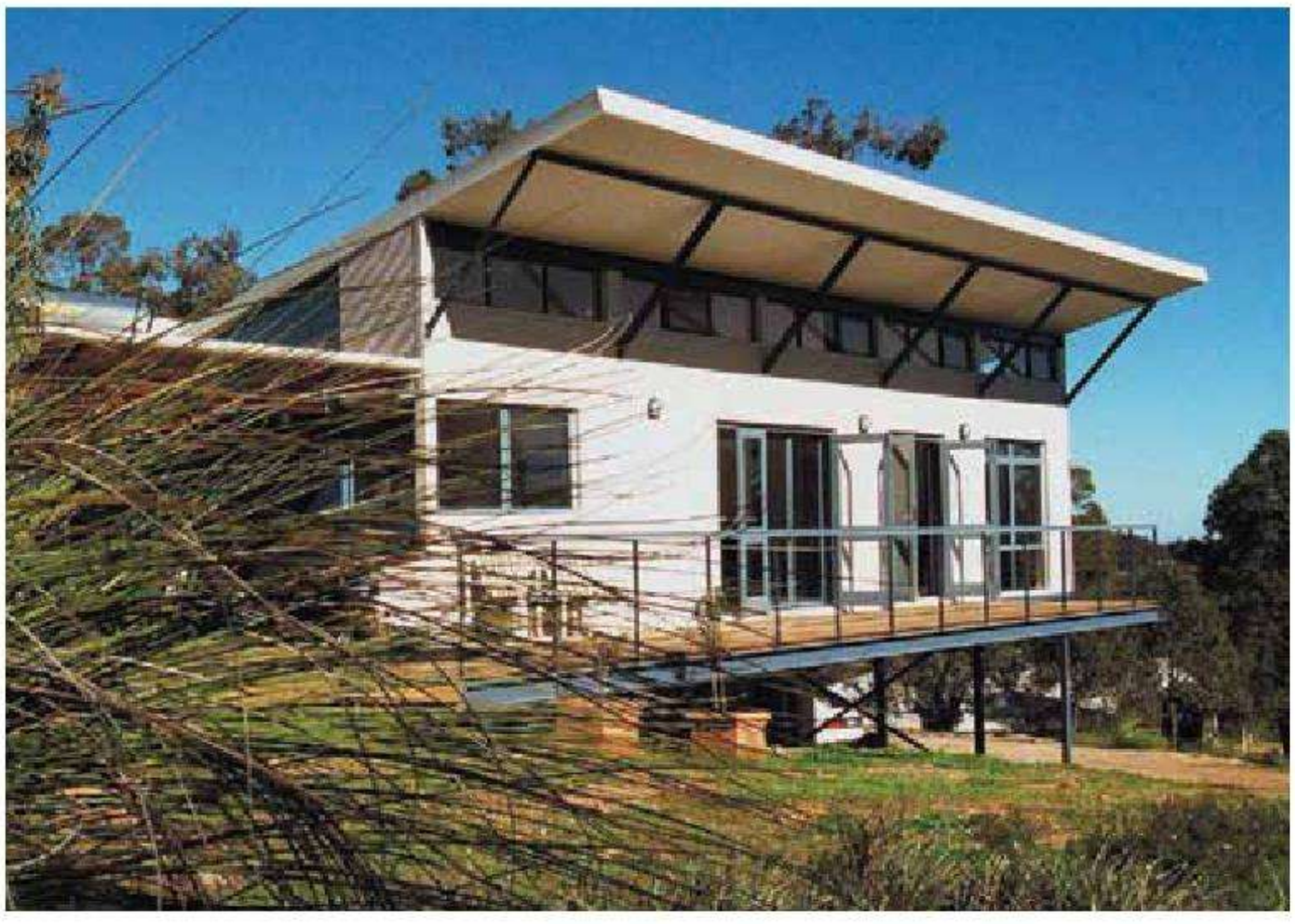
The house is divided into a living section and a sleeping section, arranged in a 'Z' shape oriented north-south (see plan view). This configuration allows for the creation of a 'breeze trap' at the southwest of the house to catch cool afternoon ocean breezes, and a sheltered solar deck at the northwest which catches the morning sun in winter.

Construction is a combination of reverse brick veneer and double brick on a concrete slab. Colourbond steel is used to clad the exterior of the reverse brick veneer section, and for the roof.

The site

The site is steeply sloped, due to its location on the side of an escarpment. It has westerly views across the coastal plains north of Perth, as well as bushland views to the north and northeast.

During preparation of the site, priority was placed on ensuring the absolute minimum of land was cleared. The owner and the architect stood alongside the bulldozer and directed the driver down to the centimetre. The owners wanted to protect as much of the vegetation on the site as possible, so chose a more



expensive partially elevated concrete slab over a full slab on ground to achieve this. This construction also allowed for the house to be on a single level.

At one stage the previous owners of the site had it cleared for farming. Since moving in, the owners have started a program to rehabilitate the bush on the site to its original state. [See: 2.2 Choosing a Site; 2.5 Biodiversity Off-site]

The climate

The climate of Perth is temperate with winter mean max/min temperatures of 17.9°C and 8.6°C, and in summer 33.2°C and 18.6°C. Solar radiation readings are extreme in summer, similar to those experienced in the Gibson Desert. There is relief from the heat most afternoons courtesy of a cool south westerly breeze. Cooling breezes from the east are common at night between 12.00am and 6.00am. [See: 4.2 Design for Climate]

DESIGN

The 'Tecto' method of low energy design was used to design this house based on a methodology developed by Gary Baverstock et al (Baverstock, 1986). This method is a step-by-step technique which allows the architect to integrate his or her clients' requirements with rigorous solar passive principles, and does not affect the architects freedom of expression.

The first stage in applying the method is to look at passive considerations. These are:

> ensure solar access for north facing windows.

> face the majority of windows towards the north.

> consider methods of shade control to windows.

> identify compromises to be made in relation to views, light, ventilation, spatial effects and aesthetics.

> decide on the method of construction and insulation strategy.

> integrate thermal mass into the design using the correct volume of masonry and concrete, to store warmth in winter and maintain a cool temperature in summer.

Once these decisions have been made, auxiliary heating and cooling strategies are worked out, and a decision is made about what sort of solar hot water heater to use. Numerical values are determined for glass area on the north, south, east and west walls, total thermal mass in cubic metres, minimum insulation levels in the roof, floor and walls, and the size of the solar hot water system. Finally, a five-stage designers checklist is followed to execute the design.

Heating

Auxiliary heating is provided in the house. Gas bayonets have been installed so a portable gas heater can be used when required.

During winter passive solar heating keeps the house to a minimum temperature of 18°C.

Cooling

There are three means of non-mechanical cooling incorporated into the design of the house:

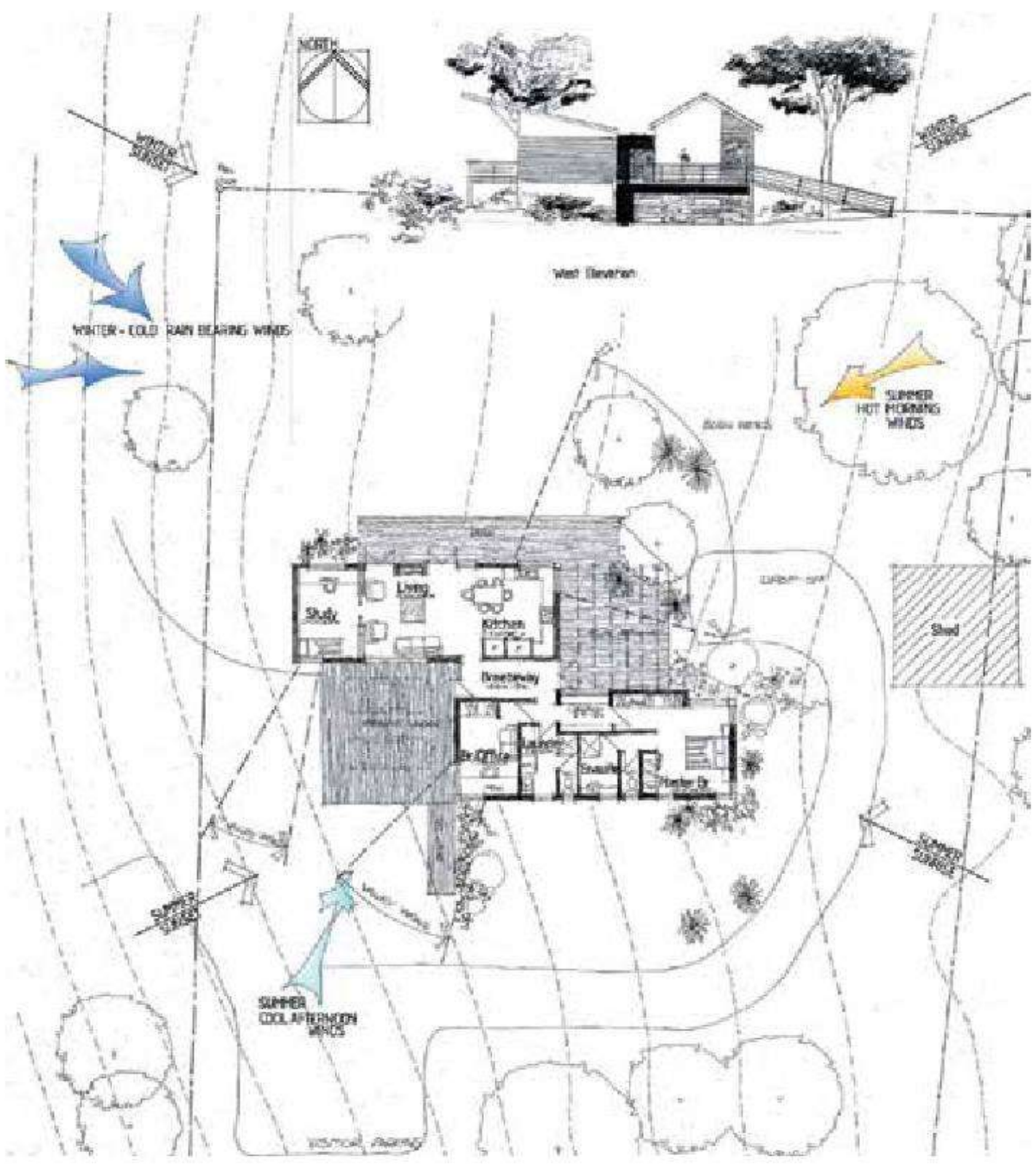
> correct orientation of the building helps form a breeze trap to the south-west (see plan view). A bank of louvre windows picks up the sea breeze to channel it into the house.

> a breeze trap on the north-east funnels cool easterly winds overnight.

> the two breeze traps function together to help suck air through the house. See description below.

The house is designed to ensure that cooling breezes move through the house on even the stillest of hot summer days. On the windward side (the southwest) the windows are small, which creates an area of increased pressure. After the pressure has built up a bit, the wind spills over the top and around the sides of the house and creates an area of decreased pressure on the side of the house away from the wind. This low pressure zone helps to suck the air through the house, increasing the wind speed and improving the cooling effect. This design results in increased air speed inside the house. If the wind speed outside the house is 5m per second, then the wind speed inside the house can be up to 10m per second.

Ventilation is achieved with ceiling fans in the living area and bedrooms. In a larger, less efficient house, the design would have included an exhaust fan mounted in the ceiling in the centre of the house to draw fresh air through the habitable areas. This is a very



efficient way to cool a house which doesn't have sufficient natural airflow, as the fan need only be rated to 200 watts if well designed. However, in this fairly small house, the ceiling fans were all that were needed.

The house naturally achieves 5 air changes per hour (5 ACH) during the night. Because the house does not absorb much heat, this is more than enough to ensure that the occupants remain comfortable even when it is very warm. An average, non-solar passive house requires about 30 ACH to keep cool.

The efficiency of the system is demonstrated by the temperature in the home, which does not exceed 28°C. [See: 4.5 Passive Solar Heating; 4.6 Passive Cooling; 6.2 Heating and Cooling]

Shading

Approximately 50 per cent of the northern facade is glazed. Based upon experience, the architect has found that this ratio is the optimal balance for maintaining a pleasant internal temperature throughout the year.

There is a solar verandah to the north-east which collects the winter morning sun. Timber blades set at a fixed angle shelter the verandah. They provide 100 per cent shade during summer and 80 per cent sunlight during winter.

A large north overhang at a 65° cut–off angle provides solid shade to living area windows. The cut-off angle is the angle between a line drawn from the bottom of the walls to the outer edge of the overhang and the ground. This allows full exposure in winter and gives 100 per cent shade in summer. [See: 4.4 Shading]

Insulation

The roof is insulated with 50mm R2 fibreglass batts at ceiling level, a 50mm air gap and a 'roof blanket' made of SisalationTM (reflective aluminium foil) glued to a 50mm thick fibreglass batt. The roof blanket is installed, contrary to manufacturers instructions, with the SisalationTM facing down. This means that dust does not accumulate on the foil, which renders it useless, and the foil can reflect back heat from the inside of the house. Because the SisalationTM is reflective on both sides, it can still reflect radiation from the roof back out. This roof has an overall rating of R3.

In the reverse brick veneer walls, R 1.5 polyester batts are placed in between the timber studs. SisalationTM covers the framing, and then colourbond steel is attached over the top. This insulation isolates the thermal mass on the inside of the house, allowing it to regulate the internal temperature more effectively.

In the double brick walls, insulation is a 35mm expanded polystyrene sheet plus a 15mm air gap. [See: 4.7 Insulation]

Solar hot water system

An electric boosted solar hot water system was chosen as the occupants were only catering for two people most of the time. This system has a low initial cost compared to a gas boosted system and manageable electricity costs. The extra cost of the gas system was not justified for the small amount of energy that would be required to supplement solar heating for only two people. The booster switch was mounted in the kitchen to enable the booster to be turned on and off easily and help minimise operating costs.

Windows



The windows are placed to take advantage of the sea breeze from the south-west. The house can be divided into 'breeze ways' to channel air through whatever part of the house most needs cooling, including to the north living wing, to the east into the sleeping wing, and straight through onto the solar deck at the northeast of the house.

The window sizes are designed to create a pressure differential across the house, with small windows on the windward side, and large windows on the leeward side. See the 'Cooling' section for a description of how this helps to keep the temperature of the house low in summer. Fifty per cent of the glass area is on the northern wall, and twenty per cent on the eastern wall, with the remainder on the south. Minimal glass is used on the west facing wall.

Single glazed aluminium framed windows were used throughout due to cost constraints. A bank of louvres is located in the southwest corner of the house to allow for ventilation by cooling afternoon breezes during summer.

Sealed highlight windows are installed to allow abundant light to enter and reflect off the ceiling. This results in a soft, even natural light illuminating the interior of the house, which is far less harsh than direct sunlight. The architect always uses fully sealed windows when installing them in inaccessible, high places. Aluminium windows that can be opened leak air at the rate of about 0.5 ACH. If they are installed near the ceiling, in winter they suck out most of the warm air in the house. [See: 4.10 Glazing]

Colour

Colour can play an important role in passive solar design. Light colours (off white) and steel grey finishes have been used on the roof and wall panels. These reflect a lot of the radiation during hot summers.

Landscaping



The gardens are filled with native plants. The owners have embarked on a rehabilitation program for the site, based on research they did on species endemic to the area. The site was cleared by farmers many years before the current owners purchased it, and there had been a natural regrowth since.

The owners have also established an organic permaculture vegetable garden on the site, which is watered using captured rainwater and fed with compost.

No watering is required for the native garden, and red gums planted on the east and west of the house will provide extra shading when they mature. A hakea hedge has been established on the southwest, which will attract birds with its abundant spring flowers. [See: 2.4 Sustainable Landscapes]

Energy use

The architect estimates that, based upon his experience with similar houses he has designed, the house uses about seventy per cent less energy than an average house of equivalent size.

Energy efficient appliances are used, with gas cooking. The owners lifestyle is quite frugal, and they spend a lot of time outdoors throughout the year. The house stays at a comfortable temperature all year round, and to date the owners have not needed to use any means other than the sun and the wind to heat or cool the house. [See: 6.4 Appliances; 6.3 Lighting]

Water use

The house and garden is water efficient but not completely self-sustaining. The house is connected to mains water and a rainwater tank of 20,000L is installed for drinking water.

Because there are no lawns the organic vegetable patch is the main water consumer in the garden. The soil on site has good water retention, which helps keep water use low.

A standard septic tank system is used for wastewater, with a leach drain that allows excess water to be released onto the land. The drain is covered with a minimum of 600mm of soil which allows air to penetrate. The wastewater is rendered safe by naturally occurring processes beneath the soil. There are no waterways nearby so there is no risk of contamination. [See: 7.4 Wastewater Re-use]

Materials use

Conventional and inexpensive materials were used in the construction of the house. These are: plantation pine framing and clay bricks for the walls; concrete for the slab, and colourbond steel to clad the reverse brick veneer walls, and roof. Reverse brick veneer construction over 2/3 of the house provides thermal mass in the interior of the house where it is most useful, while keeping costs low. The remaining 1/3 of the house is double brick. The house is combined construction for aesthetic reasons only. [See: 5.0 Material Use]

EVALUATION

For the cost of the project, the architect believes that the home is the optimum solution. However, with the addition of insulation beneath the floor of the suspended section of the house, efficiency and comfort would have been improved. In addition, a gas boosted hot water system produces less greenhouse gas emissions than the electric one installed. Both of these options would have increased the cost of the house.

PROJECT DETAILS

Architect:	Garry Baverstock Ecotect-architects

ADDITIONAL READING

Baverstock G and Paolino S (1986), *Low Energy Buildings in Australia: a design manual for architects and builders. Volume 1 – Residential buildings*, by Graphic Systems.

Principal author:
Bill Parker

Contributing author:
Chris Reardon

Tanja NSW

NEW HOME

ZONE 6: Mild temperate



Topics covered
Passive design
Passive cooling
Greenhouse gas reductions
Reducing embodied energy
Waste minimisation/ recycling
Sustainable materials use
Indoor air quality
Solar water heating
Renewable energy production
Reducing water use
Rainwater harvesting
Wastewater treatment
Food production

AccuRate (thermal comfort)	3.3 (regulatory)

This fully autonomous home generates its own power, provides for its own heating and cooling, harvests rainwater and recycles wastewater. The use of low embodied energy materials and modular, prefabricated construction reduces the demand for material resources.

DESIGN BRIEF

The owner, a renowned artist and academic, required a house for himself and his extended family and friends, and a studio for his artwork. As he has frequent visits from family and friends, a separate wing was needed to allow them comfort and privacy.

Contact with the natural surroundings was important to the owner. He had lived for many years in a remote rural location and desired a house that would support his simple lifestyle but with a greater degree of comfort than the barn that he had been using for the last 12 years.

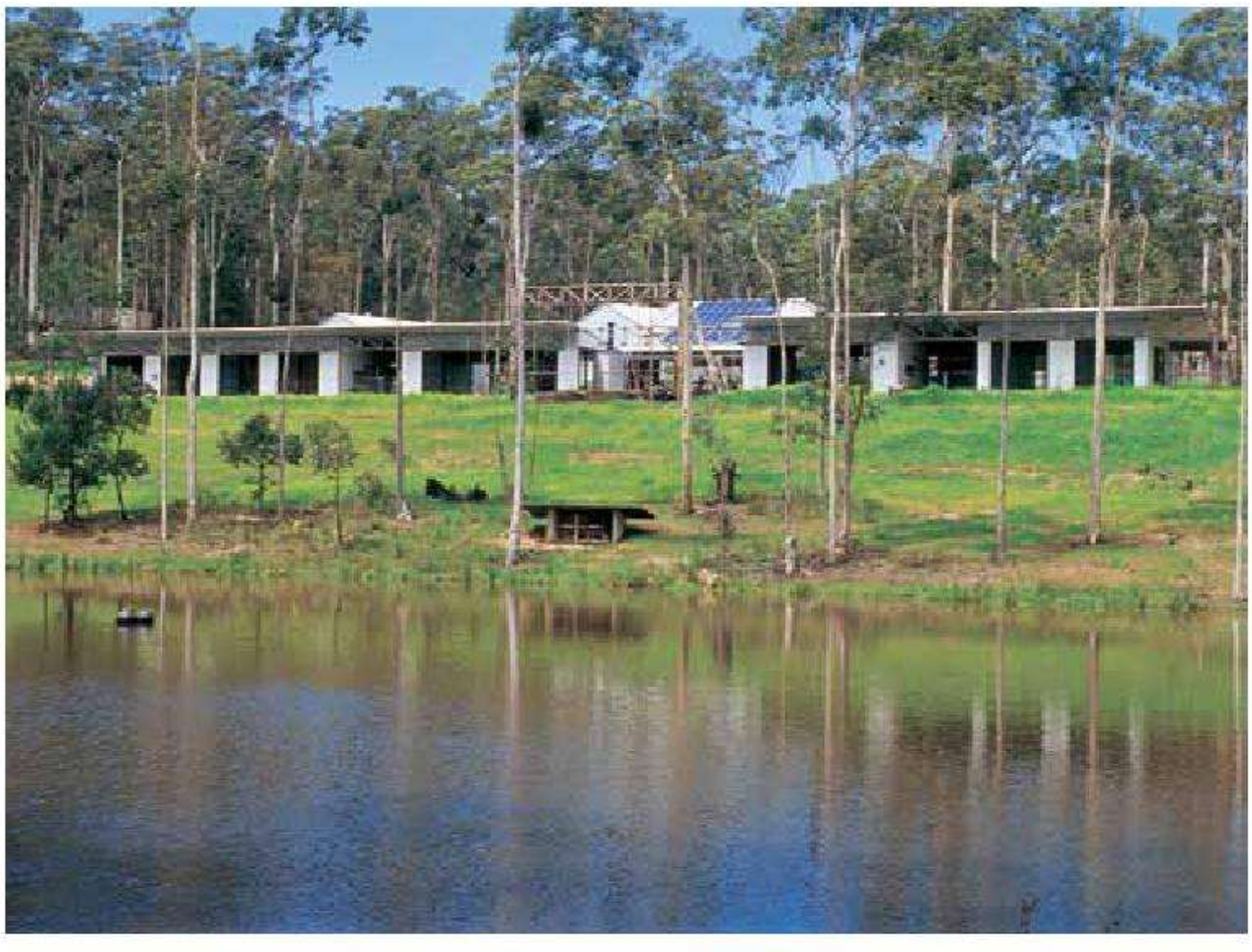
The house was to be fully autonomous, given the remote location – generating its own power, providing its own water and treating its own wastewater. The owner had grown most of his food in the past and wished to continue to do so in an area with abundant wildlife. As he travels extensively the house also had to be secure during his absences.

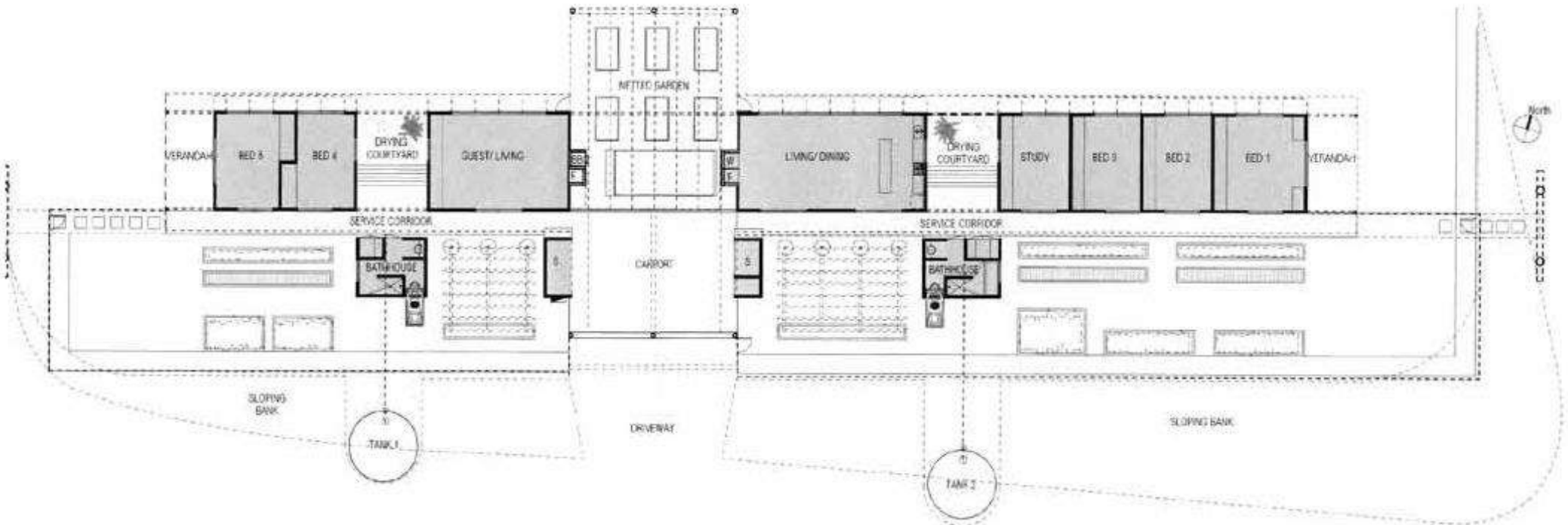
Innovative use of materials and construction techniques was a long standing interest of the owner's. He was keen to use the house as a 'test case' for prefabricated materials, to minimise on site waste and to explore creative passive solar design responses using low cost construction. The owners interest, as a sculptor, in the 'honesty' of materials and construction is reflected in the 'raw' nature of this construction.

LOCATION AND CLIMATE

The house is located in Tanja, NSW, on a bush block adjacent to a National Park. The owner selected a suitable site for the house in a secluded valley and then donated the remaining land back to the National Park, so the house is almost entirely surrounded by National Park. The house site itself is a gentle north-facing slope with a dam created at the bottom and the tree line retained on the crest.

The climate is mild temperate (New South Wales far south coast) with mild summers and cool to cold winters with relatively high rainfall. The concerns of the local Council about the planning of the house were limited, as it cannot be seen from any public area of the park or local roads. [See: 4.2 Design for Climate; 2.2 Choosing a Site]





DESIGN RESPONSE

The design concept for the house is a long, thin string of indoor and outdoor rooms. The kitchen/living/dining area and bedrooms are grouped into separate mini houses with a courtyard between each.







Modular components were used in the design, fabricated offsite to minimise waste and to allow simple, speedy erection of the house. A 1200mm modular grid is used throughout to standardise material sizes based on commonly available sheet materials and windows and doors. Sculptures at either end of the long walkway emphasise this east-west axis whilst internal covered courtyards provide visual axes in the north-south direction opposite the bathrooms. [See: 5.3 Waste Minimisation; 5.5 Construction Systems]

All these rooms face north for maximum passive solar gain. Behind these, on the south side, are three pods containing two bathrooms and a carport storage area. [See: 4.3 Orientation; 4.5 Passive Solar Heating]

The roof of the north-facing string of rooms is tilted to allow maximum sun penetration into the rooms and onto the concrete slab. The roof form of the southern pods is the reverse, with a steeply sloping roof angled to the north providing a base for the solar water heating and PV panels.

The courtyards provide both service facilities (drying area, garbage store, wood store etc.) and also provide external living areas for relaxation and enjoyment. The courtyard opposite the carport store takes the form of a large vegetable garden, netted to protect the produce from wild animals.

A covered veranda space links the long string of rooms and the pods. This recalls the use of verandas for circulation in the early homesteads of Australia, particularly in the Riverina and Southern districts of New South Wales. This was a conscious design choice by the owner who wished to maintain his contact with the daily and hourly weather patterns by continually interacting with the outside, whilst still being protected from winter wind and rain and the harsh summer sun.



The outdoor area to the north of the house is maintained as a gently sloping grass area that allows for maximum solar access and provides bushfire protection. To the south, the house has been dug slightly into the hill providing protected courtyards that received winter sun but are protected by the embankments and planting to the south.

Orientation and glazing

The house is oriented just west of north, aligning with the contours of the land to minimise excavation and maximise solar access in winter. This provides views from every room over the grassed paddock to the dam.

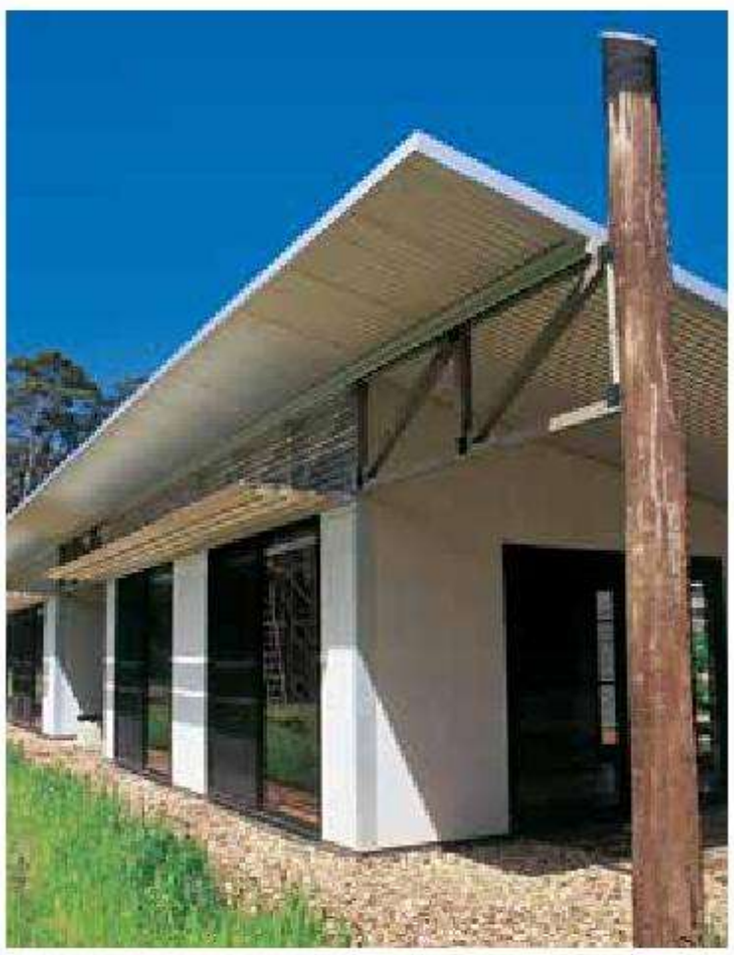
Standard single glazed aluminium-framed sliding doors are used throughout the house. Aluminium was chosen for its durability. Whilst high in embodied energy, aluminium is a low maintenance finish and can be fully recycled at the end of its useful life span. The area's relatively mild winters limit the amount of heat loss via conduction or cold bridging through the aluminium that may be experienced in more extreme climates. It is acknowledged that double glazing with insulating frames would significantly improve the thermal performance of the house, but this was decided against due to the additional initial cost and ongoing maintenance requirement. [See: 4.3 Orientation; 4.10 Glazing]

Structure and envelope materials

The floor throughout the house is a concrete slab.

The walls and roof of the 'string' of north facing living areas are made from prefabricated panel systems.

The wall panels consist of two sheets of fibrous cement bonded to an expanded polystyrene (EPS) foam core. These panels are joined with steel studs that connect a steel bottom plate to a steel top plate, providing rigidity and the strength to hold down the roof. Over the top of these panels is a beam on the south side, and a one metre tall truss on the north side, to support the roofing panels.



The roof panels are made from 'Ritek', a sandwich panel of two corrugated zinc alum steel sheets bonded either side of a 100mm thick sheet of EPS foam. The truss to the north side is clad on both sides with clear polycarbonate sheet, allowing the structure to be seen from inside and outside but providing passive solar gain through a virtual double glazed panel.

The polycarbonate sheet cladding on each side of the truss is a sensible low cost approach to improving thermal performance. The polycarbonate is passively shaded to prevent summer heat gain and performs well in winter. Replacing glass with polycarbonate marginally reduces winter heat gain (by around 3 per cent). However, although the air gap between the polycarbonate sheets allows some convective heat loss to occur, the insulation provided by the trapped air allows the system to perform considerably better than single glazing in reducing conducted heat loss.

Note: A 10 to 15mm air gap between the glass sheets is ideal for double glazing. The trapped air provides insulation and the narrower spacing prevents convection currents from forming to transfer heat between the inner and outer panes. [See: 4.10 Glazing]

On site waste is minimised, possibly even eliminated, by both panel systems. These systems also ensure that an accurate dimension house can be built in a minimum amount of time.



The 'pods' containing the carport/store and bathrooms are built from lightweight stud construction with corrugated sheeting externally and internally, and R1.5 bulk insulation in the walls and roof. The upper areas of the walls are clad with clear polycarbonate sheet to provide maximum daylight whilst allowing privacy within the bathroom areas. This also allows an exposed view of the structure from the inside and outside of those rooms. The ends of the string of rooms and the carport and netted garden are supported on round hardwood logs, cut and milled locally and treated prior to being stood in the ground.

The external surface of the walls to the living areas are left as natural cement sheet with a waterproof coating to emphasise the panel nature of their construction. This also provides excellent weather protection as the fibrous cement sheet is non-porous, unlike brickwork and other masonry products.

The internal surface of the fibrous cement sheet is also left natural in keeping with the owners desire for honest expression of materials. All internal bathroom surfaces are 'mini orb', a sheet steel material that is long lasting, provides excellent waterproofing and replaces the need for the 'wet trades' of plastering, tiling and grouting. The floors are raw concrete sloped to the drains and finished with a waterproof additive and sealant. [See: 5.1 Material Use; 5.3 Waste Minimisation; 6.5 Construction Systems]

Thermal mass and insulation

The thermal mass required for passive design in a mild temperate climate is provided by the concrete slab. The slab has a coloured oxide added to the top surface and is sealed but remains uncovered to utilise the full benefit of the thermal mass. [See: 4.9 Thermal Mass]

Insulation is provided by the layer of 100mm (minimum) thick EPS foam built into the roof and wall panels, which gives an equivalent R-value of R2.0. The carport/store and bathrooms are more conventionally insulated with reflective foil and bulk insulation in the roof and bulk insulation (polyester insulation) in the walls. [See: 4.7 Insulation]

Ventilation

Cross ventilation is achieved by the use of flyscreened doors on both sides of each room. There is no internal corridor, as the veranda acts as circulation space, allowing maximum cross ventilation through each room without compromising privacy to internal spaces.

During summer, night time cooling (radiating heat to the night sky and using the cooler night air to lower the temperature of the concrete slab) ensures that the house remains comfortable. [See: 4.6 Passive Cooling]



Shading

The raked panel roof is extended on the north side to provide shading to the upper level windows and rain and weather protection to the doors.

A series of metal louvres on customised steel brackets have been installed above the doors to control sun penetration. Set at a fixed angle, they allow winter sun penetration deep into the room (as far as the back wall of each room) but shade the glazing and ground in front of the sliding doors in summer. The louvres have been specially designed to act as a self-regulating system- as the sun's angle gets lower in the sky and temperatures drop, more sunlight is allowed into the house. [See: 4.4 Shading]

House energy rating

In a cool temperate climate like this, winter performance of the building envelope is the most critical consideration. High insulation levels, and appropriate type, size and orientation of glazing have a major impact on thermal performance.

Due to the high diurnal (day/ night) temperature range, the high thermal mass solution was ideal. Higher insulation values (around R3.5) for the roof were desirable for this climate but proved too expensive to achieve with the Ritek roofing system. The large areas of glass used to maximise solar gain also allow heat loss at night. Double glazing would significantly reduce this heat loss but was considered too expensive due to the large quantity of glass used. [See: 1.5 Rating Tools]

Furnishings

Every room in the house is fitted with built in furniture, made from Hoop pine plywood (plantation sourced timber) and some recycled timber collected by the owner over a number of years.



SERVICES AND APPLIANCES

Space heating and cooling

Auxiliary heating is provided in winter by the use of an open fireplace located in the two living areas. The 'Jetmaster' system provides radiant heat from the fire together with some convective heat around the fire box.

The owner uses the local timber harvested from fallen logs on the surrounding property.

Cooling is by natural means. There is no artificial cooling system or fans as the shading, cross ventilation and diurnal cooling together provide sufficient comfort during the summer months. [See: 4.6 Passive Cooling; 6.2 Heating and Cooling]

Lighting and daylighting

Daylight levels are high, with every room fitted with sliding glass doors to two sides. This promotes a maximum amount of balanced daylight.

Energy efficient fluorescent light fittings with efficient electronic ballast and starters are used throughout the house. They are located in pelmets that shine light up onto the zinc alum ceiling from where it reflects back into the rooms. The use of reflected light from the ceilings gives a more even lighting to the room without harsh glare. The location of the fittings in pelmets also allows for easy maintenance.

Compact fluorescent fittings in a waterproof case are used externally, and internally in the bathrooms and parts of the carport/ store. The waterproof case also keeps insects away from the light, extending their life and reducing maintenance. [See: 6.3 Lighting]

Water heating

Separate solar hot water systems are located above each of the two bathrooms, thus minimising the runs of piping to all points of use. All shower and tap fittings are WELS 3 Star rated to limit water wastage. [See: ; 7.2 Reducing Water Demand]

Electricity supply

A Remote Area Power System is installed. The system is a commercially available series of panels linked to a series of batteries and an inverter located in the carport / store area. Energy from the PV cells is stored in these batteries and is converted to 240 volt AC by the inverter to supply the house. This allows the use of conventional lights, audio equipment, television, computers etc. The system has been sized to allow the use of a five star rated fridge. [See: 6.4 Appliances; 6.7 Photovoltaic Systems]

Rainwater/ stormwater

Rainwater is harvested from the entire roof area for drinking and use throughout the house. The large area of north-tilted roof over the living areas is fitted with a special gutter system that incorporates dual gutters to allow filtering of the water and removal of all leaf material before the water enters the system. Water is also collected from the bathroom roofs. The water is collected in rain heads/box gutters at each of the bathrooms.

The water is piped through the bathrooms in an exposed galvanised steel pipe and to the rear of the house where it is stored in twin 15,000L concrete tanks. Prior to entering the tanks this water passes through a first flush diverter system that removes the first 40L of water containing dust, dirt and other material from the roof that has not been filtered by the gutter system. The tank water is pumped under pressure to the taps and to the roof mounted solar hot water system for the two bathrooms. [See: 7.3 Rainwater]

A secondary system of water supply is the dam, which supplies water for all the gardens and for the emergency bushfire spray system.

Black / greywater systems

The house is fitted with two composting toilets that have pans located inside the bathrooms and the composting unit below grade on the outside. Fitted with a large diameter tall black exhaust, they provide maximum air flow to dry out the waste and only require emptying between long intervals. The dry residue is used on non-edible parts of the garden. This system has Australia-wide health department approval. [See: 7.7 Low Impact Toilets]

Waterless toilets are probably the most effective way to save water in a household – reducing water demand by around one third and reducing wastewater needing treatment.

Greywater from the basins, showers and sinks is treated in a modified septic system before being fed to a reedbed system for transpiration. The septic tank and transpiration beds are located to the north of the house on a downward slope and are in line with the axis from the bathrooms. This provides a visual connection between the water collection from the roof, through the box gutter to the tanks at the rear, and then back through the bathrooms to the transpiration beds on the north side. Thus the owner and occupants can feel the water system flowing around them as they use the house. [See: 7.4 Wastewater Re-use]

LANDSCAPE

The landscape has been designed to complement the series of outdoor rooms in the house.

Seeded natural local grasses are planted in the area to the north of the house. To the south side, ornamental grapes provide shade to the pergola areas and the embankment is planted with species that are resistant to bird and possum attack and fenced in to prevent attack from wallabies, kangaroos, goannas and rabbits.

Enough vegetables and fruit to supply the household are grown in the netted garden, protected from birds and other animals. [See: 2.4 Sustainable Landscapes]

EVALUATION

This case study is an excellent example of the numerous possibilities that exist for reducing a home's environmental impact.

As a fully autonomous house, all water and energy resources are generated on site. The remote area power system generates electricity from solar energy, rainwater is harvested for domestic use, fallen logs are collected for auxiliary heating, and vegetables and fruit grown on site reduce the need to import food for household consumption.

Prefabricated modular construction has also been used in an innovative way to minimise materials wastage.

The remote location of the home inspired its autonomous nature, however transport to and from the home is by motor vehicle. The dependence of occupants of remote sites on motor vehicles often significantly increases environmental impact. In this case study, the owner lives and works on the site for lengthy periods, reducing travel requirements.

PROJECT DETAILS	
Architect:	Tone Wheeler, Environa Studio
Builder:	Julian Barlow Builder
Engineer:	Matthew O Hearn, O Hearn Consulting

Principal author:
Caitlin McGee

Sunbury VIC

NEW HOME

ZONE 6: Mild temperate



Topics covered

- Passive design
- Renewable energy
- Energy efficiency
- Rainwater harvesting
- Greywater re-use
- Indoor air quality
- Sustainable materials
- Construction waste avoidance

AccuRate (thermal comfort)	6.0 (regulatory)

This house, known as the EcoHome, was designed to be a resource efficient, low allergy home for a family of two adults and three children, incorporating good passive solar design, active solar systems, rain water and greywater re-use, and a high level of indoor air quality.

The conventional construction methods used in the the EcoHome make this type of building system readily replicable. The low-tech approach encourages occupants to understand how the building systems operate and work with them.

Site

The site is a hilly exposed location on top of Jacksons Hill, Sunbury, in the Urban and Regional Land Corporation's (URLC) energy efficient subdivision 'Sunset Heights'. The first 21 house sites in the subdivision were fully equipped with active solar systems (grid-connected photo-voltaic arrays and solar hot water systems) in a green field development.

The EcoHome was the first house to be built in this new sub-division. The site lends itself towards a panorama of the surrounding Sunbury Hills and long distance vistas. The block has an area of 556m^2.

Impact on the site was reduced through careful excavation, with minimal cut and fill used in site preparation.

Excavated site material was used by the Urban and Regional Land Corporation as road base in the new sub-division. [See: Choosing a Site; 5.3 Waste Minimisation]

Climate

The location is in a temperate dry climate zone, with cooling summer breezes from the south and blustery cold south-westerly winds in winter. [See: 4.2 Design for Climate]

Orientation

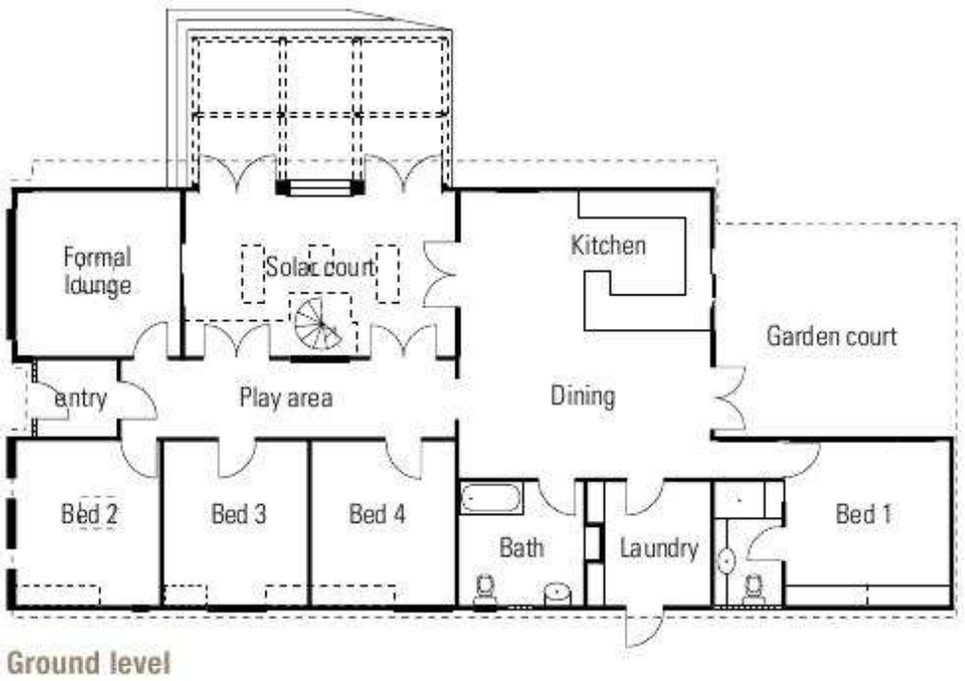
The house has a street address to the west and the living spaces are orientated to the north.

The west frontage has long distance vistas of the surrounding Sunbury hills. The garage provides some shading from early morning summer sun.

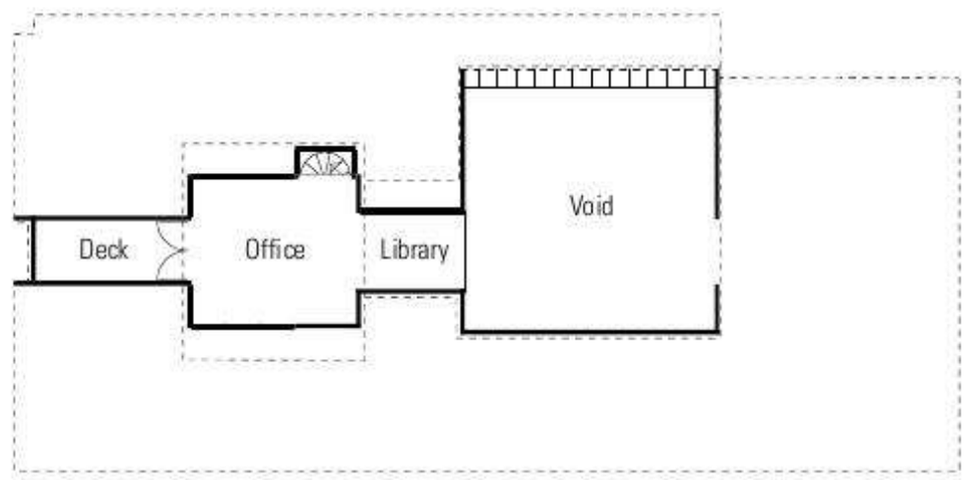
The living areas, solar court and garden court are located on the northern side for maximum solar access. Bedrooms and utility rooms are on the cooler southern side.

Flexibility was an important principle in the design of the living areas. The doors and glass walls can be opened to increase house size in summer, providing a larger volume and





Ground level



Upper level

higher ceilings to improve air stratification and circulation. In winter they can be closed to reduce room size for more effective heating. [See: 4.3 Orientation]

Shading

Eaves shade windows on the north side.

A solar pergola ensures the solar court does not overheat and provides a shaded external living area. The reflective solar film on the skylights minimizes overheating of the solar court.

The west facing double glazed windows and front door assembly also utilise solar film, reducing solar penetration in the morning. [See: 4.4 Shading; 4.10 Glazing]

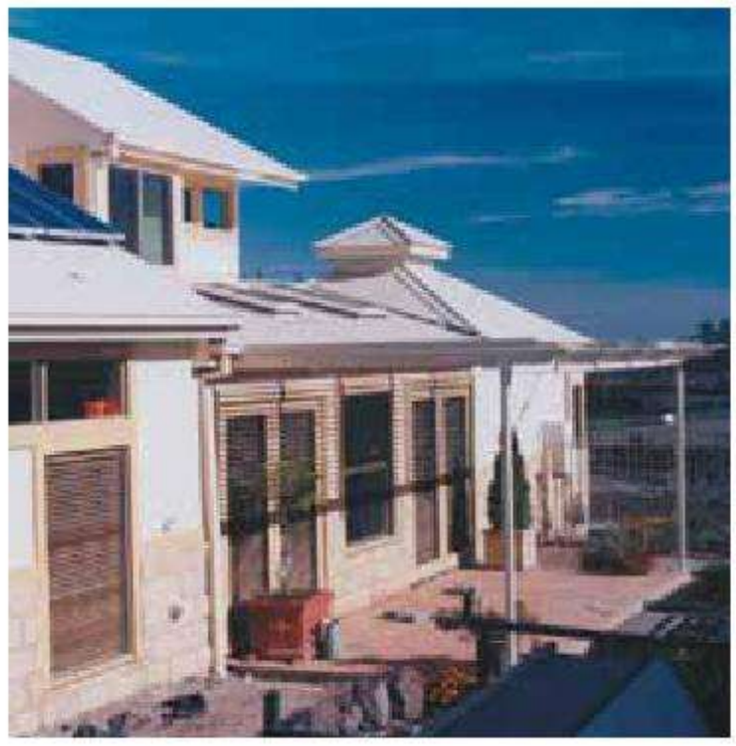
Glazing

All external windows and glazed doors are Victorian Ash timber framed double-glazed units. The timber was sourced from sustainable timber plantations. There are insulating glass brick walls and windows in the bathrooms.

The openable skylights are argon gas filled double glazed units with solar film.

The internal glass walls facing onto the solar court are single glazed and enable this space to be separated or included in the main living areas without visual exclusion.

The single glazed louvre window in the upper floor office facilitates exhausting of heat from the solar court and lower levels by the stack effect. A flexi-glass frame is fixed over this louvre window during colder months, providing a weather seal and maintaining the insulation integrity of the building envelope.



The west windows are designed as 'zen' picture windows to frame the view, limiting the thermal load and solar penetration. [See: 4.10 Glazing]

Insulation

The roof is insulated by a layer of reflective foil insulation and R3.5 *Rainbow* batts made from recycled PET bottles.

External walls are insulated by R1.5 *Rainbow* batts. Particular attention was paid to installation of the insulation to ensure effective cover without gaps.

Double glazed timber window and door frames avoid thermal bridging. [See: 4.10 Glazing]

Infiltration has been minimised by locating power points and switches on interior walls, installing surface mounting light fittings rather than using down lights (to avoid penetrating insulation), application of foam seals around window and external door frames, and using a breathable membrane vapour barrier. [See: 4.7 Insulation; 4.8 Insulation Installation]

Ventilation

Natural ventilation has been achieved by window placement that allows for cross ventilation and night-time ventilation for summer cooling.

Plants and water features strategically located in the solar court and garden court provide natural evaporative cooling.

High windows induce a stack effect and exhaust hot air via the upstairs library and home-office windows. [See: 4.6 Passive Cooling]

As indoor air quality is a primary concern, winter ventilation is provided by an air filter and mechanical ventilation system to control humidity levels and remove pollutants. A heat recovery unit conserves energy.



Embodied energy

Materials used are relatively low in embodied energy, largely due to the lightweight construction technique.

Local building materials have been sourced where practical to reduce transport energy.

Victorian Ash timber framed windows and doors from a sustainable timber plantation were used in preference to imported cedar windows and doors.

Plantation pine was used for the frame and bulk insulation was manufactured from recycled PET. [See: 5.2 Embodied Energy]



Renewable electricity

The house is equipped with a 1.6 kilowatt peak grid-connected photovoltaic array installed on the north facing roof, which is pitched at 30° to maximise efficiency of the array in winter.

The energy needs of the household are substantially below average due to the use of passive solar design, natural ventilation, day lighting and the contribution of the active solar systems.

The active solar component of the EcoHome contributes approximately 1560kWh annually to the electricity needs of the household. The photovoltaic array is generating around one quarter of required household electricity. [See: 6.6 Renewable Energy; 6.7 Photovoltaic Systems]

Greenhouse gas emissions are reduced by at least 6,500kg per annum due to the active solar system.



Hot water

Hot water is supplied by a 300L gas boosted, close coupled solar hot water system mounted on the north-facing roof above the kitchen in order to be close to the most frequent draw-off point.

Heating and cooling

Auxiliary heating is supplied by an efficient force-flued gas heater, mainly to provide additional winter early morning heating to children's bedrooms which are located on the south side.

Ceiling fans are used to provide cooling air movement in summer, and are reversible to push warm air back down from the ceiling in winter.

A heat exchanger is utilised on the mechanical ventilation system.

The water feature acts as a natural evaporative cooler. [See: 6.2 Heating and Cooling]

Lighting and appliances

The house is designed to take full advantage of natural daylighting.

Energy efficient light fixtures, which allow for compact fluorescent lamps, have been installed.

Separate switches for separate lights have been installed so lights can be turned off if not needed.

The skylights above the solar court and the high windows of the living spaces admit sufficient light for reading on full moon nights without the need for artificial lighting.

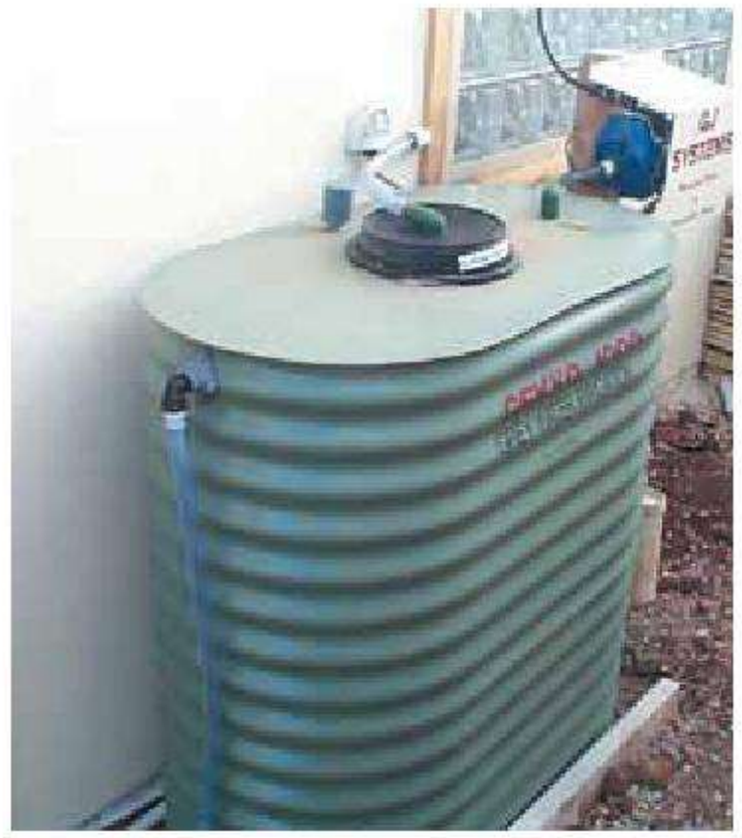
Window placement allows the occupants clear vistas through the home to observe the passage of the sun and changing climatic events.

Any new appliances are 5 Star rated. [See: 6.3 Lighting; 6.4 Appliances]

WATER MANAGEMENT

Rainwater is harvested and stored in a 5,000L tank for garden use. [See: 7.3 Rainwater]

A greywater recycling system with a mechanical filter provides water for toilet flushing and waters garden beds via a gravity flow sub-surface irrigation system. [See: 7.4 Wastewater Re-use]



Water efficient WELS 4 Star rated clothes washer and dishwasher have been installed.

Showers and sink and basin taps are 3 Star water efficiency rated. [See: 7.2 Reducing Water Demand]

The annual water consumption for the two adults and three children living in the EcoHome is less than half of the average Melbourne household.

LANDSCAPING

Plants and water features are strategically located to cool hot northerly breezes through transpiration and evaporation.

Native plants that are drought and wind resistant and rockeries are used on the exposed westerly entrance garden. These plantings provided the means to uplift the breezes over the house to protect the house from loss of heat. [See: 2.4 Sustainable Landscapes]

INDOOR AIR QUALITY

A high standard of indoor air quality has been achieved through the selection of low chemical emitting building products such as Low VOC paints and hard surfaced products.

A central ducted vacuum system minimises re-circulation of dust particles.

Low VOC building products, including paints, sealed timbers and fully sealed (top, bottom and all sides) laminates are used throughout the house.

Hard surface flooring is used throughout to facilitate effective cleaning and dust removal, eliminating a breeding ground for dust mites.

In all wet areas, laminates were used to minimise mould growth, and good ventilation levels were provided.

The kitchen range hood exhausts directly to the exterior.

MATERIALS AND WASTE MANAGEMENT

No waste from the building construction or site was taken to landfill. Construction materials were carefully chosen to minimise waste.

Fibre cement exterior cladding generated little waste and off-cuts were re-used. The rendered finish generated no excess material.

The EcoHome's framing is constructed from sustainable sourced plantation pine timber framing. The house frame includes Laser frame beams and rafters and timber-saving truss design to support the span over kitchen/living areas.

Framing was cut to size off-site according to a cut list. Any off-cuts were used for noggins or blocking, and the remainder used as fuel for a neighbours wood burning heater.

Insulation is manufactured from recycled PET plastics.

Window frames and glass door frames are made from plantation sourced Victorian Ash.

Roof metal scrap was recycled.

Excess excavated soil was used by URLC in the road base. [See: 5.3 Waste Minimisation]

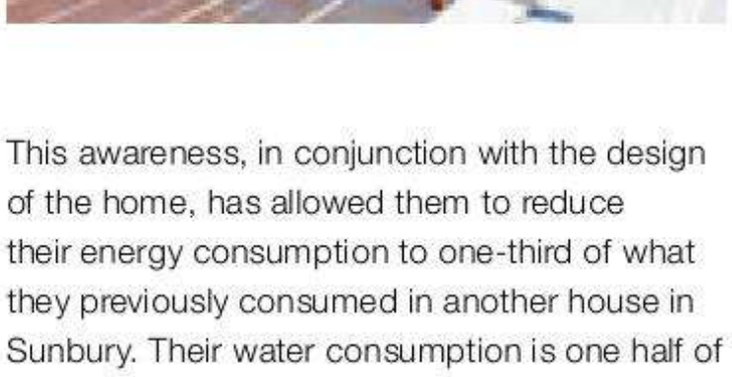
EVALUATION

The home achieved a 5-star energy rating using the First Rate software tool (maximum rating allowed by the First Rate software at the time). The lightweight walls, often considered best suited to temperate climates, have proven to work well in Melbourne combined with high levels of insulation. This construction system has lower embodied energy than a heavyweight system. The house maintains adequate thermal mass with a concrete slab on ground.

The occupants enjoy the EcoHome as a family home and in particular appreciate the air lock entry which protects from the strong winds experienced on Jacksons Hill, Sunbury. The vistas through the home allow the occupants to view changing climatic events and enjoy the panoramic view of the surrounding hills.

The high levels of natural daylight within the house make it a pleasant place to be, and reduce the need for use of artificial lighting.

This family is particularly aware of energy and water conservation.



This awareness, in conjunction with the design of the home, has allowed them to reduce their energy consumption to one-third of what they previously consumed in another house in Sunbury. Their water consumption is one half of the Melbourne average for a family of this size.

The owner-builder stated that he could not believe that the EcoHome is only 230m^2 in area as the spatial quality and efficiency of space planning provided a sense of spaciousness within the home.

The climatic design of the house provided benefits in addition to thermal comfort, energy and cost savings for the occupants. The design established long distance vistas of the surrounding Sunbury Hills. There was a visual connection between the house and the environment, for near, middle and far distance environments, and for changing climatic events/ weather patterns. Skylights and high windows allowed for ambient lighting levels from moon-light. At the local school, the children that lived in the house used the EcoHome as an example of a Sustainable House at 'show and tell'.

Awards:

Master Builders Association *National Environment and Energy Building Efficiency Award for Housing 2002* – Under $300,000.

The Architecture Show Magazine and The Francis Greenway Society *Green Buildings Awards 2003* – Silver Medal.

PROJECT DETAILS	
Architect:	Bridget Puszka, BP Architects
Builder:	Jan Brandjes
Engineer:	Keith Altmann and Associates

Principal author:
Bridget Puszka

Bairnsdale VIC

NEW HOME

ZONE 6: Mild temperate



Topics covered

- Orientation
- Design for climate
- Passive heating
- Passive cooling
- Insulation
- Thermal mass
- Glazing
- Shading
- Reduced water demand
- Water harvesting
- Water re-use
- Material selection
- Renewable energy
- Solar hot water
- Electric lighting
- Sustainable materials
- Construction waste avoidance

AccuRate (thermal comfort)	6.2 (full rating)

This case study is an example of an autonomous house that generates its own electricity and hot water, collects and uses its own water, and recycles wastewater onto the vegetable garden and orchard. Due to the highly effective building fabric, it provides a comfortable and attractive internal environment with the temperature fluctuating between 17°C and 26°C.

The site is 75 acres of farmland outside Bairnsdale. The aim was to rejuvenate the land with new dams and a tree planting program. The house site is on a northern slope of the land with mid range views to neighbouring towns and distant views to mountain ranges. There is no overlooking from neighbours and no obstruction of solar access.

The climate is a mild temperate one in the south-east of Victoria.

The brief from the client team of a husband and wife for this project was for a beautiful low maintenance house that they could use as a base for their trips into the Australian bush. The house had to be light and airy, have wall space for paintings, and have a view from each room. It should be naturally warm and well ventilated when necessary, single level, and be a shelter.

The owners planned to spend most of their time outside. The emphasis was that the home be a house in the environment with an attached carport for the storage of kayaks, camping gear and a 4WD vehicle. Two associated sheds were also to be provided that would form part of the overall design, with one being a woodwork area and the other one an artist's studio. The clients were well informed and very supportive of the environmental approach taken in the design.

Shape and orientation

The design begun by establishing the axis mundi, the vertical axis for the building that secured it to the site. This axis was determined by walking over the site many times until it became clear where the heart of the building should be.

This axis point was used as the starting point for the design, and later on, as the starting point for the layout and dimensioning. Around this vertical axis, a tower was developed that would form the basis for a stack ventilation effect. It would also function as a welcoming top-lit point of arrival in the entrance space.





From the tower a gently curving spine, oriented east/west, leads off which formes the basis for a corridor connecting all the rooms. The corridor also containes a library. North/south ribs run off from this spine, defining the spaces on either side. This initial concept, seen in plan view in Figure 1 below, made it possible to achieve excellent passive solar design. [See: 2.2 Choosing a Site; 4.3 Orientation]

Zoning of spaces

The client requested a house that could be zoned off for various patterns of use. The three core spaces were the main, sitting and dining areas. These three spaces lie side by side on the north side of the building, and can be sealed off from each other and the remainder of the house. Sliding doors separate the zones. The remainder of the spaces required were designed around these main spaces. Figure 2 below shows this arrangement.

Building fabric

The building fabric was designed to be high in thermal mass (internal) and wrapped with high levels of insulation.

The floor is a concrete slab, and the termite treatment was as minimal in environmental impact as possible for the project.

The walls are two leaves of rendered concrete masonry brick, with a roofing blanket consisting of 75mm of fibreglass insulation bonded to SisalationTM that faces the outside masonry leaf. The gap between the insulation and the masonry leaf is maintained by spacers. The overall insulation value of this system is R 2.6. [See: 4.7 Insulation; 4.9 Thermal Mass]

The windows were made locally in Bairnsdale. Stained local hardwood timber was used in the frames and sashes. Windows were double glazed with both inner faces low-e coated. [See: 4.10 Glazing]

The roof/ceiling was constructed using corrugated steel roofing, a roofing blanket consisting of 25mm fibreglass and SisalationTM, a 30mm air gap, two layers of R2.5 polyester batts (made from recycled polyester bottle fibre) and lined internally with 10mm plasterboard. The overall insulation value of this was estimated at R6.5. [See: 4.7 Insulation]

Internal walls were bagged masonry concrete bricks, except where service pipes were required between the ensuite and bathroom. Where required, electrical conduits were run through bricks with hollow cores. Elsewhere, solid blocks were used.



Photovoltaic system

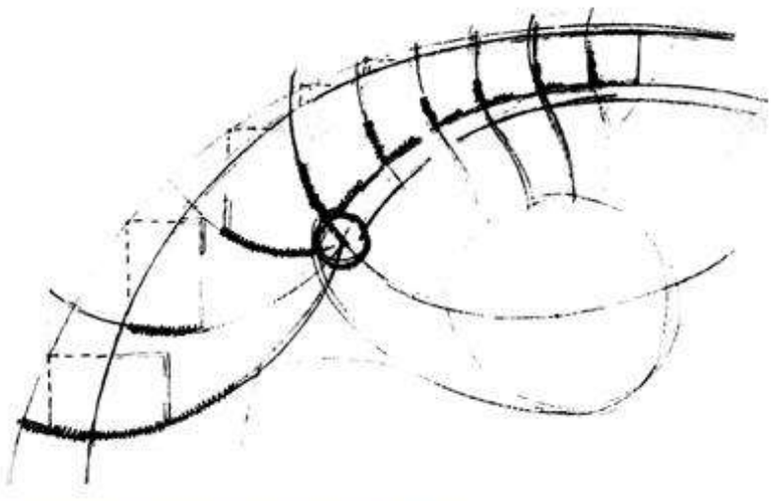
In keeping with the client's wish to be as environmentally friendly as possible, a grid interactive PV power system was designed. The architect worked with two tenderers, and Sustainability Victoria to develop a performance specification that was used as the basis for the tender.

Tender documents incorporated this performance specification (that called for a 1.28kW peak output system with a grid interactive inverter), a somewhat redundant load analysis table that showed the intended use by the client, and architectural drawings.

The winning tender was for $11.70 per peak watt and both tenders were within 1 per cent of each other. The price included supply, installation, commissioning, six month warranty period and any necessary rectification, negotiations with Sustainability Victoria in order to achieve a successful outcome with the Australian Government Photovoltaic Rebate Program, and successful negotiations with the supply authority Eastern Energy in order to gain net energy trading.

The system size was later upgraded to include an air displacement water pumping system and the final system was 1.92kW peak, consisting of two 12 x 80W peak solar arrays (mounted on low profile zincalum frames) that feed two separate inverters. This twin system was an elegant solution to the two phase power supply to the farm. The final cost, after deducting the PVRP rebate, was $7.70 per peak watt.

There have been some problems with the functioning of both inverters but they have now been rectified. Final payment for the completed and commissioned system is not due until the system has been operational for six months, and this includes the errant inverters. This money retention is a sensible course of action for any installed appliance, renewable energy or not. However, it is a delight to visit the site and see the electricity meter going backwards. [See: 6.7 Photovoltaic Systems]



Underlying structural concept for house.

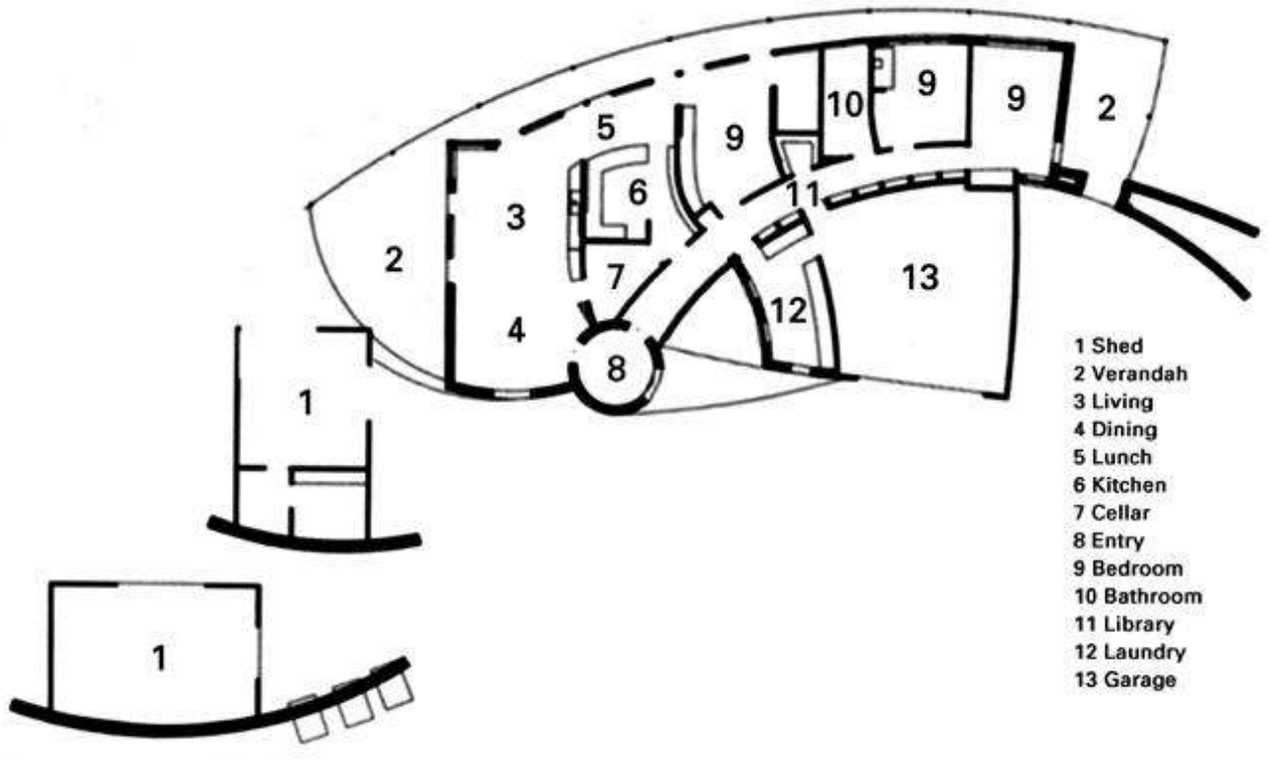


Figure 2 Plan of house.

Solar hot water system

The solar hot water system was installed with a 400L stainless steel tank, using off-peak electricity as the back up since no natural gas is available. The system had some leaks from faulty gaskets, which have been replaced by the manufacturer under warranty. Pipes are insulated with black foam lagging.

Water system

Rain water is collected off the roof and piped to three water tanks positioned to the west of the house. The storage capacity of the tanks is 15,000L, and the water is returned to the house under pressure using a pump. The tanks were relocated to a lower position on the site when it was found that discharging rainwater did not have sufficient head pressure to flow into the tanks without overflowing from the gutters.
[See: 7.3 Rainwater]

Wastewater treatment system

A wastewater treatment plant was supplied locally. It cost much the same as a normal septic tank and consists of two chambers. The first chamber is a septic tank that requires cleaning out every five years or so. The second chamber air treats the liquid that is then used as a spray to irrigate the landscape. [See: 7.4 Wastewater Re-use]

Compostable waste and vegetable garden

A composting enclosure is provided on the site as well as a vegetable garden.

BUILDING COSTS

Excluding the cost of the photovoltaic system, the house and garage cost $1350 per m^2. The sheds and their associated retaining walls cost $700 per m^2.

EVALUATION

Energy rating

The house was rated using the Accurate software and received a rating of 6.2 stars. 5 stars is the current Building Code of Australia requirement in Victoria. The rating could have been improved by adding 20m^2 of north facing windows, which would have brought the north window/floor area ratio up from 16 per cent to 27 per cent. It was felt that this would severely compromise summer performance, unless the window had been provided with more shading which in turn would have produced poorer winter performance.

The use of fuels will be monitored over the coming year to determine the actual operating performance.

Rules of thumb

The internal floor area is 174m^2 excluding the garage and laundry, with the library corridor making up 20m^2 of this. The north facing windows have a surface area of 28m^2 measured to the outside of the frames. The surface area of the internal masonry walls is 144m^2 , with the surface area of the internal faces of the external walls being 149m^2. This accords with the general rule of thumb that the area of the floor, the area of the internal walls, and the area of the internal faces of the external walls of a house should all be roughly the same value.

A rule of thumb established by the author for this climate indicates that the north window area should be 15-20 per cent of the floor area, with a tendency to be on the small side to compensate for the very hot summers that can be experienced in this climate. This house has a north window/floor area ratio of 16-18 per cent depending on whether the library corridor is included or not.

The surface area of the internal mass should be a minimum of six times the surface area of the north facing glass area, with nine times and above being preferable. This house has a thermal mass surface area/north window area ratio of 16 indicating that there is ample thermal mass.

A rule of thumb for thermal mass developed by Brenda and Robert Vale (Vale, 2000) suggests that 1,200kg of thermal mass per m^2 of floor area will produce a zero heating house in cold European climates, with the Vales' own autonomous house at Southwell, UK having a ratio of 723kg/m^2. This Bairnsdale house has approximately 101,000kgs of thermal mass, which is 580kg/m^2 of floor area. More theoretical work needs to be undertaken for temperate climates to determine the appropriate rule of thumb for this mass/floor area ratio, as experience shows that the level of mass provided at the Bairnsdale house is sufficient.

Overall

The Bairnsdale house represents a good example of an autonomous house that is grid connected. It is a single storey house with high mass, very good insulation, and correct window sizing. It incorporates a solar hot water system, a 1.9kW peak grid interactive photovoltaic system, an environmentally friendly sewage disposal system, and rain water collection storage and re-use. Details of these are provided. Kitchen waste is composted. Clothes are dried on a clothes line. A vegetable garden and orchard have been established. Whilst these environmental design features are now not unusual, what is different in this house is that they have been incorporated into a finely crafted building that was designed using a philosophical position that encompasses both the physical and metaphysical aspects of design.

PROJECT DETAILS	
Architect:	David Oppenheim
Builder:	NJ and MN Brooker
ESD design:	Sustainable Built Environments, Melbourne

Principal author:
David Oppenheim



In memory of David Oppenheim (1948 – 2007) who was an energetic warrior for sustainable buildings. David was the Director of Sustainable Built Environments (Melbourne, Sydney, Perth) and was involved in energy efficient and low environmental impact architecture for three decades, participating in over 1,000 projects. The designs of his built work have won awards both at State and National level since 1985. He co-founded the firm Taylor Oppenheim Architects in Melbourne in 1980, and building on the firm's green body of work and credentials, established SBE on the vernal equinox, 2001. David has been employed by the United Nations, and has represented Australia at two international energy forums involved with building design.

Yarra Junction VIC

NEW HOME

ZONE 7: Cool temperate



Topics covered
Passive solar heating
Reducing water use
Rainwater harvesting
Greenhouse gas reductions
Wastewater recycling

AccuRate (thermal comfort)	6.9 (full rating)

This case study shows how a well designed suburban home can cost effectively minimise its environmental impact whilst simultaneously improving comfort and lifestyle for its occupants.

The innovative wall construction system used yields high level insulation whilst providing thermal mass and reducing noise transmission.

The house also eliminates heating, cooling, water and sewage disposal costs.

This single storey house has been designed to allow for maximum winter sun whilst totally excluding summer sun. It is split into two sections: the main section has three bedrooms and a study while the second section is a self-contained unit with a separate living area.

The brief called for the house to be very comfortable and take advantage of the magnificent views. The house was designed with a high emphasis on winter warmth with low running costs as the house is in an area that can get quite cold as it is surrounded by Yarra Valley mountains.

The site is in an urban residential area in the Yarra Valley, Victoria. It is surrounded by mountains that often have snow on them in the winter. It has a gentle slope down to the East. The northern aspect of the block is open with no overshadowing from trees or other houses.

The climate is temperate to cool temperate. The prevailing winds coming from the Southwest in winter and temperatures in the area range from –5° in winter to 40° in summer.

DESIGN SOLUTIONS

The land has northerly aspect to the long side of the block. This allowed the design of the living, lounge, dining and kitchen to have northerly aspect. This amount of solar access enabled the house to be designed so that it did not require any auxiliary heating devices.

Great northerly aspect and good passive solar design were combined to maximise winter sun penetration.





Floor plan

High levels of insulated thermal mass in the wall and floor construction absorb this free energy from the sun during the day and re-release it at night. This maintains winter indoor temperatures above 17° with no auxiliary heating.

The designer was asked to incorporate two separate living quarters under the one roofline. The only part of the house to be shared was the laundry.

The unit was not to look any different to the rest of the house and was to take advantage of the northerly aspect and views just like the main section of the house and required a separate entry. These client requirements were successfully achieved by locating the unit at the front of the block.

Specially designed shade battens on all windows exclude all summer sun to protect the house from overheating in summer. Well designed cross ventilation paths allow cool breezes to draw heat from thermal mass when night time temperatures are lower, maintaining summer daytime temperatures below 24°. The western side of the house was also designed with minimal windows.

The house remains comfortable without auxiliary heating and cooling because it was designed well with:

> zoned floor plan with north facing living areas

> passive solar orientation

> very high insulation levels

> advanced shading details

> high thermal mass

> efficient windows

> well planned cross ventilation

> thorough draught sealing

[See: 2.2 Choosing a Site; 4.0 Passive Design]



East elevation



North elevation

MATERIALS

Walls

Internal and external walls are all built with Thermacell™ (polystyrene blocks filled with concrete). This construction system provides insulated thermal mass and low sound transmission between rooms.

The polystyrene insulates the thermal mass to ensure that its benefits are felt inside and not wasted to external temperature extremes. It provides a barrier against the extreme cold in winter and high daytime temperatures in summer. [See: 4.9 Thermal Mass; 5.5 Construction Systems]

Floors

A concrete slab floor provides additional thermal mass. Winter sun passes through the windows and onto the floor, the warmth is stored in the slab during sunny days and is radiated back into the rooms throughout the night and on sunless days.



The high thermal mass solution with passively shaded north glazing is ideal for the climate and is a major contributor to the thermal stability and comfort of the house without auxiliary heating. [See: 4.9 Thermal Mass; 5.12 Concrete Slab Floors]

Roof

Plantation grown radiata pine roof trusses are a renewable resource which is structurally efficient minimising waste. Colourbond steel sheeting is durable, can be recycled and has low transport costs.

Good insulation levels make for a durable, resource efficient roof structure which minimises heat loss in winter and heat gain in summer.

Windows

Well shaded PVC frame double-glazed windows were used in the project. The style was double hung to maximise the amount of opening area to improve cross flow ventilation.



PVC frames are an insulator and minimise heat loss by conduction through the frames.

Double glazing restricts heat loss through the glass allowing larger areas of glass to be used to maximise passive solar heat gains in winter.

The air gap in the clear double glazed units is 14 –16mm. The windows are Generic Type 11 from the WERS table of Generic Window Types and are rated: Four stars for heating climates and two stars for cooling climates, making them ideal in this climate. [See: 4.10 Glazing]

Insulation

Walls: Thermacell™ 250mm thick external walls have an overall system insulation value of R2.9.

Roof: The ceiling and roof space have R2.5 wool/polyester bulk insulation with a layer of concertina foil batts placed on top. These reflect any radiant heat that escapes through the bulk insulation back to the inside in winter. They also reflect heat back out in summer but this effect will eventually be lost as a coating of dust on the upper surface reduces the reflective properties.



Reflective Tyvek™ was placed on the underside of the roof sheeting. The Tyvek™ is the first barrier against radiant heat gain through the roof cladding.

The downward facing reflective surface into the roof cavity works in two ways. Firstly, it reflects heat back into the building in winter and secondly, the low emissivity surface prevents downward radiation of heat gained through the roof cladding in summer. [See: 4.7 Insulation]

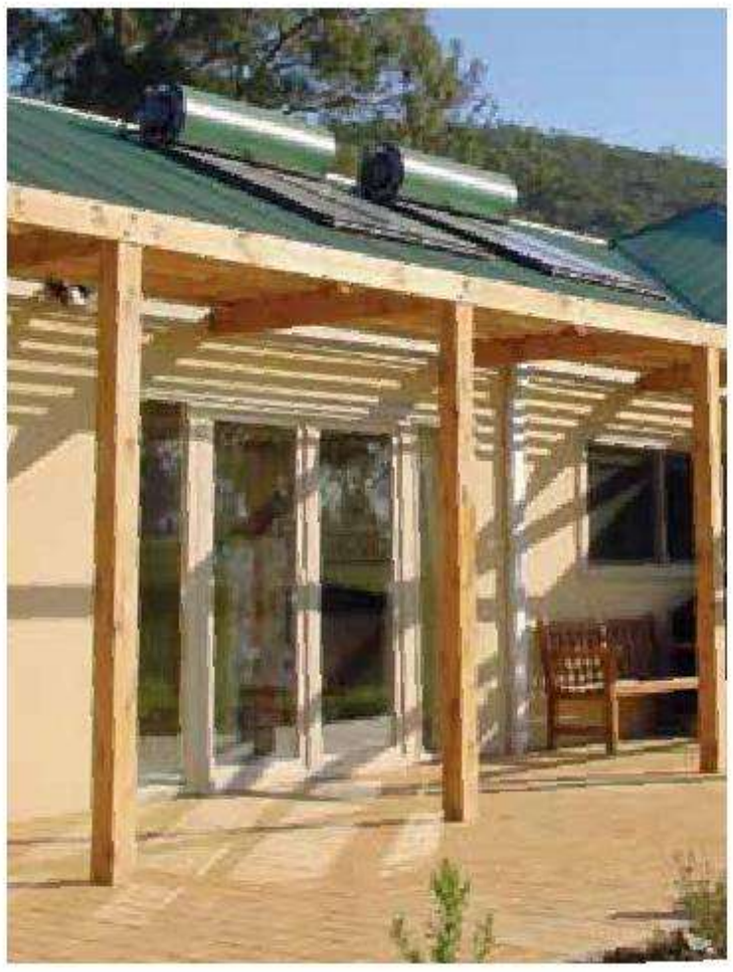
Thorough construction draught sealing combined with advanced seals on the windows and doors has eliminated heat loss by infiltration and leakage.

Ventilation

We introduced a mechanical form of ventilation to bring fresh air into the home in a controlled manner. The unit also filters the existing and incoming air and distributes it around the house. This eliminates the need to open the windows and lose warmth during the winter months.

Hot water

The hot water in the house and unit is supplied by separate solar hot water systems positioned on the northern roof space.



Greywater and black water

An aerated wastewater treatment system has been installed to treat all household wastewater. Treated wastewater is recycled onto the garden. [See: 7.4 Wastewater Re-use]

Water use and rain water

All roof water is piped to a large inground tank of adequate capacity to meet all household needs. An electric pump is used to pump the water back to the house for all house hold requirements. [See: 7.3 Rainwater]

All shower and tap fittings are WELS 3 Star rated to reduce water consumption.

Walling system

The main advantage of the wall system used is its very high system insulation values. These occur because of the combined effect of thermal mass and insulation as a system.

Because the thermal mass of the concrete fill is insulated from the interior of the house by the polystyrene blocks, some of its effectiveness as a thermal battery is lost.

The internal insulation slows absorption of heat energy into the mass. However, it also slows the re-release of that energy. The slower absorption and release rate of the insulated mass in the walls is of benefit in prolonged sunless winter periods and summer heatwaves.

With similar insulation levels internally and externally, more heat is lost to the outside (because this direction has the largest temperature difference).

The amount of accessible thermal mass present in the concrete slab floors is adequate for evening out day/night (diurnal) variations and maintaining the passive design function in the home. [See: 4.7 Insulation; 5.0 Material Use]



PROJECT DETAILS	
Designer:	Darren Evans – Solar Solutions Design and Drafting
Owner / Builder:	Ian McDonald
Engineer:	Buratt Engineering

Principal author:
Belinda Evans

Contributing author:
Chris Reardon

Images courtesy of Solar Solutions Design and Drafting

Shading system

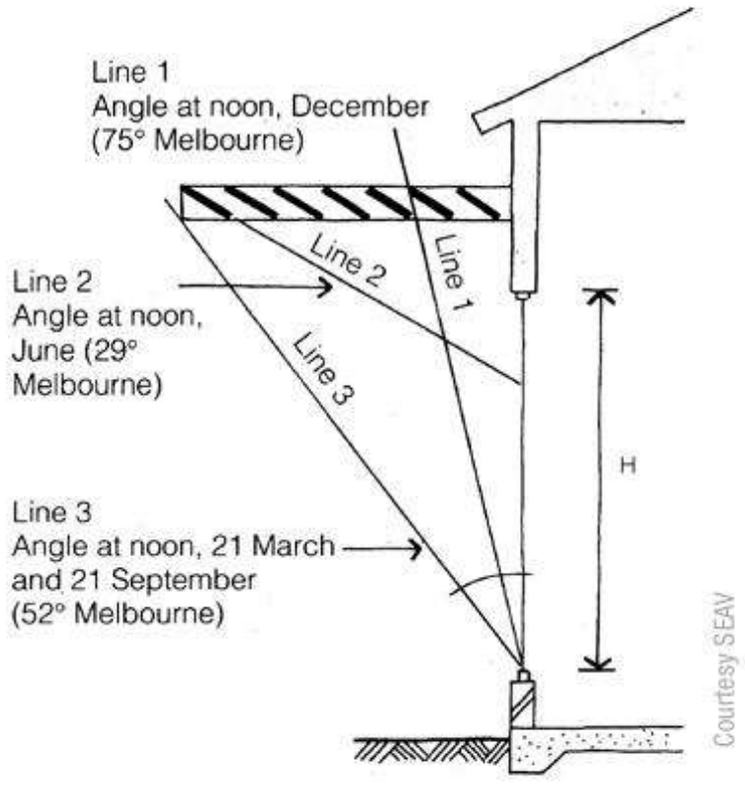
The system of angled louvres used to shade the north facing glass has distinct passive solar design advantages over other systems.

In most eave shaded applications, up to 30 per cent of the glass area remains in constant shade. This is always a significant source of heat loss in cool and cold climates as the warmest inside air rises to the ceiling causing greater heat transfer rates. Double glazing and insulating drapes with snug pelmets drawn at night can almost eliminate this.

With a louvre shading system, a shallow eave is used and the louvres are set to allow full winter sun penetration on the whole glass area whilst gradually excluding it in bands of shadow over the whole glass area in autumn and spring. Winter sun penetration at the top of the window allows deeper penetration of sun onto the concrete floors where it is absorbed for night time release.

This system is also ideal for shading an elevation where window sill heights vary. A single uniform system provides correct passive shading to all windows regardless of their height.

All overhead summer sun is excluded and a larger shade area outside the windows can be created by extending the system. This minimises heating of paved surfaces and lowers the temperature of air entering the building through open windows in summer.



Courtesy SEAV

In this example, the thick timber louvre blades, whilst attractive, cast shadows over 25 per cent of the glass in mid winter, This is a loss that can be reduced to around 5 per cent by using thin metal louvres that are longer and set further apart.

EVALUATION

The owners are extremely happy and have found the house meets all their requirements. [See: 4.4 Shading]

Dandenong Ranges VIC

NEW HOME

ZONE 7: Cool temperate



Topics covered	
Rainwater harvesting	
Wastewater treatment	
Reducing Embodied Energy	
Greenhouse gas reductions	
Sustainable materials use	
AccuRate (thermal comfort)	6.9 (regulatory)

This family home was designed to the highest energy efficiency standards to minimise auxiliary heating requirements. Low embodied energy materials were used at every opportunity. Water supply and wastewater treatment are autonomous.

The project is a four-bedroom family home on a gentle sloping site in the Dandenong Ranges on the outskirts of Melbourne.

The site has spectacular views over the Clematis valley to the north and this was of prime significance in the design and siting of the house.

The building was to be designed to the highest energy efficiency standards to minimise auxiliary heating requirements in a climate where temperatures as low as minus 5°C are experienced.

The design created a highly-insulated building envelope that steps along the contours of the north sloping site protected by an earth bermed wall to the south and opening to large areas of glazing to the north.

LOCATION AND CLIMATE

The site covers approximately 4 hectares on a gentle ten-degree slope to the north-west. It was originally a tree plantation with 0.4 hectares cleared to form the house site. The remaining area was retained for commercial tree plantation.

An access road is situated to the north-east of the site where water, electrical and gas services are available.

No sewerage service was available.

The elevation above sea level means that site temperatures are several degrees cooler than in Melbourne, ranging from minus 5°C in winter to the high 30s in summer.

Prevailing winds are from the south-west in winter and the north-west in summer. The internal temperatures are designed to fall between 18 and 25°C. [See: 4.3 Orientation]



DESIGN RESPONSE

The building is situated on the highest point of the property to take advantage of the spectacular northerly views and to facilitate vehicular and services access from the existing road.

The designers chose to orient the building approximately 15° west of north to follow the line of the contours and to avoid overshadowing by the large adjacent trees to the north-east.

The two storey building form is set into a bermed wall on the south and opens out with large areas of glazing to the north.

All main living areas are located on the north of the home for optimum solar access. The ground floor steps up the contours of the slope from the west to the east with a floor level difference of 0.75m.

Living areas are located on the ground floor with bedrooms on the upper floor set back from the line of the ground floor to form a north facing deck.

Service areas and carport are located on the south side and the entrance is on the sheltered east side. Existing trees were retained to the south and west to provide a windbreak. [See: 2.2 Choosing a Site; 4.3 Orientation]

DESIGN SOLUTIONS

Daylighting and sun control

Natural daylight is maximised in the building. Main living areas are orientated north.

Adjustable shading devices are used on ground floor rooms to allow flexible control of solar access in an unpredictable climate.

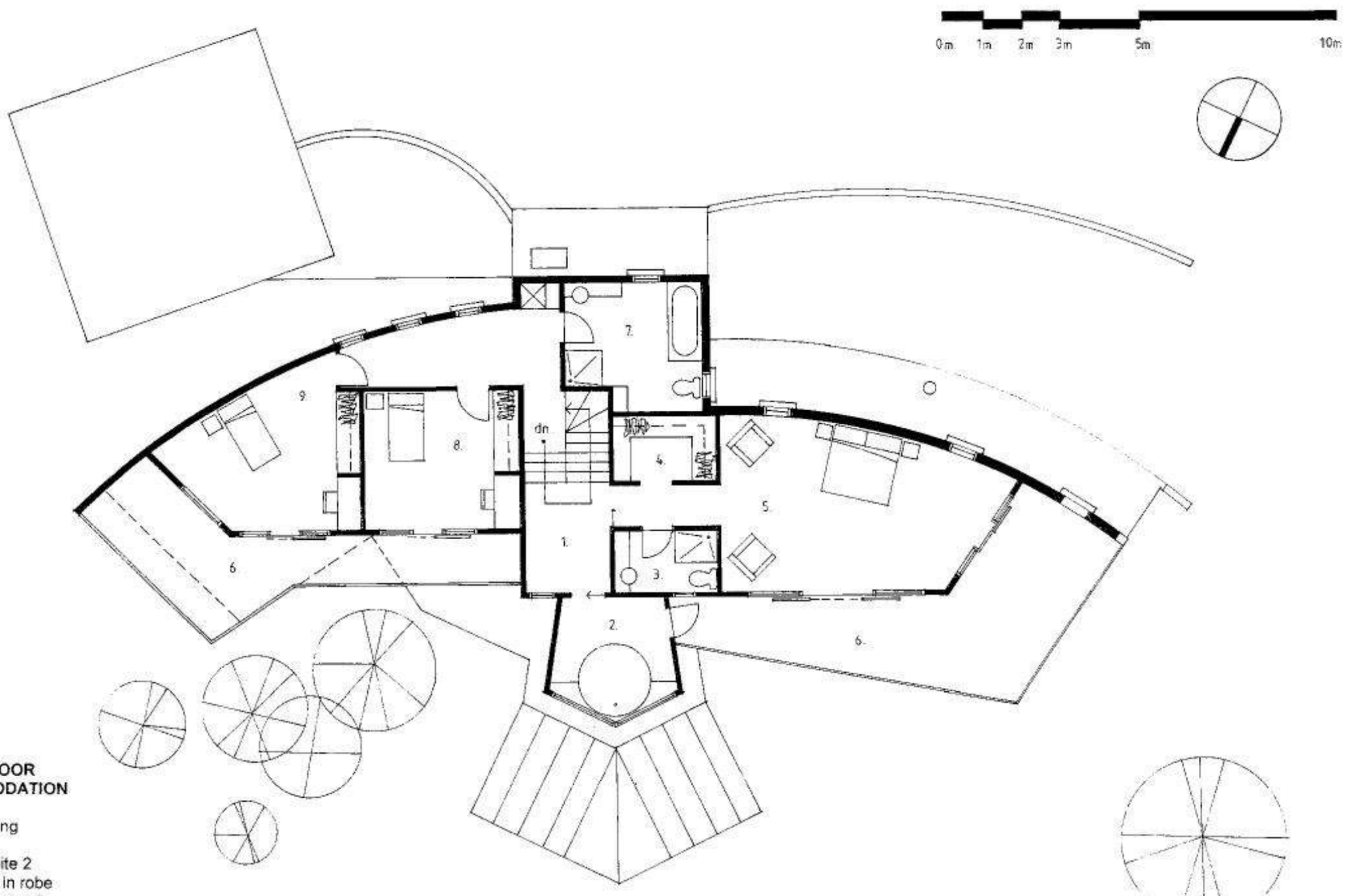
The dining area is shaded by a pergola with adjustable shade sails. Other north and west facing windows are shaded by parallel arm awnings. First floor windows are shaded by fixed eaves, sized to admit winter sun and exclude summer sun.

In addition to the fixed eaves, the spa area is also fitted with Azurlite, a heat restricting glass with a shading co-efficient of 0.66 and visible light transmittance of 77 per cent. While this is insufficient to prevent some unwanted heat gain in summer, the spa can be closed off from the rest of the house and vented through the door and the north-east windows. [See: 4.4 Shading]

Passive heating and cooling

The main energy efficiency strategies for the cool-temperate climate were to provide a well insulated envelope with internal thermal mass and maximum solar gain in winter.

Large areas of north glazing admit winter sun, which is stored in the thermal mass of the ground floor slab and earth bermed wall to the south of the dwelling.



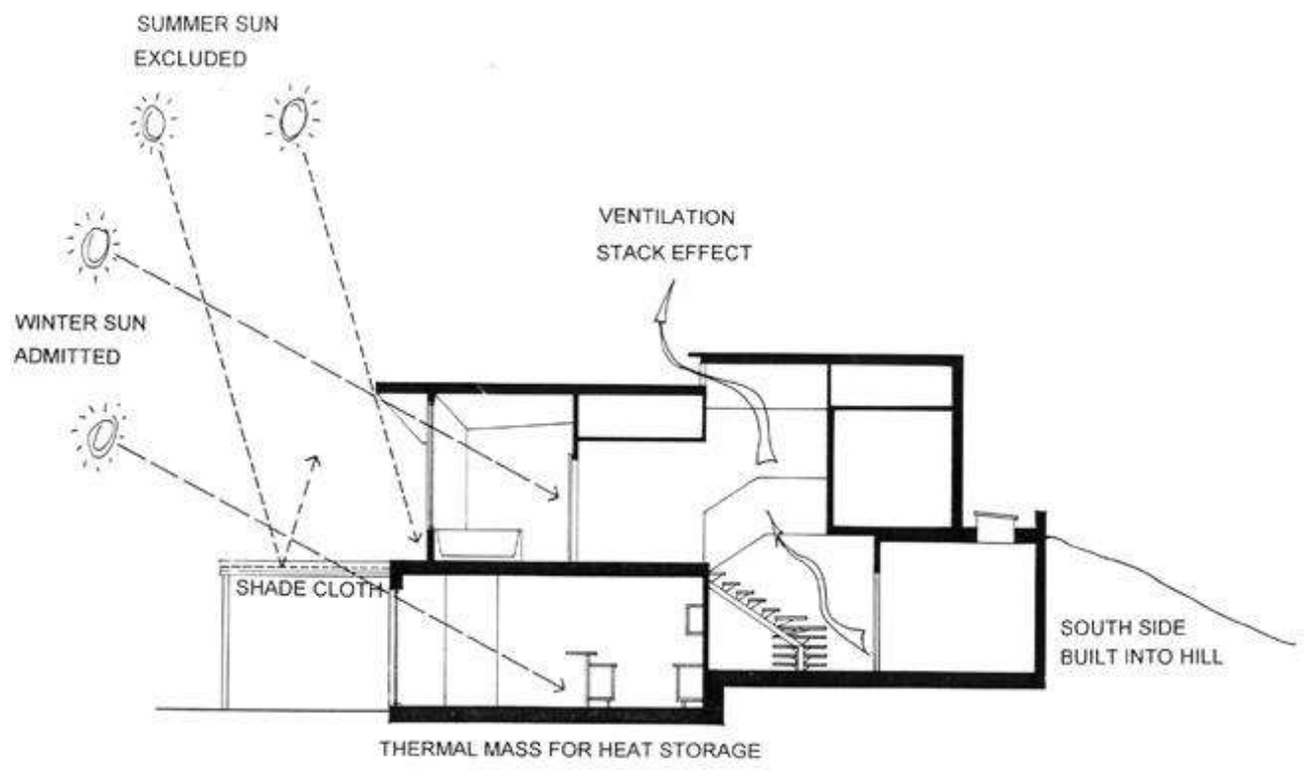
UPPER FLOOR ACCOMMODATION

1. landing
2. spa
3. ensuite 2
4. walk in robe
5. bedroom 1
6. balcony
7. bathroom 2
8. bedroom 2
9. bedroom 3

Floor plan

Thermal mass also moderates the internal temperature in summer by acting as a heat sink.

A wine cellar is located in the south bermed wall section so that fairly even cool temperatures are maintained throughout the year. Night-time cooling of the thermal mass is achieved by admitting cool summer-night breezes from the south. [See: 4.5 Passive Solar Heating; 4.6 Passive Cooling; 4.7 Insulation; 4.9 Thermal Mass]



Passive solar design – Cross section.

Insulation and draught proofing

The entire building envelope is well insulated.

Walls: Some R1.5 AAC blockwork is used in service areas. R2.0 wool/polyester bats are used in timber framed walls (majority of walls).

Roof: R3.0 wool/polyester bulk insulation and R1.0 polyester blanket with down facing reflective surface and 25mm air gap. Total composite R4.5.

Slab edge insulation of R1.0 is fitted to prevent heat loss from the slab to cold outside air.

All windows and doors have draught proofing.

Windows are double-glazed, with all large areas of glass on the ground floor fitted with low-e glass to give performance equivalent to triple glazing.

Window frames are timber to minimise heat transfer losses through the frame. [See: 4.7 Insulation; 4.10 Glazing]

Ventilation

Cool summer breezes from the south-west are funnelled by the western, south bermed wall and admitted through small casement windows in the south wall that open to admit the breezes.

Cool air passes through the living area and out through the glazed doors to the north of the living and dining area. The eastern side of the home is also ventilated through southern casement windows, but due to the smaller areas of glazing does not require the same level of ventilation. Stack effect ventilation is also encouraged in summer through openable roof level windows above the staircase. The upper floor is ventilated in a similar manner with the addition of roof ventilators to supplement the ventilation rate.

Appliances and equipment

Auxiliary heating is provided by a Rinnai 4.5 star rated gas wall heater and an open fireplace in the living room.

Auxiliary heating is located at the lower level of the ground floor to allow heat from this area to rise to the mezzanine level and then up the staircase to heat the upper floor.

Additional off-peak electric floor coils were provided in the slab of the meals, kitchen and rumpus area. These were intended only to take the chill off the slab on cold winter nights after several sunless days. During the first year of operation they were used by the owners as the main source of space heating. The resulting high energy bills soon changed this practice and now gas heating is used almost exclusively.

No auxiliary heating is required on the upper floor.

No auxiliary cooling is employed throughout the entire residence.

The hot water system is an Aquamax 200 gas 5 star storage unit. It was thought that a solar hot water unit with electric backup would be too expensive to run due to the amount used in the spa. The owners now regret this decision because the spa is rarely used. [See: 6.2 Heating and Cooling]



The designers specified low-energy appliances and a high proportion of efficient compact fluorescent light globes. [See: 6.3 Lighting]

Embodied energy

Building materials with low embodied energy and highly durable finish were chosen. Most walls are constructed in aerated concrete block, a material that has approximately half the embodied energy of standard brickwork.

Wall finishes are a highly durable exterior coating that has a guaranteed service life of more than 20 years. Other materials used in the construction, such as pine framing, recycled timber and cement sheet cladding were also chosen for their low embodied energy. [See: 5.2 Embodied Energy]

Water and waste management

All roof water is collected and fed into two large water tanks, sized to provide all the water requirements for the property. [See: 7.3 Rainwater]

Grey and black water is recycled in a Biocycle integrated waste management system and then re-used on the garden. [See: 7.4 Wastewater Re-use]

The garden has been designed with xeriscape plants, heavy mulch and a drip irrigation system to reduce water requirements. [See: 2.4 Sustainable Landscapes; 7.4 Wastewater Re-use]

Appliances such as the Dishlex global 400 dishwasher and WELS 3 Star rated showerheads and taps were also selected for their low water usage. [See: 6.4 Appliances]

Biodiversity and resources

Site excavation was minimised by locating the home close to the road and designing a stepped ground floor slab to follow the contours of the site.

Soil from the excavation was used to form the earth bermed wall to the south of the dwelling. Waste from off-cuts of the AAC and concrete blocks were also used in the bermed wall to provide a degree of drainage.

All timber in the dwelling was selected from sustainable managed sources, including the plantation pine framing, 'Plyfloor' flooring and cedar windows which are harvested from sustainably managed forests in Canada. [See: 5.1 Material Use]

EVALUATION

The owners have found the house to be extremely comfortable year round. Although shading devices have yet to be installed, the owners did not find the house uncomfortable in summer due to the high ventilation rates.

The house is used as the designers intended in summer with the operation of the south casement windows and the roof windows to create a thermal stack-effect, flow through ventilation.

The single criticism of the performance of the dwelling by the owners was a lack of cross ventilation to one of the upstairs bedrooms. A roof ventilator will be installed to remedy this problem.

The main lessons

Despite high level passive design and use of energy efficient appliances and lighting, the energy used during the first year was more than double that of a standard dwelling.

An audit revealed that this was due to pumping equipment not associated with the house. Planning is now under way to install solar pumps and gravity feed tanks.

The designers intended that the floor coil be used as an occasional source of slab heating only and that the more efficient gas heater should be used as the primary source of heating.

Unfortunately, the floor coil was used as the primary heating source until high energy bills forced a re-think.

This highlights the equal importance of operating patterns on energy consumption. The designer has now explained the impact of different fuel types on greenhouse gas emissions and the consequences of heating choices on energy use to the client.

On completion of a building, this information should be included in a user manual presented to the owners. A more drastic alternative would be to limit user choices by not specifying electric storage heating systems in future projects.

PROJECT DETAILS	
Designer:	Sunpower Design
Engineer:	Andreas Sederof, Sunpower Design
Builder:	Totally Organised

Principal author:
Adapted from the Roger Fay/Ceredwin Owen Australian Building

Kangaroo Island SA

NEW HOME

ZONE 6: Mild temperate



Topics covered
Rainwater harvesting
Wastewater treatment
Reducing Embodied Energy
Greenhouse gas reductions
Sustainable materials use

AccuRate (thermal comfort)	5.8 (full rating)

Designed for an older couple and their active, close family, this house demonstrates a straightforward, effective application of passive design principles for a house in a beautiful, but demanding, location. Its use of thermal mass has been integrated and expressed in the design as a effective aesthetic feature wall that also tells a story about the family's interests.

DESIGN BACKGROUND

The clients comprise an extended family of grandparents, their children and grand-children. The whole family were involved in the decision to secure the land, eliminate farming activities and deal with the consequences of trying to repair a degraded landscape.

With the goal of rehabilitating the land back to something like the original stable ecosystem it was clear that there would be a good deal of work to do to that would include addressing problems of soil erosion and weed control. In order to do this and to create a springboard for wider involvement, the choice was made to place a sustainable home on the property.

The older generation in the family have worked in international education up to UNESCO Pacific region level and continue today to provide elective programs in sustainability to Japanese university student groups. Their idea was to create a retirement home that was also accessible and able to offer cross-generational ownership to other family generations, and to give access to visitors as a 'show and tell' educational destination.

LOCATION AND CLIMATE

The property faces the northern coast on Kangaroo Island's 'neck', formed by the bay and Pelican Lagoon.

The land has been farmed since European settlement. As a result most of the indigenous vegetation has been replaced by grazing grasses.

The site is subject to the sea influence from both north and south coasts, particularly winds and salt spray.





STRATEGY

Plan and orientation

The relatively modest plan provides for the grandparents' personal spaces including a library, adjacent to the main entry, with a central shared living area and kitchen. The west wing of the house has two spaces for visitors and the rest of the family.

The building was placed to provide:

> Good solar orientation to the north.

> Land and sea views – also to the north.

> Earth sheltering, with a berm into the rising ground on the south side of the building.

The earth sheltering design strategy not only contributes to passive design goals but it also minimises the visibility of the building from outside the site, notably from the nearby viewing area on Prospect Hill/Mount Thisby.

Shell fabric

The insulated roof, ceiling and walls are set within an 'exoskeleton' portal frame system that sets most of the main columns outside the walls. This avoids thermal bridging from large steel members crossing the wall thicknesses and provides a strong architectural theme.

The construction system permitted the roof to be erected and construction to continue beneath irrespective of weather conditions.



Thermal mass and insulation

The project has good thermal mass and earth linkage with the concrete floor and limestone rear wall. The earth coupling of the berm construction against the south wall assists with maintaining stable temperatures and comfort conditions.

The 'Pale Eucalypt' corrugated steel roof is insulated with R2 batts, an air gap and reflective foil sisalation. Where there is a lower ceiling it is also insulated and insulation extends into the deep overhangs (which form narrow verandahs), helping to reduce heat transmission in summer. The walls of the main framed structure are clad with 'Gull Grey' horizontal corrugated steel sheets with R2 insulation batts and sisalation and have plasterboard linings.

Ventilation

Cross ventilation to the main living spaces is extremely good with the air able to flow 'passively' from the cool side windows set with their sills at the height of the earth berm, to the high clerestorey openable windows. A narrow but wide pantry is set into the earth berm wall to maximise the effect of 'coolth' with a ventilation tube and induction vent that cools incoming air.

Offset ceiling fans (not set centrally over the space) are used to bring warm air down to the floor in winter, and to accelerate cross-ventilation in summer.

Windows and glazing

The clerestory windows are set to let in the winter sunlight to the main central area where it strikes the tiled floor. The eaves and the verandah formed by the 'exoskeleton' portal frames provide summer shading.



Materials and waste management

The corridor in both the stone and plywood walls is shaped to provide privacy from the front door and then continue the geological 'story' being told along the full length of the building. A curved front wall visually ties the entry of the building to the horizontally corrugated rainwater tanks. Other curved elements include the entry masonry port hole.

Waste control included ordering materials pre-cut to size and fitted on-site, with waste returned to the mainland.

Lighting and daylighting

Daylight in the house is pervasive. Artificial lighting includes high efficiency LED lighting on trapeze wires – set below the fans to avoid 'strobing'.



EVALUATION

The reported experience from the occupants is that comfort is maintained passively with some supplementary heating from the stove, and that energy use is within the capability of the stand alone photovoltaic system (5.8kWhr/day on average).

The architect's assessment placed the building in the 'close to carbon neutral' category, well above South Australia's minimum 5 Star compliance (which is assessed as equivalent to requiring 21kWhr/day in this climate zone).

PROJECT DETAILS	
Architect:	Emilis Prelgauskas
Engineer:	Lindsay Ames
Builder:	Owner Builder

Principal author:
Paul Downton

Floorings and finishes

Family ownership is expressed in the detail of the limestone wall, with a wave form between the faced limestone and upper levels of render, displaying the son's geological rock samples from around the planet.

Rainwater

The house has 80,000L rainwater tank capacity to store captured roof water. Water efficient fixtures were selected to minimise consumption.

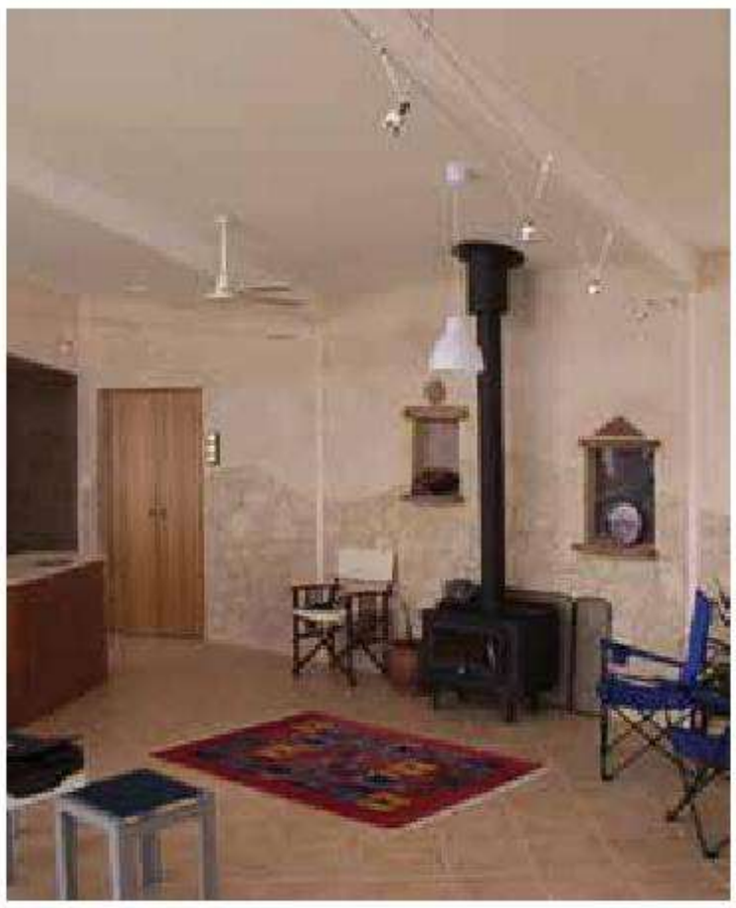
Water heating, energy and appliances

Heating is by slow combustion wood stove. Appliances run from bottled gas. Kitchen appliances have been selected for their energy efficiency. Hot water is provided by a close-coupled solar system.

The house is powered from a 1.3kW photovoltaic array on the roof of the nearby garage that also houses a 1100ah 48V battery bank and a 2kW inverter with remote in-house read out.

Landscaping and site impact

The site is relatively exposed and denuded. It now provides a secure base for the family to continue land revegetation activities and bring in student groups for study stays at the property.





Canberra ACT

NEW HOME

ZONE 7: Cool temperate



Topics covered	
Passive design	
Rain water	
Embodied energy	
Greenhouse gas reduction	
Indoor air quality	
Sustainable materials	
Renewable energy production	
Bio-septic treatment	
Autonomous from electricity grid	
Active solar shading devices	
Solar hot water	
AccuRate (thermal comfort)	6.8 (regulatory)

The brief for this house was for a building with the highest possible environmental credentials. It is of mud brick and recycled timber construction, is independent of the electricity grid, and is powered by a large photovoltaic system.

DESIGN BRIEF

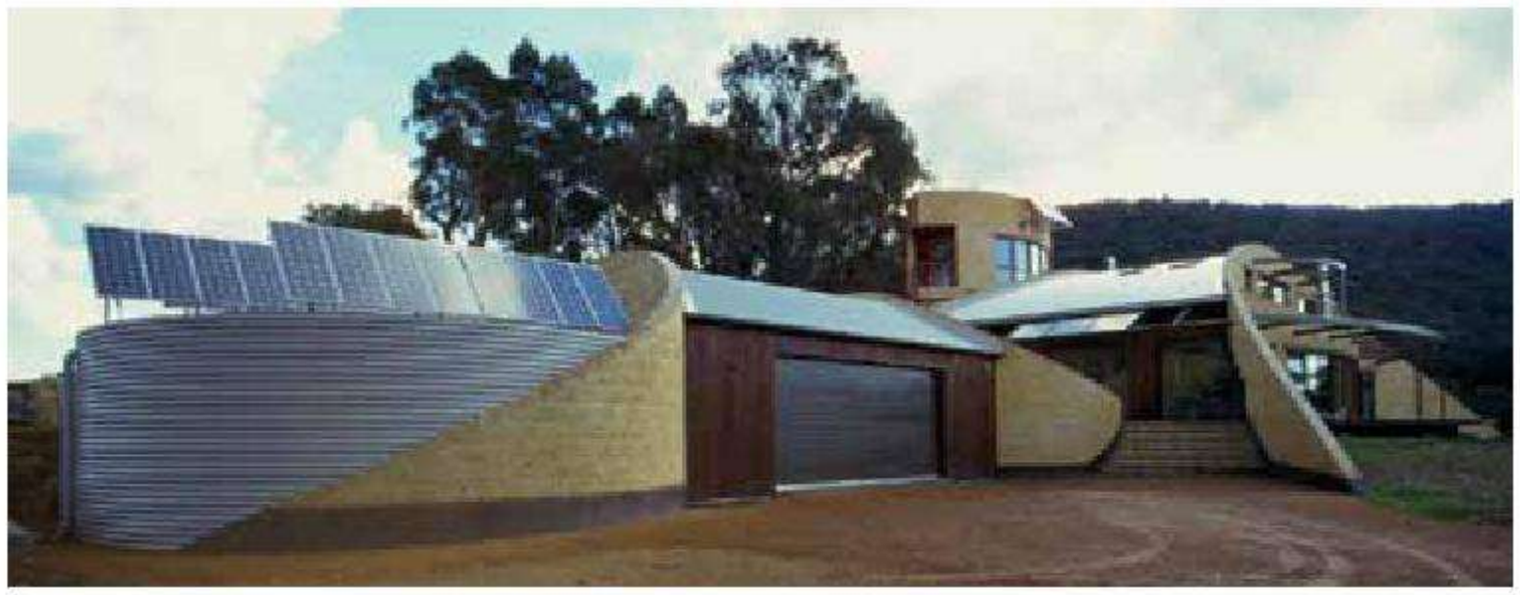
The clients' brief was to produce a thoroughly environmental building. The architects adopted virtually every strategy possible to create an exemplary environmental building. Last year TT Architecture won a national environmental building award for the visitors centre at Tidbinbilla nature reserve in the ACT. This building is a natural progression of the trend set in the Tidbinbilla project towards autonomous buildings.

The building is a fine example of environmental house design, and is well suited and appropriate for the region.

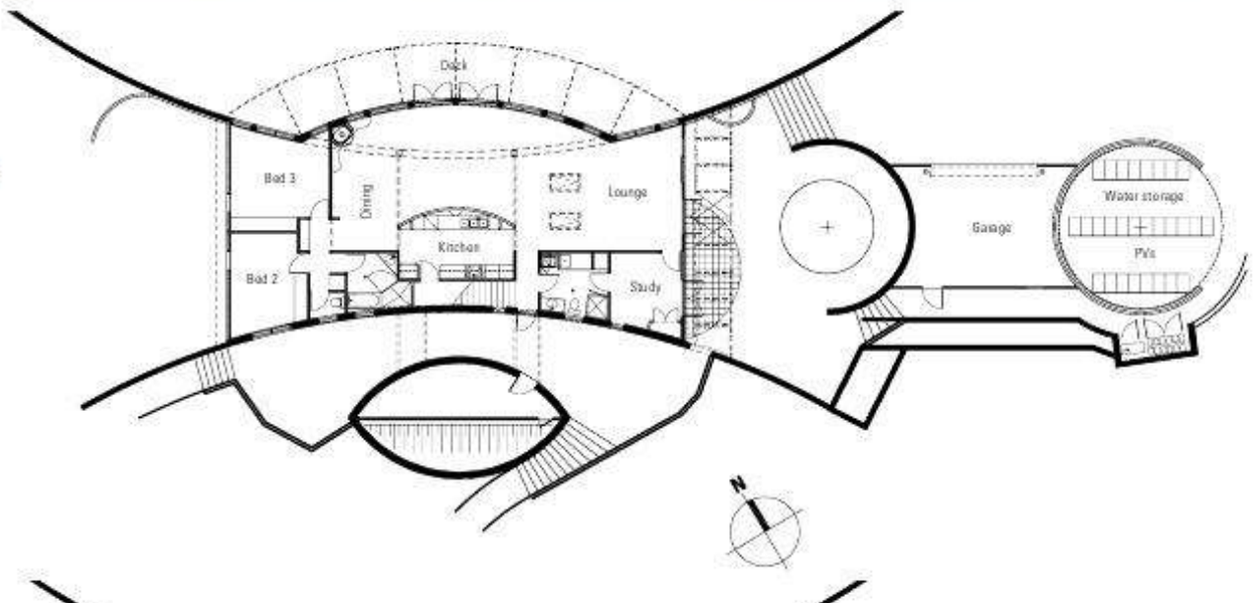
THE SITE

The site is in a rural location 30km west of Canberra (ACT), at a higher altitude than most of Canberra and right on the border of NSW. The site was selected to give maximum views of the Canberra district, to enable a house on the site to respond to the local topography and to maximise winter solar gain within the house.

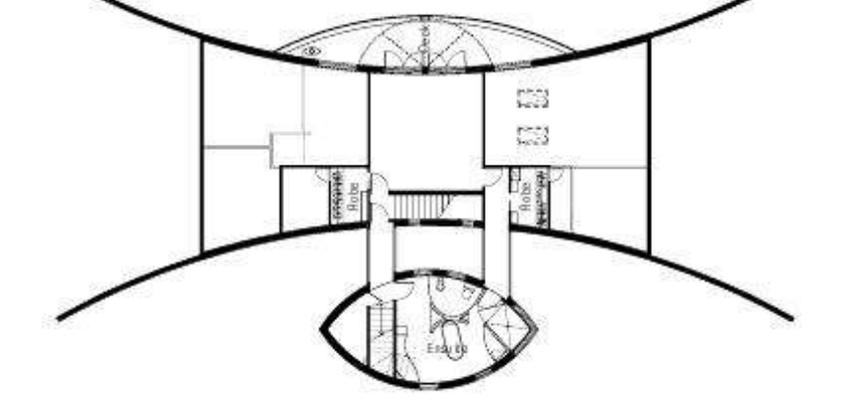
[See: 2.2 Choosing a Site]



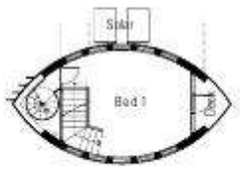
Ground floor



First floor



Second floor



THE CLIMATE

The local climate is classified as cool temperate and the main characteristics of this climate are:

> low humidity.

> high diurnal range.

> four distinct seasons.

> summer and winter conditions exceeding human comfort range.

> cold to very cold winters.

> rainfall shared fairly evenly through all months of the year.

> hot, dry summers.

> variable spring and autumn conditions.

> cold winter and hot summer winds from the north-west.

> cool summer breezes from the south-east.

[See: 4.2 Design for Climate]

DESIGN AND BUILDING FORM

The house is designed with very high levels of thermal mass, good orientation and excellent insulation. The thermal mass takes the form of concrete floor slabs and internal masonry construction.

The following is a list of some of the issues that were taken into account during the design and construction of the dwelling.

MATERIALS

The house is constructed from locally manufactured mud bricks and recycled timber. The form of the building, with curved earthen coloured external walls, is intended to give the impression of a structure that rises directly out of the ground. The selection of materials brings together the overall environmental theme of the project.

The Scully home is a comprehensive attempt to create an environmental exemplar of a national standard. [See: 5.0 Material Use]

INSULATION

Styrofoam boards have been used at the edge of the slab and under the perimeter of the slab to minimise the losses in this area.

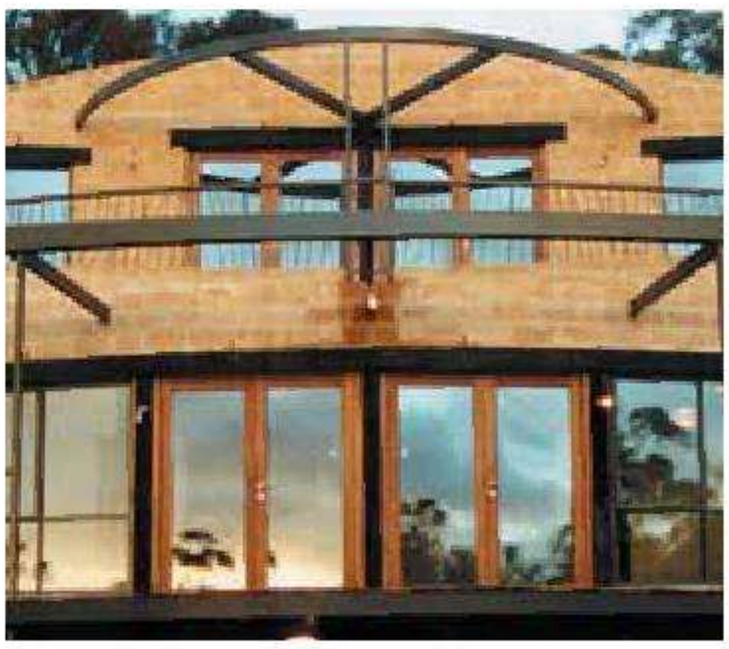
Polyester batts have been used in the ceiling as insulation.

The external cavities have been filled with rockwool insulation to improve their thermal performance. The rockwool is a benign substance and it should be noted that the cavities have been made wider than standard (at 100mm) to allow for a higher level of insulation. [See: 4.7 Insulation]

THERMAL MASS

The house is generally of high thermal mass construction. It has external double masonry walls, and the internal skin uses rendered clay bricks. The clay bricks add significantly to the total available thermal mass inside the skin of insulation. The building is built on a concrete slab. This high thermal mass construction is the most appropriate design response for the local climate which experiences high diurnal range. [See: 4.9 Thermal Mass]

WINDOWS



The windows have an external frame of aluminium and a timber frame and reveal internally. These windows provide a low maintenance solution to weathering yet have a significantly higher 'R' rating than aluminium–only frames. The windows are all double-glazed and perform as well or better than timber double-glazed equivalents. [See: 4.10 Glazing]



MATERIALS

Recycled materials

Significant effort has been made to source recycled materials for this building.

> **External cladding** is fabricated from recycled brushbox from the Walsh Bay wharf in Sydney.

> **Joinery** throughout the house has been made from either hoop pine from plantations in Queensland or blackbutt recycled from the Kingston foreshores site in Canberra.

> **Lintels** are made from ironbark, sourced from the old Pyrmont Flourmill in Sydney. Some of these lintels and massive structural posts are up to 100 years old.

> **Flooring** in the kitchen and the stairs is made from red mahogany, a rare timber native to the coastal forests of south-eastern Australia. It is now only available as recycled timber. The remaining floors are made from blackbutt, which grows in the same area as the red mahogany. The red mahogany was recycled from government workshops that were demolished at the Kingston foreshores site, and the blackbutt came from the old Pyrmont flourmill. The flooring is laid on the concrete slab. [See: 5.3 Waste Minimisation]

Mud bricks

The external walls of this house are constructed of mud bricks made locally. The bricks were strengthened by the addition of cement to the mix, and were strength-tested by the CSIRO. The bricks were all made by hand at the Old Canberra Brickworks and transported to site. Rather than being laid as puddle blocks in the traditional manner these blocks are used as the external skin in a cavity construction.

Paint

Natural organic paint has been used in this project that does not give off potentially hazardous vapours. The vapour from normal paint contains numerous toxic chemicals including pigments, solvents, dryers and fillers.



Reconstituted wood products

No reconstituted wood products (such as particleboard) were used in the house. The binding agents used in these products produce and release formaldehyde gas as they cure, a process which can take up to three months. Formaldehyde is an unpleasant smelling irritant and possible human carcinogen. The lengthy curing period means that both contractors and occupants are exposed to the gas.

GREYWATER AND SEWAGE TREATMENT



The house uses a novel approach to sewage treatment. A Bio-septic system takes the sewage product of the house, and after macerating it, sends it to a tank containing a reed-bed system. This tank uses the sewage as a natural nutrient source for the reed-bed. The effluent from the bio-septic tank is filtered with sand and ultra-violet light and produces water of a suitable quality to use in gardening. In fact this water comes out so clean that both the clients and the architect have drunk it.
[See: 7.4 Wastewater Re-use]

POWER

Power connection

The house has no connection to mains power. Power is drawn from an array of 28 photovoltaic panels mounted on top of the stormwater tank. These feed into a sub-system of 24 large batteries and inverter housed in a custom designed store. The complete system produces approximately 13 kilowatts of power using BP Solarex monocrystalline solar modules, and includes an 8.5KVa gas generator as a backup. The system is fully automatic. [See: 6.7 Photovoltaic Systems]



Solar hot water system

Two solar hot water panels mounted on the rear tower provide the hot water for the house.
[See: 6.7 Solar Hot Water]

OTHER FEATURES

Adjustable shade structures

The house incorporates adjustable shade structures to the north. This enables the house to be suitably shaded in the summer. With the removal of the structures in winter the winter solar gain is improved. [See: 4.4 Shading]

Water efficiency

The landscape plan has been devised with low water use in mind. The large 20,000L water tank makes the house self-sufficient for water needs. [See: 2.4 Sustainable Landscapes; 7.3 Rainwater]

Lighting and appliances

Wherever possible (lights, fridge etc) low energy appliances and fittings have been used, with little or no sacrifice in comfort or convenience.
[See: 6.3 Lighting; 6.4 Appliances]

Heating

Despite the fact that the high energy rating of the house will make it largely self-heating, a heating system has been installed. This system relies on reticulated hot water feeding into radiant panels mounted throughout the house. When necessary this system will operate on overcast winter days. It will be run on bottled gas powering a high efficiency hot water tank.
[See: 6.2 Heating and Cooling]

Building process

The building process has revealed many areas of technical difficulty and innovative construction. Dowse Building has shown much ingenuity in solving the constructional issues as they arose and have always been on hand to offer positive advice to the clients and the architects.

PROJECT DETAILS	
Architect:	Tony Trobe, TT Architecture
Builder:	Ron Dowse, Dowse Constructions

Principal author:
Geoff Milne

Clayfield QLD

MEDIUM DENSITY
ZONE 2: Warm humid summer, mild winter



Topics covered
Passive design
Rain water
Renewable Energy production
Indoor air quality
Orientation
Embodied energy

AccuRate (thermal comfort)	5.1 (full rating)

These medium density walk-up apartments were developed to test the commercial viability of a multi-residential development which addressed issues of sustainability. The 14 two bedroom units were designed to make maximum use of the site in terms of town planning allowances and market demand. The project stemmed from a display by the architect as part of the 2003 World Environment Day Sustainable Apartment prototype in Brisbane.

SITE AND CLIMATE

The site is located in the Brisbane suburb of Clayfield around 6 km north-east of the CBD and is situated close to rail and bus transport. From Clayfield out to Morton Bay in the east there are few topographical obstructions so the location enjoys breezes off the bay as well as Brisbane's benign sub-tropical climate.

The block was an amalgamation of house lots as well as a central parcel of land which was a redundant piece of road terminating at the rail line; this was purchased from the council. Along the southern edge, the site is bounded by a minor rail line or 'spur' line, while busy Sandgate Road is off to the east.

There were a number of significant existing trees on the site, particularly to the north and west, which were retained and used to the advantage of the scheme. Boundary relaxations were granted in part due to this.

Much of the success of the scheme relies on achievements made during the development approval phase, The design team enjoyed working closely with Brisbane City Council's Sustainable Design Unit to get the best outcome in terms of sustainability.

Construction system

The construction concept was to exploit the properties of both lightweight and thermal mass construction systems.

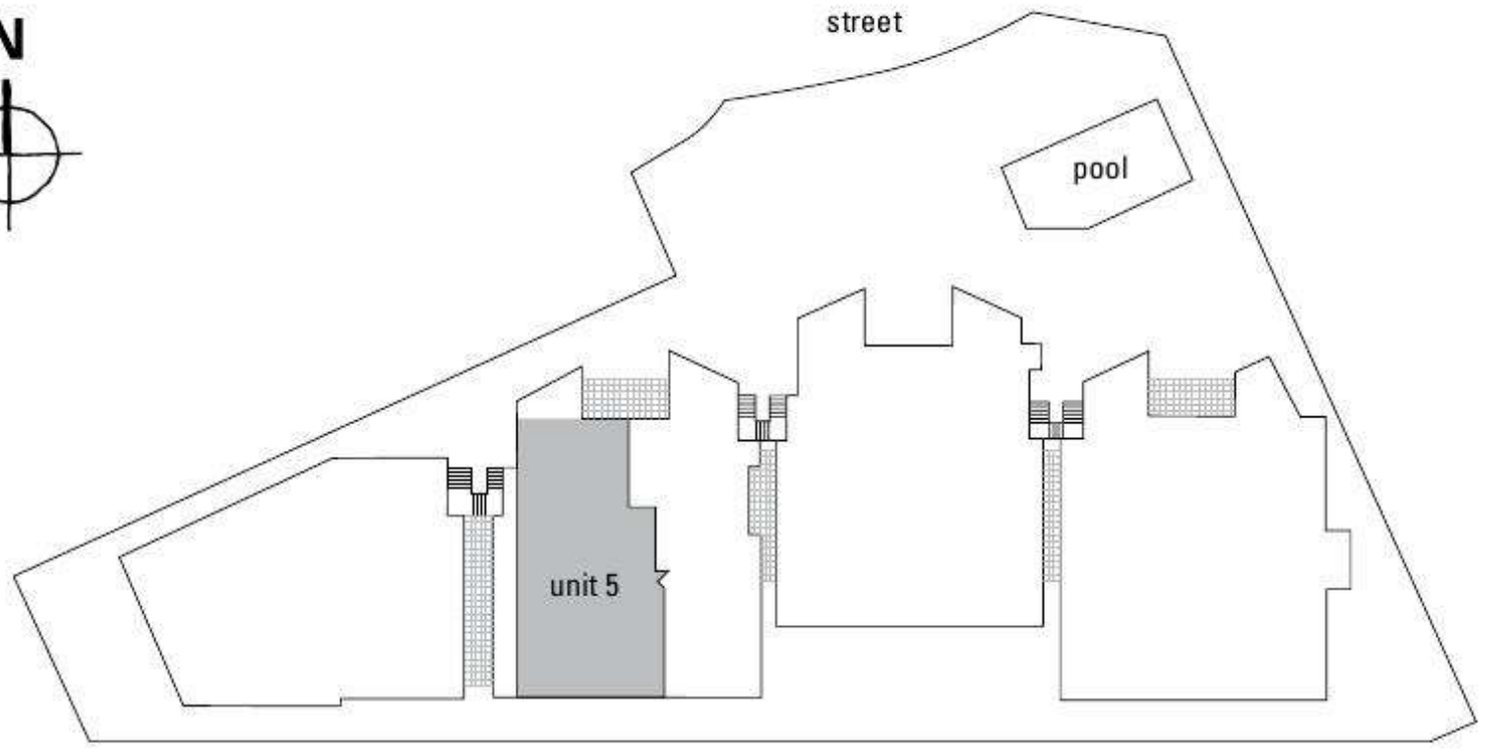
Thermal mass was provided by the use of concrete slabs and blockwork at the ground level to gain the benefits of earth coupling and to upper level walls protected from solar radiation. When protected from being heated up by direct sunlight, thermal mass serves to stabilise the temperature promoting cooler indoor temperatures in summer and buffering the cold in winter.

The upper level walls which are subject to direct solar radiation are largely comprised of lightweight timber stud framing with a proprietary autoclaved aerated concrete panel system. Lightweight construction systems respond better when subject to the heat of the sun by cooling down much faster than high thermal mass construction. Aerated concrete panels also have good insulation properties due to the amount of air in the composition of the material which means they will assist in heat retention in winter. [See: 5.11 Autoclaved Aerated Concrete]









Orientation

Despite being a challenging shape the site is well orientated with its length running north and south. The units are orientated with their outdoor living spaces to the north with adjacent indoor living, and with bedrooms generally to the south. North facing living areas enjoy low winter sun but are roofed to protect from the heat of the summer sun.

Shading

The covered verandahs provide shading, particularly in summer, to the north façade. To the south a large existing mango tree has been incorporated into the scheme to draw cool air from it though the breezeways. The west of the development gains protection from two significant existing trees. Additional hood awnings and batten sun shading is placed on windows that require extra protection as well as circulation and breezeway areas. Vegetated trellis screens provide shade to north facing basement walls. [See: 5.13 Green Roofs and Walls]

Glazing

Double glazed windows are provided to the south elevation which overlooks the train line, providing both thermal and acoustic benefit to the dwelling.

Ventilation

The main feature of the project is the cross ventilation achieved by having each apartment open on three sides; all living zones and most bedrooms feature cross ventilation with windows on two sides of the rooms. Breezeways between each pair of apartments create opportunities to bring daylight and natural ventilation into the depths of each apartment. The breezeways were designed with blade obstructions which deliberately create a venturi effect, in inducing airflow past the units via the creation of positive and negative pressure zones.

There is some potential to naturally ventilate the bathrooms, despite a lack of external walls, by way of using high level internal windows and the laundry to separate bathrooms from the kitchen.

The ground floor of the building is taken up by basement car parking. With most of the apartments raised to the first and second level they are better positioned to catch prevailing breezes. Additionally this arrangement means that the basement requires no mechanical ventilation.

Insulation

The insulating qualities of the AAC panel wall cladding reduced the general need for additional bulk insulation to the walls of the building. Some bulk insulation was used to provide acoustic insulation from nearby noise sources. Reflective foil sarking was provided to all walls and Insulation was provided to the roof with R2.5 foil backed polyester blankets.

BERS rating

The project was initialled modelled using the BERS software with all units meeting a 4 to 5 star rating level.

Embodied energy

Consideration has been given to the selection of materials with low embodied energy in their manufacturing process. The architect also adopted a holistic approach by considering the impact of the lifecycle maintenance for various materials, as well as the potential of materials to be recycled in the future. There has also been an effort to source locally manufactured products where possible. Such materials include:

> Low toxicity external paint and coating systems from local manufacturer.

> Battening and decking made from a pre-finished hardwearing composite material of recycled plastic and sawdust that requires no initial painting or finishing and no maintenance in the long term, whilst providing the vernacular aesthetic of timber.

> Hardwearing pre-finished bamboo flooring from a renewable source was specified to reduce the need for on-site coatings to assist in indoor air quality.



> Autoclaved aerated concrete panels.

> Low-emission particle board.

> A low VOC (volatile organic compound) paint was used for internal finishes as well as selected external painting to promote good health with a higher indoor air quality; this product was certified by the Australian Greenhouse Office as being 'Greenhouse Friendly' (100 per cent greenhouse neutral.)

> Floors on the basement level were specified as 'eco-concrete' with recycled crushed aggregate mix.

> Crushed concrete was used in the landscaping instead of riverstone pebbles.

Heating/cooling system

While perceived market demand meant that split system air-conditioning units were provided, the apartments were deigned to reduce if not eliminate the need for active heating or cooling systems. An energy efficient model of air-conditioner was specified.

Ceiling fans have been provided to all bedrooms and living rooms.

Lighting

Light fittings have been selected for their energy efficiency comprising mostly of compact fluorescents with some low voltage IRC dichroics. Common areas have timed sensor lighting which in the larger basement areas is also zoned.



Designing for cross ventilation to all habitable rooms has the added benefit of providing enhanced daylighting to the units. The quantity and depth of daylight penetration increases with the number of glazed fenestrations provided but just as importantly the quality of light is enhanced due to the provision of multi-directional light sources. This helps to reduce the effects of glare and provides overall good quality lighting reducing the need for artificial lighting during the day.

Solar tube roof lighting has been added to the upper level units to provide natural daylighting to the bathroom areas. Vertical openings in the breezeways bring light down into the lower level breezeways, assisting in providing diffused light to these spaces.

Fixtures and Appliances

Another feature of the development is the relatively inexpensive addition of an energy monitor to each unit. The proprietary simple monitoring device provides constant real-time feedback to the resident, assisting in educating them on the amount of energy various appliances require and empowering them to make lifestyle decisions and changes to further contribute to saving energy.

Gas stovetops and water heating also help to reduce energy consumption.

Drying courtyards and external clothes lines encourage residents to use passive means of drying clothes.

The development is fitted with water efficient tapware, showerheads, toilets and dishwashers.

Hot water

The development is supplied with a reticulated central gas hot water system, further reducing reliance on mains electrical power.

Rainwater

Rainwater is collected in two 30,000L concrete tanks which are buried underground and coupled with variable speed submersible pumps. The rainwater is used for toilet flushing, balcony taps, subsurface irrigation of the garden, car washing and to top up the pool, overall providing 55 per cent of the project's water requirements.

Renewables

A 1kw photovoltaic system provides power to the communal areas of the building. The system is connected to the grid and provides the economic benefit of greatly reducing the body corporate fees.

Site impact

The design largely balanced the cut and fill which occurred on site. The development collects a lot of the water the site receives and the landscaping has been carefully designed to filter any groundwater run-off through garden beds before it enters the stormwater drains.



Landscaping

A local nursery provided great assistance in the selection of plants that require little water and were appropriate to the area; this included a mix of exotic and native species.

Other issues

The development encourages recycling; there are recycling stations in the common areas and each apartment is fitted with a recycling cupboard for the temporary storage of rubbish. Provision has been made for composting in communal areas and the wormfarm in particular has been a big success.

Over half of the apartments sold prior to completion of the project and the majority of them are owner occupied. Most of the owners did not cite sustainability as a reason for purchasing the apartment however many of the residents have now engaged with the optional environmentally friendly measures.

PROJECT DETAILS	
Architect:	Mark Thomson, TVS Partnership
Developer:	QM Properties Pty Ltd

Principal Authors:
Richard Hyde
Catherine Watts

City of Adelaide SA

MEDIUM DENSITY

ZONE 5: Warm temperate



Topics covered

Passive design
Lifestyle modification
Rainwater harvesting
Waste reduction
Wastewater recyc.(proposed)
Greenhouse gas reductions
Indoor Air Quality
Reducing transport impacts
Embodied Energy reduction
Renewable Energy production
Food Production

AccuRate (thermal comfort)	6.9 (full rating)

This case study shows how a mixed density community housing project addressed the lifestyle and environmental impact features listed below within a reasonable budget in a difficult inner-city context. These homes, like other case studies, cost less to run whilst providing year round thermal comfort and a healthier environment for the occupants.

This Study is of 14 dwellings that include linked 3 storey townhouses with full solar orientation, a 3 storey block of six apartments with east-west orientation and a full roof garden, three 2 storey strawbale cottages and a 3 storey strawbale townhouse. As part of the development there is also a 5 storey apartment building containing 13 apartments with community facilities (meeting room, library, kitchen, toilet and 'interpretive room') that serves the whole Christie Walk site. [See: 10.1 City of Adelaide SA]

The project was designed for a group of clients represented by a development cooperative, Wirranendi Inc., and created by the non-profit educational association, Urban Ecology Australia Inc. The purpose of the cooperative was to create community-based projects that maximise environmental performance and energy efficiency. The cooperative structure provided a means for people to build for themselves in urban environments where single house blocks are rarely available. The clients included first-time home buyers, investment purchasers, experienced home owners seeking the advantages of an urban lifestyle and older people wanting to retire in an active, mixed community.

With reduced car park provision and no internal traffic, the site was developed to take advantage of its inner-urban location within easy walking distance of Adelaide's Central Market and public transport services. [See: 2.3 Streetscape]

The project is on a T-shaped site the size of two quarter-acre blocks in inner-city Adelaide, South Australia. The site is small, awkwardly shaped and severely constrained, with buildings hard on or close to most of the boundaries. The constraints of the site made it impossible to provide all the buildings with ideal passive solar orientation. [See: 2.2 Choosing a Site; 4.3 Orientation]

Adelaide's climate is 'Mediterranean' with warm to hot summers and cool winters. It is subject to 'cool changes' when temperatures can plummet from the high 30s to low 20s (degrees Celcius) in less than an hour. Although the City of Adelaide rarely experiences freezing temperatures it can feel very cold. Buildings need insulation to keep heat in during cold weather and keep heat out in hot weather. [See: 4.2 Design for Climate]

The land was owned by the Wirranendi development cooperative during construction and individual properties were then sold on a community title. Each purchaser owns their own dwelling but also shares ownership and responsibility for the landscaped community areas that include a productive community garden and roof garden. On completion, the ground floor of the 5 storey apartment building will include a shared kitchen and laundry and small, general purpose hall for parties that won't fit in small apartments.

House and apartment prices were intended to include all the community areas and facilities that would eventually be provided and have ranged from the low $200,000s to $425,000. The non-profit structure of the development cooperative and its 'in-house' building company played a key role in keeping house prices in a range comparable to conventional inner-city properties in Adelaide.



DESIGN BACKGROUND

The brief demanded energy efficiency and high overall ecological performance. User participation in the development process and an ethical investment funding base were also important. It was intended to demonstrate and trial both the problems and possibilities of ecological, 'community-driven' development on urban sites.

Concerns ranged from broader issues of community participation to the detail of specifying materials to create non-toxic, healthy homes.

The site was purchased cheaply and this helped to keep development costs down, but because the buildings are relatively innovative and possess exceptional levels of insulation, etc., they each cost a little more. An individualised approach to each dwelling design also added costs.

The structure of the first completed building, a straw bale cottage, was built by volunteer labour. This helped reduce 'start up' costs in the building program. Most of the construction has been via a conventional building contract with some augmentation by volunteer labour. The timeline for the development was stretched by a series of unforseen circumstances and provided a series of financial challenges for the cooperative.

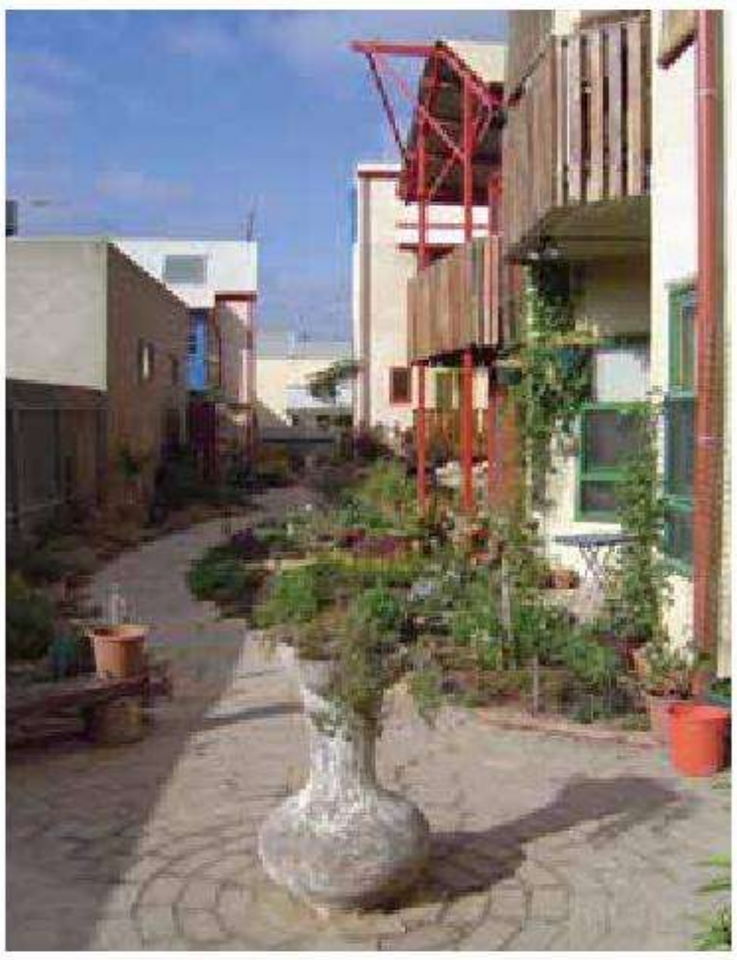


STRATEGY

The overall strategy was to use high internal mass within highly insulated envelopes with multiple user-controlled ventilation options and thermal flues. Vegetation and outdoor spaces were included as an integral part of the passive house design approach. Smaller house plan areas were favoured with quality of space considered more important than mere quantity. This is most clearly demonstrated in the first cottage built on the site, a two-storey, two bedroom straw bale house of just 55m^2.

A range of dwelling types are represented in the project with differing configurations; 4.3 Orientations and construction systems that demonstrate the effectiveness of environmental design for various conditions and lifestyles.

The 2 and 3 storey cottages are detached structures but the 3 storey townhouses are linked. Solar control for the cottages and the first six apartments is limited to controlling east/west sun penetration (traditional timber shutters are planned for the apartments). The other dwellings have ideal solar orientation. Solar access angles dictated building heights and form within the site. Solar access to the neighbouring childcare centre was protected by careful design of roof profiles.



Plan and orientation

Each dwelling was individually designed but also planned to fit with its neighbours to create an urban environment of secluded gardens. Balancing privacy with shared community space was a requirement addressed by the creation of an internal pedestrian street based on the theme of a walled garden.

Shell fabric

Construction includes 300mm thick load-bearing autoclaved, aerated concrete for all external walls on the six apartments and linked four townhouses. 400mm load-bearing, low-strength concrete ('earthcrete') was used for much of the internal mass party walls between townhouses. There is some steel framing in the apartment building construction and these have reinforced concrete slabs on all floors. Timber-framed non-load-bearing, rendered 500mm straw bale walls were used for the cottages. [See: 5.5 Construction Systems]



Pinus radiata proprietary trussed joists are used in the townhouses with plantation pinus or recycled timbers for joists in the cottages. Floor decking is generally pinus radiata. Joinery makes extensive use of Ecopanel, a compressed straw equivalent to particle board, containing no woodchips or formaldehyde. Unfortunately, the Australian company that made the sheets no longer operates and any equivalent product would now have to be imported.

All the buildings are set on stiff reinforced concrete slabs designed to resist the effects of Adelaide's notoriously unstable clay soils. The high volume of material content of the slabs was necessary to carry the townhouses and apartments and is justified by the small building footprints and their long life span.

Each house works as a 'thermal flue' allowing controlled release of warm air whilst drawing in filtered, cooled air from the vegetated, landscaped surroundings. In a real sense, the development is not complete until the accompanying landscaping is complete. The apartments rely on good cross-ventilation and high thermal mass for cooling with the roof garden adding a thermal buffer to the upper floor apartments.



The planned life of the buildings is in excess of 100 years. During this time the shells are expected to remain much the same but internal partitions, doors and windows – made mostly from renewable materials – may be changed.

Thermal mass

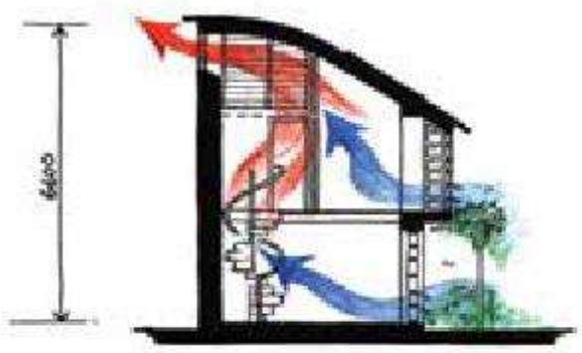
The concrete slabs provide substantial internal mass, particularly to the cottages and apartments. With no freezing days, perimeter insulation of the slabs was not regarded as necessary. The 'earthcrete' walls place additional thermal mass between the townhouses and assist in noise reduction between dwellings. The cost and logistical problems associated with poured concrete technology prompted a change to thick masonry walls in the apartment and townhouse buildings. [See: 4.9 Thermal Mass]

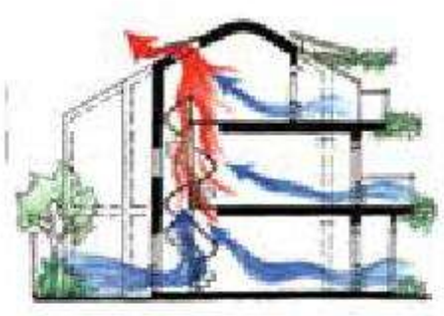
Ventilation

Good ventilation is critical to the performance of these buildings. Fresh air is filtered and cooled by surrounding vegetation and landscaping and drawn through the dwellings by convection. Many opening windows are small, top-hung and set low in sets of two or three to draw in the low lying cooler air. Purpose designed vents, high level louvres, or ventable skylights exhaust warm air at the top of the dwellings. They create outlets for the thermal flues formed by the stairwells of each dwelling. [See: 4.6 Passive Cooling]

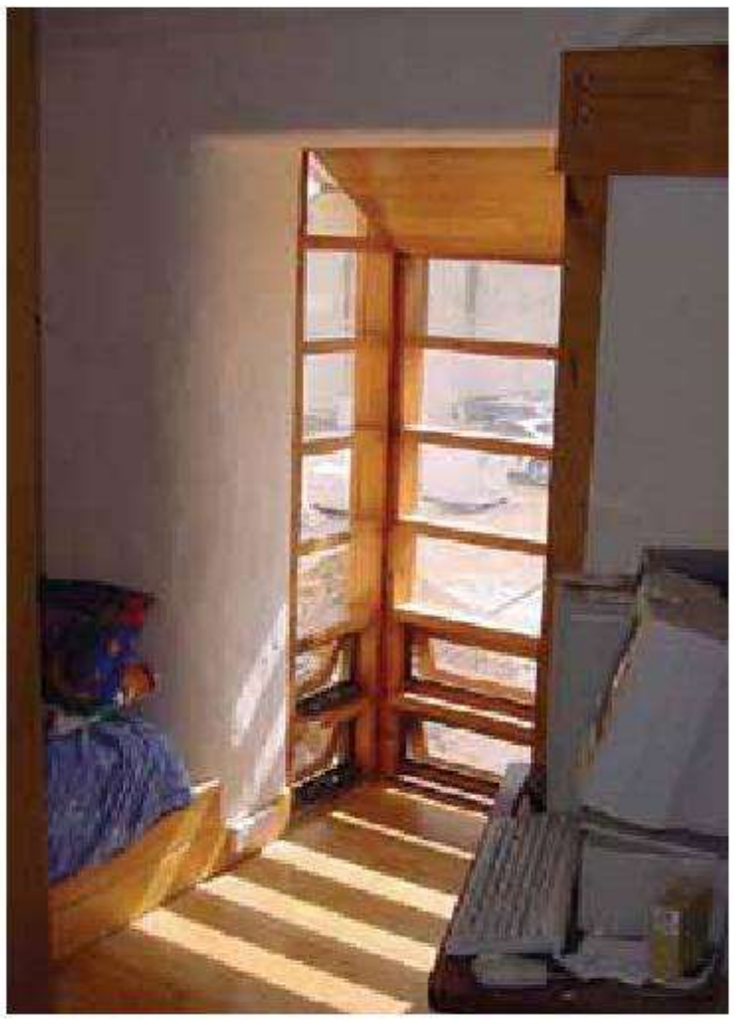
Windows and glazing

Windows are all purpose-made from recycled timber.





All fixed windows are double-glazed. Sealed units are used throughout except for the first 2 storey cottage. Louvred windows are single glazed because they represent a small proportion of the glazed area and are expected to be open most of the year and will thus only lose a small amount of heat during cold periods.



Materials

Non-toxic construction and finishes are used throughout, avoiding products that could emit formaldehyde. The design team chose to use minimal amounts of PVC. Timbers are plantation Pinus radiata or recycled (typically, oregon). The environmental plus cost criteria for materials led to unexpected choices with aesthetic benefits, eg. purpose-built spiral stairs in steel and recycled jarrah. [See: 5.1 Material Use Introduction; 5.3 Waste Minimisation]



All concrete in slabs and mass walls contains the maximum percentage of flyash that the engineers and suppliers would allow. Flyash is a waste product from power stations and its use reduced the amount of new cement used in the construction. Cement production is one of the largest contributors to global greenhouse gas emissions.

Insulation

Insulation is provided to the townhouses and apartments by 300mm AAC walls. 450mm straw bales insulate the cottages. A basement in one of the townhouses is insulated by earth berming and provides additional 'coolth' to that dwelling. Ceilings generally follow the roof-lines and are insulated with reflective foil sarking and 150mm polyester batts. The preferred option of cellulose fibre (recycled paper) insulation was not appropriate due to the sloping ceilings. [See: 4.7 Insulation]



Floorings and finishes

Flooring throughout is generally a modern variant of linoleum that was selected on its aesthetic merit and environmental credentials. It consistently tops the list of 'green' proprietary flooring materials in studies around the world and allows a rich design palette of colour and pattern. Wet areas are tiled with ceramic tiles. Some clients have chosen ceramic tiles for living areas and others, including the owner of the first straw bale cottage, chose bamboo flooring in some areas. This attractive and environmentally promising material is currently only available as an imported product but Australian plantations and production are supposedly imminent.

All finishes are chosen on the basis of environmental and non-toxic criteria. Externally, it has been found necessary to use more conventional formulations to cope with Australian conditions.



Lighting

Considerable effort was made to ensure naturally well-lit rooms and spaces. Light fittings are conventional, with almost a 100 per cent use of compact fluorescents. [See: 4.10 Glazing]



Heating and cooling systems

Some ceiling fans are included to assist in maintaining air flow on still days, but no heaters or air-conditioners were provided and the expectation was that none would be needed to supplement the passive heating and cooling of the houses. [See: 4.5 Passive Solar Heating; 4.6 Passive Cooling]

Stormwater

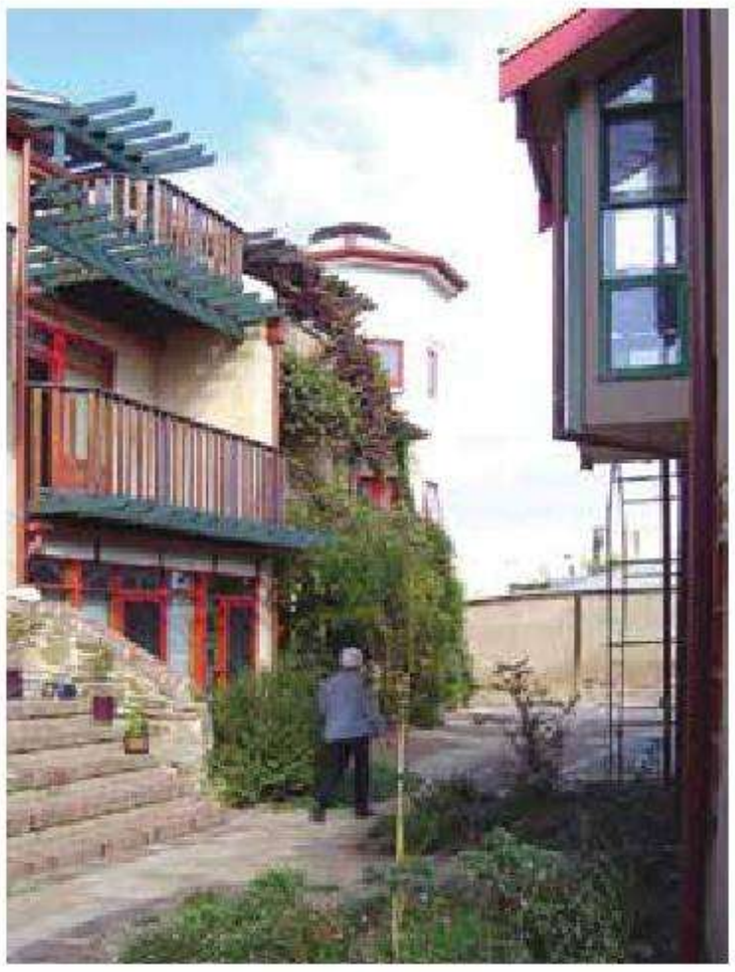
Water shed by the roofs, balconies and other impervious surfaces is collected for use on site in two 20,000L underground tanks situated beneath the carports. The water is used for irrigation and toilet flushing, reducing total water importation to the site. [See: 7.3 Rainwater]

Greywater and Blackwater

Chlorine-free sewage treatment was planned. A Coast and Clean Seas grant enabled the provision of a sewage mining system (by Resource Recovery) but its running costs were such that the community corporation decided to retire its use. The Christie Walk community revisited the challenge of on-site treatment of black and greywater and negotiated an innovative onsite treatment system with the support of Adelaide City Council and SA Water, but the water utility withdrew its commitment to the system in late 2007. [See: 7.4 Wastewater Re-use]

Hotwater and fittings

All dwellings have solar hot water with electrical backup. The apartments have a shared system with banked solar panels and a gas-fired boiler backup. Low water use shower heads help control the water supply. Some proprietors have installed under-bench filters that provide drinking water at low flow rates.



Energy supply

Mains electricity is drawn from the grid but the Stage 3 apartments roof carries some 5kW of photovoltaic panels that generate electricity for sale to the local energy utility. The original hope had been that the site will export energy for much of the year because the dwellings require little energy for space and water heating, cooling or lighting.

Major appliances

All new appliances have high energy efficiency ratings. Companies with a recycling program were favoured when specifying appliances. 5 of the dwellings have gas cooktops, all dwellings have high efficiency electric ovens. Gas was initially favoured for its energy efficiency but the improved efficiency of electric cookers and concerns regarding indoor air quality led to the developer specifying electric-only appliances in the latter stages of the project. [See: 6.4 Appliances]

Site impact

The site was occupied for predominantly commercial and some residential use prior to redevelopment. The overall site impact might be regarded as positive as the project retains nearly all stormwater on-site and there is already a considerably more productive and vegetated landscape after redevelopment than before. [See: Biodiversity On-site]



Landscaping

Native and indigenous species and plants with low water requirements were used. Some exotics were used where appropriate to suit passive design considerations (the largest tree will be a deciduous Neem). Exotics and productive food plants are supported by on-site water recycling that assists in maintaining minimal overall water consumption. [See: 2.4 Sustainable Landscapes]

The project's 'intensive' roof garden (the first in South Australia) is an important contribution to biodiversity and site amenity. [See:5.3 Green Roofs and Walls]

Waste minimisation

Paving and feature elements incorporate bricks, stone, steel and timber retrieved from demolition of pre-existing structures on the site. [See: 5.3 Waste Minimisation]

Noise control

The highly insulated external skins, double glazed windows and massive party walls make this a much better acoustic environment than might be expected in a dense urban setting. The passive cooling strategy requires windows to be open much of the time but the baffling effect of vegetation and absence of hard road surfaces contribute to relatively good noise control.

Transport and food

Reduction of transport demand and provision of food production capability were part of the strategy for this project. The site's location within walking distance of good public transport meant fewer cars were needed so Council planners supported a lower than usual car park provision, 11 spaces for fourteen 2 or 3 bedroom dwellings. Despite extreme site limitations it was possible to include a small community garden to demonstrate that even the tightest urban site can produce food. [See: 2.6 Transport]



EVALUATION

The non-profit development structure, ethical investment base and community involvement enabled this experimental project to proceed and withstand delays and personal tragedies. It survived where a conventional development would probably have been abandoned or changed beyond recognition.

The 'earthcrete' wall was difficult to construct and cost more than anticipated. As an attempt to provide affordable high-mass construction and as an alternative to rammed earth, it is moderately successful.

The building designs are being proven through occupation and use and the signs are that they are mostly successful. There is a tremendous sense of ownership and understanding about the designs that both reflects and reinforces the community basis of the development approach. People have been able to purchase much more than just a house in the city.



The community facilities are an important part of the project, providing a meeting place and a laundry. These facilities are part of the project's third stage of development – a small 5 storey building containing 13 apartments. [See: 10.1 City of Adelaide]

The use of recycled material and the requirement that residents lay the external paving has contributed to the creation of a creative, attractive environment. Any project not able to tap the same level of commitment and goodwill from its clients would be more expensive.

Rigorous cost planning requires good information that was not available the first time around but details and costs associated with the innovative approaches to construction and design have now been tested and refined. It should be much easier to predict programming and costing for future developments and to manage the interface between community engagement and conventional building processes.

The gardens are important to the community of Christie Walk as the landscaping has matured and the roof garden has become established, the importance of outdoor spaces and their relationship to the dwellings has been reinforced.

Independent studies by Monica Oliphant through Urban Ecology Australia and by Veronica Soebarto of Adelaide University (available from Ecopolis Architects) indicate that the buildings demonstrate a very high level of performance that can be significantly dependent on the patterns of use by their occupants. This reinforces an observation being made by a number of designers working on sustainable domestic design.

Awards

The project has attracted various awards including the Silver Prize in the Ryutaro Hashimoto APFED Awards For Good Practices from The Asia-Pacific Forum for Environment and Development (APFED).

PROJECT DETAILS	
Architect:	Paul F Downton, Ecopolis Architects.
Structural and Mechanical Engineer:	Sagero Consulting, Adelaide (Stages 1 and 2)
Landscaping:	Ecopolis Architects Pty Ltd (Chérie Hoyle) supporting on-site community initiatives

Principal author:
Paul Downton

City of Adelaide SA

HIGH DENSITY

ZONE 5: Warm temperate



Topics covered	
Passive design	
Rainwater harvesting	
Greywater use	
Renewable energy production	
Greenhouse gas reductions	
AccuRate (thermal comfort)	6.8 (full rating)

This study is of 13 apartments and community facilities in a 5 storey building on Sturt Street in the City of Adelaide. The apartments were opened in January 2007 and are the third and final stage of the Christie Walk development built for the non-profit cooperative Wirranendi Inc. They were designed to be energy and water efficient with a practical, healthy environment, and built to a budget to make them competitive with standard apartments with prices that ranged from $280,000 to $460,000 (in 2006) and included all community areas and facilities. Designed to accommodate up to 28 people, in 2007 its 18 residents ranged from retired individuals to families with young children.

LOCATION AND CLIMATE

The site is within easy walking distance of Adelaide's Central Markets, park lands and CBD, hence car use is minimised. Negotiation with the city council allowed for the provision of just 11 car parking spaces to cater for the needs of the 27 dwellings in the total Christie Walk development with no car spaces at all provided to service this building. [See: 2.2 Choosing a Site; 2.3 Streetscape]

The climate is 'Temperate' with warm to hot summers and cool winters. 'Cool changes' can see temperatures plummet from the high 30s to low 20s (degrees Celcius) in less than an hour. Although the City of Adelaide rarely experiences freezing temperatures it can feel very cold. Buildings need insulation to keep heat in during cold weather and keep heat out in hot weather. [See: 4.2 Design for Climate]



DESIGN

The building faces north and has a more or less square footprint of 260m^2 being about 16m on each side.

The ground floor comprises one apartment, an information centre operated by Urban Ecology Australia Inc., a central, naturally lit and ventilated lobby, and community facilities including; a laundry, common room and library, kitchen and toilets. These facilities are designed for the use of the whole Christie Walk development which includes 14 other dwellings as well as these apartments.

The first, second and third floors each contain 4 apartments, one in each corner of the building. The narrow site and high density of the



development limited options for solar orientation. The apartments surround a stairwell and lift shaft situated at the centre of the building. There is a fourth floor (fifth level) on the southern half of the building which contains the upper levels of penthouse apartments 12 and 13. Apartments 1 to 9 are all approximately the same in area (52m^2 excluding balconies) and consist of 2 bedrooms or 1 bedroom and a study, plus a living/dining/kitchen area and bathroom. They also have balconies facing outwards from the north or south side of the apartment. Apartments 10 and 11 which face north on the 3rd floor have slightly larger second bedrooms which cantilever out to the depth of the balcony.

Apartments 12 and 13 are on two levels and consist of 1 large bedroom plus a living/dining/kitchen area and bathroom on the lower level with a second bedroom, study and additional bathroom on the upper level.



Each apartment is personalised according to the owner's preferences and is slightly different in layout from the others. The interior walls in the apartments are deliberately made easy to shift so that the layout can be changed if required and consideration has been given to disabled access. [See: 3.2 The Adaptable House]

BUILDING STRUCTURE

Materials

The apartments are built on a concrete pad with exterior walls of 150mm autoclaved aerated concrete (AAC) blockwork and insulated studwork linings finished with 10mm plasterboard. The roof is steel decking. Steel sheet cladding is used on the upper penthouse levels on insulated steel framing and extends on the south wall of the apartments over the top of the AAC blockwork down to the third floor level.

The interior party walls between apartments are AAC with insulated studwork and plasterboard linings, whilst the interior walls within apartments are plasterboard with polyester acoustic insulation on steel studs. [See: 5.11 Autoclaved Aerated Concrete (AAC)]



The lift shaft and stairwell and an east-west party wall are made from precast concrete for structural strength and thermal mass. Exterior doors to the apartments are solid and fire proof, with timber facing whilst interior doors are solid plantation pinus. The concrete balconies have steel framed balustrades with recycled timber balusters. The floors are concrete slab with insulated suspended ceilings. In the apartments the floors are covered with linoleum or tiles selected by the owners.

There was little opportunity to use recycled materials in the structure except for the capping and columns on the ground floor verandah which were salvaged from the original house on the block and the recycled timber handrails.



Insulation

The steel roof sheets are laid on reflective foil sisalation and insulated with R3 polyester batts; this is extended on the south facing wall down to the bottom of the 3rd floor. The exterior walls of AAC have R1.5 polyester batts with foil backed plasterboard linings. The interior party walls and walls within apartments have acoustic insulation. The floors on the first floor apartments directly above the driveway have R3.5 insulation. The doors to the balconies have seals for draught and waterproofing. [See: 4.7 Insulation]

Heating

The apartments were first occupied in December 2006 and at the time of this study had not been through a full winter. They are not supplied with supplementary heating, however up until the end of May most residents have found the passive heating and insulation sufficiently effective to keep the apartments at a comfortable temperature. As an example, the minimum temperature in one of the north facing apartments was found to be approximately 20ºC after an outside, overnight minimum of 11ºC. The exception to this is the ground floor apartment where solar access is reduced by a verandah on the north facing wall and some additional heating is required in winter. (See: 6.2 Heating and Cooling)

Cooling and ventilation

Cooling is provided by two common evaporative cooling systems mounted in the east and west sections of the roof lantern structure which are ducted to each of the apartments. The cooling in each apartment is independently controlled by switching dampers in the ducting. The system then adjusts its fan speed depending on the demand. Internal ventilation is assisted by glazed louvres over the internal doors between the bedrooms and living areas and external sliding, sash windows. Ceiling fans in the living areas assist with the air flow.

The windows in the lantern above the stairwell are opened automatically to increase ventilation through the core of the building when the temperature exceeds 29ºC and closed to retain warmth when the temperature drops below 25ºC. [See: 6.2 Heating and Cooling]



Lighting

All lights in the building are compact fluorescent with lights in the foyer and stairwell being activated by movement and light level sensors. [See: 6.3 Lighting]

Covered with a semi-transparent layer of built-in photovoltaic cells, the roof lantern above the stairwell provides good natural light during daylight hours. [See: 4.11 Skylights]



Inside the apartments every living space is designed to have direct external light access and the glazed louvres over the doors to the bedrooms and bathroom allow the penetration of some additional natural light.



The north facing apartments on the third floor have additional features including a double glazed skylight in the kitchen area which can be opened to assist with ventilation. The second bedrooms which are extended to the level of the balcony, have a large north facing window which slopes inwards from the top to allow in winter but not summer sun.



Daylight penetration into the living areas of the south facing apartments is assisted by the bay window projections that extend to the depth of the balconies and allow light to enter the rooms through windows facing onto the balcony in an easterly or westerly direction.

The ground floor apartment although facing north has a verandah over the windows and is relatively dark. It is provided with small round clerestory windows in the living and bedroom areas for additional light.

Windows and glazing

All the windows and glass doors have sealed double glazing with untreated clear glass and a 10mm air gap with aluminium frames. The windows on the north facing side are shaded throughout the summer by the very deep eaves of the building and the balconies of the floor above. The window coverings are at the discretion of the individual owners but in most cases retractable double sided shades have been installed for privacy. [See: 4.10 Glazing]

Air quality

A healthy environment is maintained by using low volatile organic compound (VOC) paints and varnishes on interior surfaces. Floor coverings are tiles or linoleum. The interior doors and cupboard doors and skirtings are plantation pinus and the interiors of cupboards are all made from accredited low VOC particle board.

WATER

Hot water

Hot water for all the apartments is piped from communal heat pumps located on the roof of the building. This works like a reverse cycle air conditioner and pumps heat into the water from the atmosphere. The energy consumption of this is included in the total community electricity bill and is supposed to be at a similar level to solar heating but it has not yet been itemized. [See: 6.5 Hot Water Service]

Rainwater harvesting

Rain water from the roof of the apartment is collected, along with rainwater from the rest of Christie Walk, in two 20,000L tanks that were installed under one of the car park/ courtyard spaces during the earlier stages of the development. This water is plumbed into stages 1 and 2 of the development for use in the toilets and for irrigating the gardens around the site. The tanks are automatically topped up with mains water. [See: 7.3 Rainwater; 7.5 Stormwater]

Grey and black water

It was planned that by the end of 2007, grey and black water would be taken from the all of the Christie Walk dwellings to an organic composting system located underground at the rear of the building. The outflow from this system would be run to nearby Whitmore Square for irrigation. Although strongly supported by the Christie Walk community and Adelaide City Council, delivery of this innovative cross-sectoral infrastructure provision remains dependent on sponsorship by the SA Water utility.

Appliances

Other than the ovens and cooktops, appliances are chosen by the owners of the individual apartments. Gas is not supplied so all appliances are electric and generally chosen for their energy efficiency. Low water use shower heads are installed in the bathrooms. There is a community laundry on the ground floor of the building which is used by most residents. [See: 6.4 Appliances]

The one lift for the apartments was chosen for its energy efficiency.



Occupant behaviour

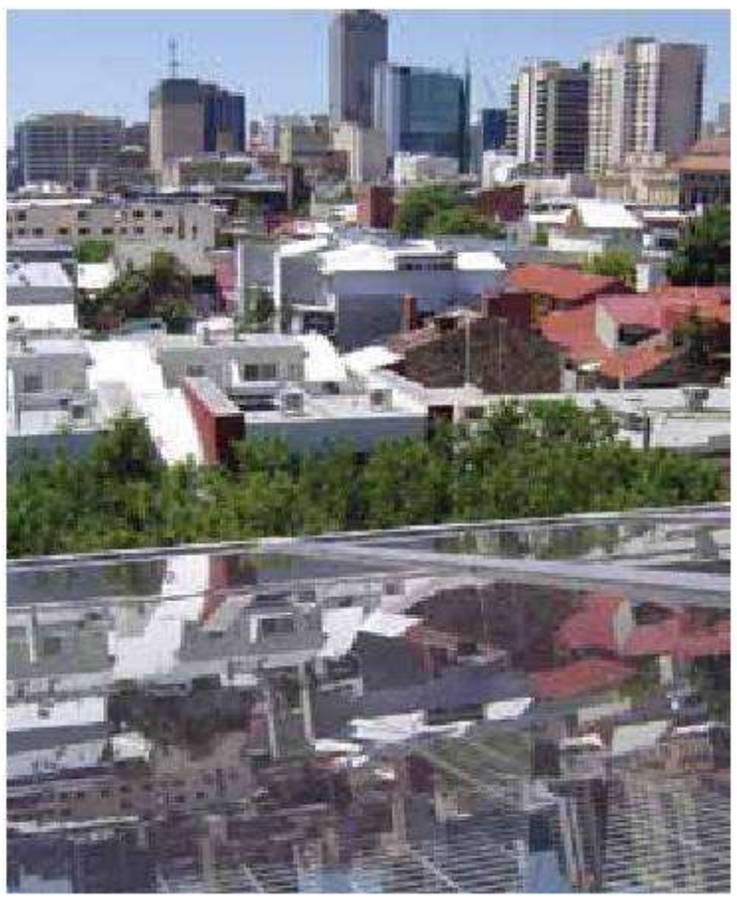
The residents of the whole Christie Walk development have formed a supportive community which works together on the gardens and grounds and offers a resource for the exchange of information on energy and water saving initiatives including regular site tours. [See: 2.3 Streetscape]

Energy use and generation

A 5kW grid connected photovoltaic (PV) system is installed on the north facing roof of the building which is inclined at 15° to the horizontal to optimize the solar output in summer. The cells are amorphous (thin film) silicon and produced approximately 3450kWh in their first five months of operation. This is approximately 22kWh/day which is about the expected figure in Adelaide.

A second PV system is integrated into the glazing of the lantern above the stairwell. The thin film cells are spaced onto the glass so that approximately 10 per cent of the incident daylight is transmitted down into the stairwell. This system consists of 10 panels which generate 300W and is the first of its type in South Australia. The modules also have a low heat transfer coefficient to minimise heat transfer into and out of the building through the lantern.

Electricity generated by these systems is first used in the building and any excess exported to the grid. [See: 6.7 Photovoltaic Systems]



The community facilities which include the community room, laundry, air conditioning, lift and hot water system and lighting in the stairwell are metered separately and the bill shared between the residents. The consumption over the first five months including the power taken from the PV systems was approximately 12,500kWh or 81 kWh/day. This was higher than expected because of teething problems with the air conditioning system which had been running for significant periods even when not required. After the air conditioning system was turned off at the end of April, daily communal electricity consumption dropped to approximately 54kWh/day.

To date only one set of electricity bills has been received and these have given consumption figures for individual apartments that range from 2.5 to 8kWh/day, with 10 of the apartments using less than 5kWh/day. This illustrates how important occupant behaviour is in determining the energy consumption. The reasons for the high consumption figures in some of the apartments are being investigated and are possibly due to large or inefficient refrigerators.

The total energy use for the apartments during the early commissioning period averaged out at between 6.7 and 12kWh/day depending on occupant behaviour; this is low to average for an Adelaide apartment.



Garden

There are community gardens including a roof garden which is part of the original development. These include indigenous and native shrubs and trees, some exotics to suit the passive design considerations and a produce garden with herbs, vegetables and fruit trees. These plants are watered from the rainwater system with very little need for additional water. [See: 2.4 Sustainable Landscapes]

EVALUATION

At the time of this study the building had been fully occupied for approximately five months and the residents so far had been very happy with the comfort of the building. As with any new building there have been some initial teething problems; these include difficulty in adjusting when and for how long the sensor lights come on in community areas, and possible difficulty with the air conditioning system which has no readily accessible manual override and has run when not required. These problems were being investigated with the expectation that they would be corrected by the end of 2007.

PROJECT DETAILS	
Architecture and Urban Design:	Ecopolis Architects
Project Architect	Paul F Downton
Structural and Mechanical Engineer:	Dare Sutton Clarke
Builder:	Tagara Builders
Services Engineers:	Lincolne Scott
Developer:	Christie Walk Joint Venture (Wirranendi Inc in association and EcoCity Pty Ltd)

Principal author:
Stewart Martin

Mt Ommaney QLD

RENOVATION

ZONE 2: Warm humid summer, mild winter



Topics covered
Passive design
Shading
Rainwater
Landscaping
Greenhouse gas reductions

AccuRate (thermal comfort)	Existing 2.1 (regulatory)
AccuRate (thermal comfort)	Renovation 2.8 (full rating)

This ecologically orientated renovation project demonstrates the importance of setting environmental priorities and staging work over time to suite the client needs and budget. The designers holistic ethos assisted with establishing these priorities and achieving significant environmental and social improvements.

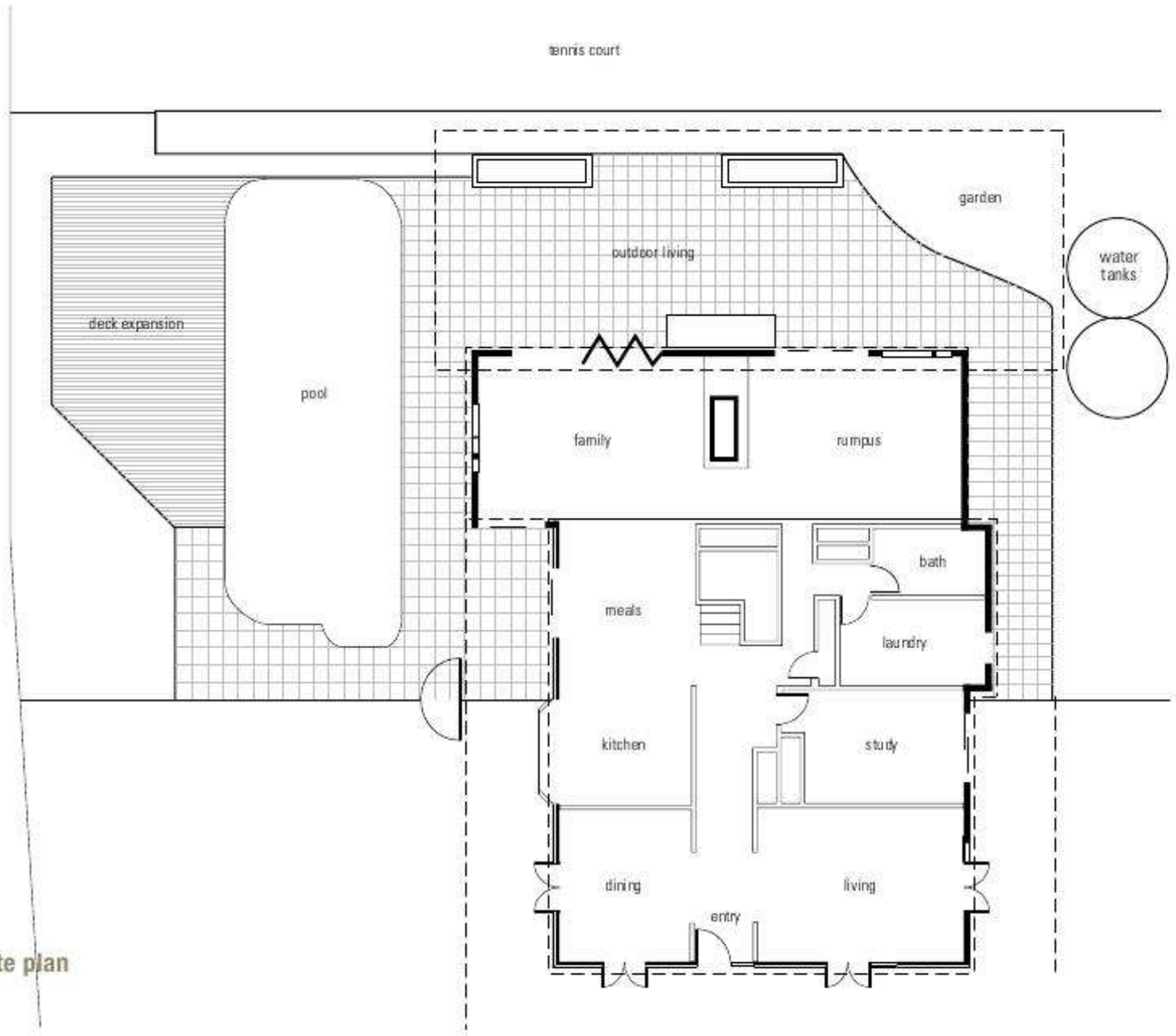


THE CLIENT BRIEF

The existing four bedroom house was a deep plan, brick veneer building built in the 1980's after the federation style. The house had some poorly located rooms in terms of solar aspect, which when combined with small eaves and limited ventilation openings required extensive use of air-conditioning to make the house habitable in the warmer months.

The client had a rather vague brief; as well as some renovation work to the existing house. They were looking for some ideas to address a poorly utilised outdoor area with a south westerly aspect attached to the informal living area. The site was large, but despite featuring a pool and tennis court the outdoor areas were largely underused as there were no comfortable outdoor spaces nor connectivity for entertaining or for the children to play in.





Site plan

SITE AND CLIMATE

Located at Mt Ommaney, approximately 14 km South West of the Brisbane CBD, the site is in a quiet pocket of the suburb with the Brisbane River nearby to the West.

Design response

The design team recognised that the process of establishing the client brief was one of the most important phases of the project. They took a holistic approach that considered the families present and future needs and financial capabilities. Considering how best a small renovation could improve the overall performance of the house. The result was a staged proposal.

Stage one addressed the outdoor area with a large verandah extension adjacent to the house, some rainwater collection, and minor renovation of some of the upper level bedrooms.

Stage two introduced a thermal chimney/ atrium into the centrally located stairwell which provides light and ventilation to the deep plan house, as well as the addition of more rainwater storage, a solar hot water system and insulation to the roof and walls. [See: 4.6 Passive Cooling]

Stage three will see the implementation of permaculture gardens using greywater irrigation and a new 'living wall' to protect the upper level bedrooms from the western sun as well as to protect the bathroom and provide it with ventilation opportunities. [See: 5.13 Green Roofs and Walls]

Construction materials

The pavilion-like pergola extension is predominantly constructed in a combination of steel, for primary structural elements, locally sourced recycled hardwood timber and laminated plantation pine beams. High level battens are completed in a proprietary composite material manufactured from recycled plastic and sawdust that is expected to require little or no maintenance. Drop-down plywood feature panels mark the location of the outdoor dining table and provide a ceiling to frame the space into which compact fluorescent lighting is recessed.

Shading

The existing house was poorly shaded to the south and west, with no significant vegetation and limited eaves overhangs. The extension provides protection to the family living areas which open out onto it from the harsh west sun.

The pavilion roof provides upper level shelter whilst opening to the north allowing in desirable low oriented winter sun. Landscaping and 'living walls' have been used and proposed down the western side of the house to provide further protection. The north east of the house is protected by an existing verandah and some significant trees. The plywood panels have been positioned to the south eastern side of the pavilion extension, to maximise winter morning sunlight.

The mass shading provided to the house has also created a lot more visual privacy. As a result the house can be opened up and outdoor areas can be used without onlooking or overlooking neighbours.

Ventilation

The existing house featured French windows but was poorly ventilated. While there are plans in future stages to further address this, the stage one renovation made a huge difference by just opening up the back wall with a large bi-fold door. This has enabled air to be pulled and directed right through the house from all areas of the ground floor, as well as forcing ventilation into the upper level circulation area. The effect is further enhanced by the design of the verandah extension; the high edge of its roof sits over one metre above the existing house roof ensuring that hot air can be expelled.

The second stage of work proposes a thermal chimney over the central stairwell. This will draw air from the open planned informal living areas on the ground floor.



Cooling Systems

The existing air-conditioning unit sits in the middle of the wall of the existing dwelling at the edge of the extension. Previously, not only did it have to cool an unprotected sizable area, subject to the full force of the western sun, with the unit itself was subject to that same western sun thus working very inefficiently. On the result of a cost analysis and availability of an alternative location, the unit has remained *in situ*. It is now incorporated into a battened enclosure which screens both the unit and the associated pipe work, and acts as the main serving bench for the verandah entertaining space.

The shading provided by the pavilion of the pool, allows maximum evaporative cooling whilst uncovered via the full opening of the bi-folding doors to the internal living spaces. Subsequently, since the addition of the pavilion extension, the residents have not found it necessary to turn the air-conditioningon, even during peak summer periods. The choice of floor material being masonry pavers, provides valuable thermal mass for cooling the home with summer shading, as well as providing passive heating of the adjacent living spaces by slow release of great winter sun solar gain. The rain water tanks provide substantial thermal mass properties also by shielding and cooling of the direct pavilion environment.

Lighting

A complete audit of the home's lighting was conducted so that the house could be fitted with more energy efficient lighting layout. The introduction of the daylight into the centre of the deep plan house through the proposed thermal chimney/atrium will reduce if not eliminate the need for artificial lighting during the day.

The inspiration of this passive lighting benefits not only the central circulation areas but most importantly flooding the upper level of the





home with priceless energy neutral light and ventilation.

Artificial lighting for the extension is all from 240v compact fluorescent globes and provides alternative lighting for the tennis court that reduces the need for the power thirsty court lights when the area is being used for general play by the children.

Rainwater

Three rainwater tanks with a total capacity of approximately 15,000L total have been installed as part of stage one. They are located to the west of the outdoor space helping to buffer the afternoon sun. The tanks have been plumbed to the house ready to be connected to all services inside the house as part of a later stage of works. At the moment the collected rain water is being used for wash down, irrigation purposes and for pool top up. There was also another tank being installed towards the other end of the property next to the garage structure, this bringing the total rainwater storage capacity of the site to approximately 28,500L. A pool blanket has been installed to reduce evaporation, provide solar heating and reduce heat loss whilst minimising fossil fuel energy use for sanitising the water.

Landscape

One of the main features of this renovation has been the integration of the landscape into the design. The colorbond roof cladding of the verandah, has been phased in the southwest corner with polycarbonate sheeting, buffering harsh summer sun as natural filtered light through random under battens. A pleasing feature allowing the garden to thrive as it extends well beneath the protection of the roofline.

Tensioned steel cables, ladder from the landscape to the roof structure allowing for vines to climb into the structure itself. The intent is to act as a living, active, cooling corner within the outdoor space, serving to filter and cool breezes for both direct external and internal air quality and temperature. Garden beds to the extended edge of the extension assist in filtering out the dust which filters off the crushed granite tennis court.

As part of stage three a deciduous vine will be incorporated into a 'living green wall' which will protect the children's rumpus room minimizing artificial lighting by shedding its foliage to allow in desirable winter sun. There has been a focus on productive gardens and where possible vines and edible plants have been chosen. The vines as part of stage one are passionfruit and the intention is to provide a raised vegetable garden down the side of the house as part of stage three.

EVALUATION

The principle focus of the design team on passive design, incorporating total integration of landscape, achieved through microclimate control, has greatly improved occupant comfort whilst achieving a massive reduction in the use of fossil fuel sourced energy. Water harvesting and water conservation strategies enable maintenance of the thirsty pool for summer comfort refuge whilst providing the potential to meet new stringent water usage targets. The social connectivity and interaction inspired by natural and passive elements of the pavilion structure has undoubtedly improved the comfort, health and quality of family life.

PROJECT DETAILS	
Architect::	Sascha Christensen, Sustainable
Engineer:	Sustainable
Landscape architect::	Sustainable Landscapes
Sustainability consultant:	Brett McKenzie

Principal author:
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Catherine Watts

Northern Beaches NSW

RENOVATION

ZONE 5: Warm temperate



Topics covered

Passive design
Lifestyle modification
Rainwater harvesting
Waste reduction
Greenhouse gas reductions
Renewable energy generation

AccuRate (thermal comfort)	4.2 (regulatory)

This case study shows how a well planned renovation has improved year round thermal comfort, reduced energy and resource consumption and lowered waste production within a tight budget. The case study showcases the principle of 'reverse brick veneer', one of the most effective construction techniques available.

In this renovation, the lounge room was relocated to the north and redesigned to take advantage of the site and climate. A new home office was located on the first floor away from the noise and fun of family life. As it would be occupied all day most days, it also had to be north-facing.

The remainder of the house remained untouched as it had been previously optimised.

The project aim was to improve year round thermal comfort of the house, reduce its energy and resource consumption and waste production. This is commonly referred to as creating a sustainable house, although this term should be used with care as it is rarely literally true.

The major constraint was budget: maximum benefit for minimum expenditure. Much use was made of found or secondhand materials and the entire project cost around $95,000.

The original house

Since its purchase in 1981, the house has been a testing ground for ideas and the subject of several on-going projects. Its rather rambling layout comprises four bedrooms, two living areas, a games room for the children and an office for the owner, who works from home.

'Design for climate' was not considered by the original spec. house builder when the house was built in 1962. [See: 4.2 Design for Climate]

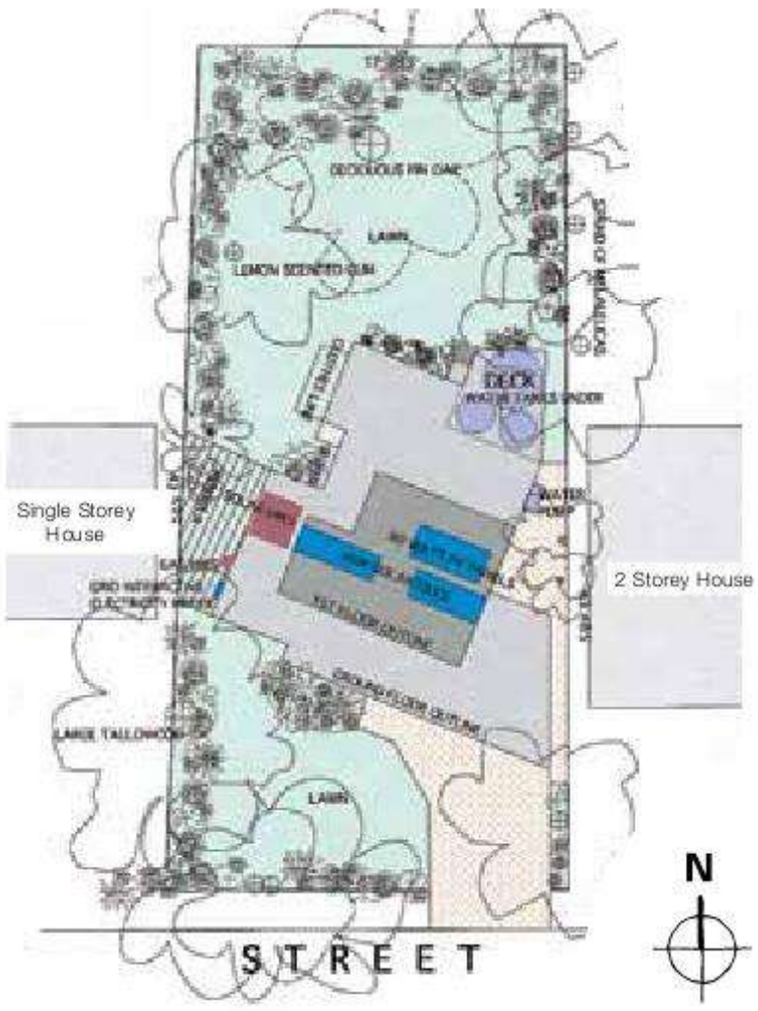
The original lounge room was located on the south side of the house, facing the street.

The floor plan was a simple rectangle with a brick perimeter dwarf wall and footings. The timber framed structure with raised timber floor and concrete tiled roof was completely uninsulated.



Site and climate

The site is located on a gently rising escarpment above the northern beaches of Sydney. It slopes gently to the north east, with a stand of mature melaleucas along the eastern boundary. A large deciduous tree is immediately to the north of the house, and several medium to large eucalypts are to the west and south west. To the north east there are some ocean views.



Surrounding houses are detached bungalow houses, dating from 1960 onwards. To the north is a two storey terrace and to the south a large volume single storey house with a garden studio at the rear.

The climate is mild to warm temperate. Because the site is on the north side of a spur and within 2km of the ocean, the micro-climate is milder than the Sydney average. It is well protected from cold southerly winds, suffers no frosts and receives cooling summer sea breezes. [See: 2.2 Choosing a Site]

THE AIMS OF THE RENOVATION

The main aims of the renovation were:

Transport – To provide a design office at home so the owner could cease commuting, thus reducing traffic congestion and greenhouse gas emissions.

Energy – To reduce energy consumption by reducing demand and producing as much or more electricity than used on site.

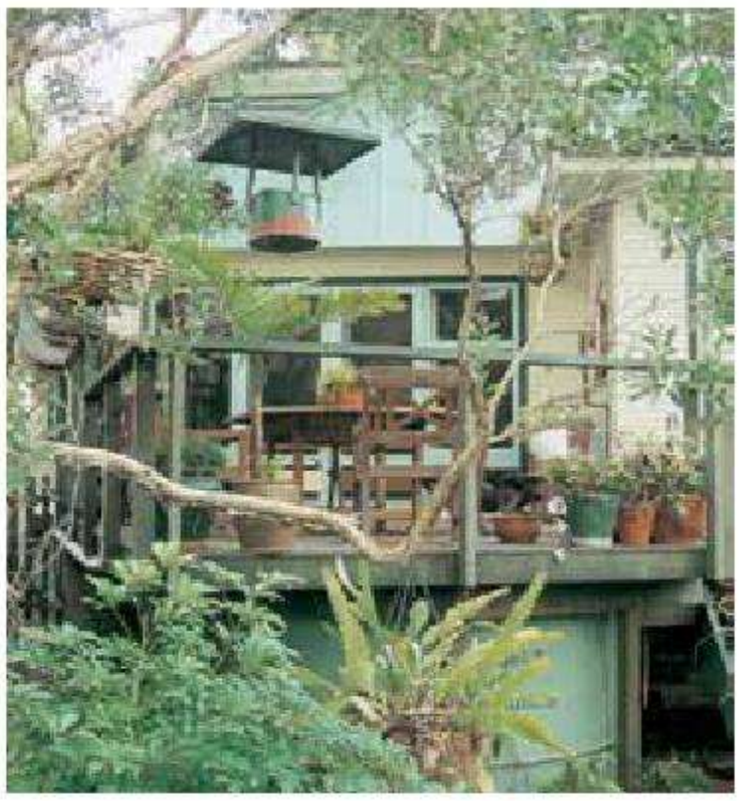
Water – To discontinue use of town water by collecting all water needed on site and increasing the efficiency of water use within the building.

Hot water – To use the freely available heat from the sun to generate as much of the home's hot water as possible.

Waste – To minimise construction waste from the renovation, treat all wastewater on site and release no wastes beyond the property other than a minimum amount of household garbage.

Planning controls

The local council has a strictly interpreted Development Control Plan, which limits building height and set-backs to appease neighbours but takes little account of solar access or sustainability. All the aims except solar hot water were subject to development consent.



GENERAL DESIGN PRINCIPLES

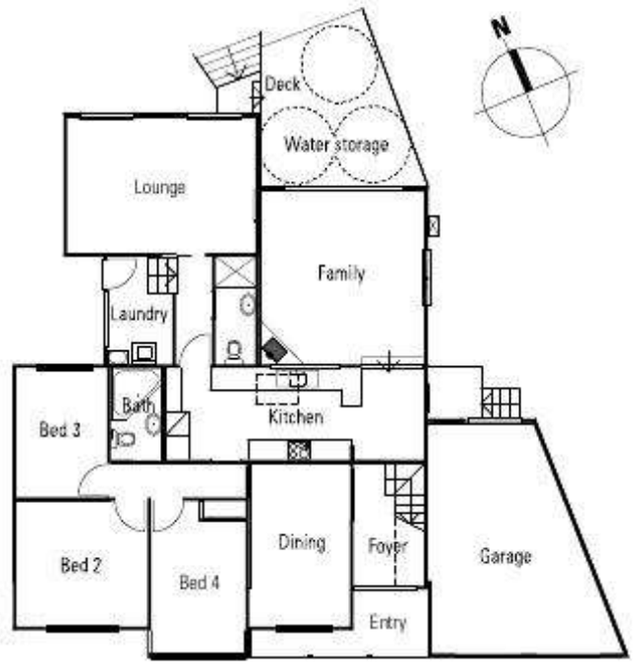
Interaction with the landscape was a critical part of the design response. An intimate relationship between external and internal spaces is encouraged by the relatively natural surroundings. This connection encourages the occupants to appreciate daily and seasonal weather changes.

Natural shading and wind protection is provided by the landscape. [See: 2.4 Sustainable Landscapes]

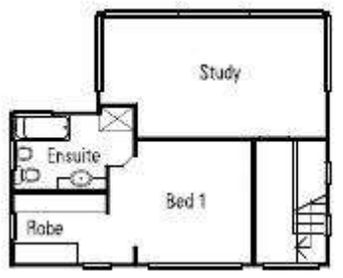
Orientation

Siting the main living areas on the north side means winter sun is the primary source of heating, with summer cooling provided free of charge by the sea breeze from the north east.

Windows and doors are placed to favour this winter sun/summer breeze orientation. [See: 4.3 Orientation]



Ground floor



First floor

Structure and envelope

The original house had a hardwood frame with cypress pine weatherboards and plaster linings. All subsequent extensions have repeated this but with sustainable plantation timbers used in the frame.

New cladding is cypress pine from NSW and Qld plantations. Plasterboard linings have been used in most rooms but a few also have cypress panelling.

Thermal mass and insulation

The house is of low mass construction, which is acceptable in its climatic situation where winters are relatively mild.

The lowest night temperature is around 6°C and the lowest day temperature rarely less than 12°C and usually 16-20°C.

However, occasional summer days when there is no sea breeze show how quickly a low mass house is overcome by high temperatures.

Summers are benign, usually upper 20s with a high summer temperature of 42° on rare occasions.

These conditions make it easier for older timber buildings to achieve a satisfactory degree of thermal performance by renovation rather than demolition. [See: 4.9 Thermal Mass]

Insulation has been gradually added to old walls and all new walls have had two layers of reflective insulation and/or bulk insulation added. The average wall insulation value is R1.5.

Ceilings have a minimum of R2.5 in the form of reflective insulation, bulk fibreglass (installed in the past) and more recently installed bulk wool. Some old sections of roofing did not have sarking fitted so additional reflective insulation has been provided.

Floors are enclosed by perimeter brick foundation walls, thus providing some control of air flow to the sub-floor. [See: 4.7 Insulation]

Shading

The surrounding trees are used to advantage. There is a deciduous tree immediately to the north and to the east and west native trees such as tallow wood and melaleucas provide morning and afternoon shade. The melaleucas over the deck create a pleasant natural shade pergola.

East or west facing openings are few. The three west facing windows are partially beyond the shadow of the trees. Rolling canvas awnings have been fitted as far from the glass as possible to reduce re-radiation onto the windows. [See: 4.4 Shading]



Ventilation

Sliding doors and windows are fitted to all north facing openings. These can be opened and locked in place to varying degree. All windows and doors have draught seals.

Cross ventilation is provided on all levels and to all rooms. The house can be left unattended in a 'breathing' condition without fear of rain entering. Protection from rain is provided by awnings over openings to the east, west and south and appropriately designed eave overhangs to the north. [See: 4.6 Passive Cooling]

Landscape

Permeable surfaces have been maximised to prevent stormwater run-off. The double driveway, made to satisfy council's off street parking requirements, is the only large area of paving. Other areas have pebbles with stepping slabs of timber. [See: 7.5 Stormwater]

Lawn has been limited to about 60 per cent of the garden area that is required for children's games. The remainder is planted predominantly with native shrubs and trees.

The garden is encouraged to hug the house for the visual and psychological benefit that this provides. Termite inspection access has been maintained and no soil is allowed within 100mm of the lowest weatherboard.

THE LOUNGE ROOM RENOVATION

The Lounge Room renovation involved several inextricably connected changes:

> Re-orienting the living areas to the north side of the house.

> Increasing the thermal mass in that living area.

> Allowing winter sun in while excluding summer heat.

> Improving insulation to keep the thermal mass temperature-regulated.

Reverse Brick Veneer was the wall construction technique used for the renovation of the lounge room. Although its use in retro-fits is still almost unheard of, used correctly it allows buildings that would otherwise be demolished to be retained, renovated and significantly improved. [See: 5.5 Construction Systems]

Why reverse brick veneer?

Reverse Brick Veneer (RBV), as the name suggests, is brick veneer turned 'inside out' with the bricks on the inside of the house. It is one of the most effective and powerful construction techniques available to us, yet it has been quite rare until recently.

The principle of Reverse Brick Veneer can be applied to almost any renovation. It provides the home-owner with a radical improvement in comfort for a modest outlay.

Thermal mass is provided by the inside brick skin. For the thermal mass to work well, RBV must be used in conjunction with good passive design principles.

Commonly used Brick Veneer is one the supposedly great inventions of the Australian building industry. It provides some important perceived and real benefits:

✓ Low cost for a supposedly brick building.

✓ Low maintenance in the long term.

✓ Speed of achieving lock-up during construction.

✓ Perceived solidity – 'it's a brick home'.

The disadvantages of brick veneer, however, are:

✗ No useful thermal mass (it's all on the outside).

✗ No real brick solidity internally.

✗ Difficult to termite-proof when built as slab-on-ground.

Placing the bricks on the outside where they are heated by the summer sun and cooled by freezing winter rain and wind, and then attempting to insulate the 10mm of plasterboard that separates the occupant from these extremes is a classic case of 'putting the cart before the horse'.

Placing the bricks on the inside, where their thermal mass is of most benefit in regulating internal temperatures, is what makes RBV work so well. External walls must be insulated to protect the thermal mass from exterior changes, just like putting a hot or cold drink in a vacuum flask.

The advantages of RBV are:

✓ Thermal mass is protected from external changes.

✓ Thermal mass is inside, next to you.

✓ Thermal mass regulates indoor temperatures throughout the year.

Renovations using RBV as a construction method are particularly cost effective for the following reasons:

> The existing building frame can be utilised, eliminating the need for excessive demolition. The RBV can be constructed entirely within the existing building frame, including external claddings.

> Existing footings can generally be utilised when using RBV. Footings and support structure will need to be appraised by a structural engineer, but this is standard practice anyway. [See: 4.9 Thermal Mass]

New concrete floor slab

To increase the thermal mass of the lounge room, the original timber floor was removed (and all timber re-used on or off site) and a 'Bondeck' suspended slab installed in its place.



This type of slab uses the existing piers and footings, and requires no filling or excavation. The concrete is poured over prefabricated steel decking. The slab was installed lower than the original floor to gain extra ceiling height.

The subfloor was sealed and insulated to limit air movement and heat transfer, thus enabling the slab to make indirect thermal contact with the ground temperatures. If the floor is close to ground, and fill is available, it is thermally advantageous to fill the subfloor and sit the slab directly on the compacted fill. Termite barriers need to be maintained.

The slab surface was burnished (steel trowelled until it shines) and post-stained, avoiding the need for floor tiles or other finishes. Insulative finishes (such as carpet or timber parquetry) should not be used where thermal mass is to be utilised. These materials prevent the thermal mass of the slab from interacting with the room interior.

Winter sun falls directly on the floor, allowing radiant heat to be absorbed by the thermal mass of the concrete. This is then released back to the room later in the day and into the evening, long after the sun has set.

In summer the concrete floor is shaded from direct sun and keeps the occupants cool by absorbing heat. [See: 4.9 Thermal Mass; 5.12 Concrete Slab Floors]

Sub-floor insulation

The subfloor walls must be sealed and insulated to some extent when using a suspended floor, depending on the climate. In cold climates all external subfloor walls (or 'dwarf walls') should have a layer of impervious insulation installed to the inside face (ie not exposed to the outside).

In this case, large lattice-covered openings had woven mesh garden screening applied behind the lattice to keep the external appearance unaltered, and 15mm Foil-Board installed inside that. This material has a core of rigid expanded polystyrene (EPS), covered on both sides with reflective foil. Openings to other parts of the subfloor were also sealed with Foil-Board.

Other external brick dwarf walls have not been insulated due to the mild micro-climate, but any site 5km further from the coast would demand insulation be fitted. [See: 4.7 Insulation; 4.8 Installing Insulation]

New internal brick walls

Almost any bricks are suitable for RBV construction, but Austral 90mm SlickBricks were selected for this project because of their slender width, which consumed less floor space. Second-hand bricks are ideal if available.



No cavity is required for RBV. The brick skin is laid tight to the wall frame without a cavity, as the external cladding provides the primary moisture barrier.

Wall ties must be provided to meet the requirements of the local council and the Building Code of Australia, as in any other brick construction.

In this case, ties were limited to the top course of two of the straight walls, due to the SlickBrick's inherent rigidity and acceptable slenderness ratio. Other shorter and cross-connected internal walls can stand without tying to the structure.

A cement render finish with a white set plaster top-coat was used on the inside walls. As for floors, it is important to maximise the interaction of the thermal mass with the room interior, so insulative wall finishes should not be used.

The set plaster top-coat looks exactly like the existing plasterboard linings when painted, ensuring that the renovation is not out of character with the original.

The owner considers the Reverse Brick Veneer a 'winter heat investment'.

When winter sun enters the room, some is reflected off the concrete floor and absorbed by the brick walls. This stored heat is re-radiated into the room later when needed, like a 'warmth bank'. The insulation on the outside prevents heat from escaping (unlike RBV's poor cousin, brick veneer). [See: 4.5 Passive Solar Heating]

Summer heat is kept outside the building envelope, and provided that doors and windows are kept closed during periods of extreme heat, the thermal mass of the walls will act like a 'cool-bank', absorbing heat and keeping the occupants cool. Stored heat dissipates in the evening, when the building is thrown open to a cool southerly breeze. [See: 4.9 Thermal Mass; 4.6 Passive Cooling]

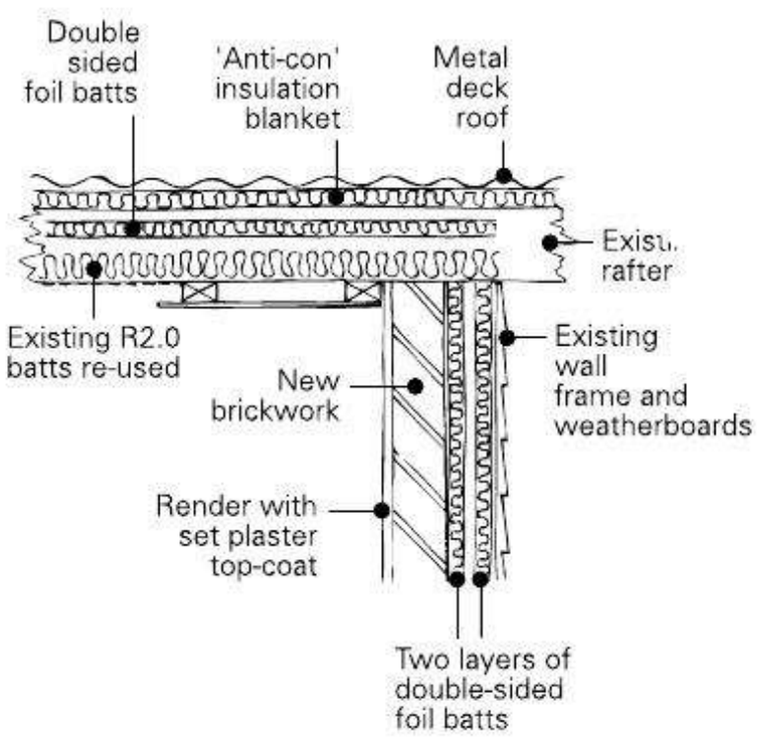
Wall insulation

Insulation is a critical step in the process, as it protects the internal thermal mass from temperature changes outside. If there is adequate insulation already in the walls, internal wall linings do not need to be removed. In this case, no insulation had ever been fitted, so all linings were removed and insulation added throughout.

Reflective foil insulation was used, as it is well suited to a coastal climate with no winter frosts and hot summer afternoons. In cooler climates, a combination of reflective and bulk insulation would be used. [See: 4.7 Insulation]

Reflective insulation resists radiant heat better than bulk insulation, whereas bulk insulation is better at resisting convected and conducted heat and protecting against cold-induced condensation.

Two layers of Foil Batts with air gaps between each layer were installed. If the building had sarking (reflective foil laminate) in its original construction, one layer of Foil Batts would have been sufficient.



Roof and ceiling insulation

The roof and ceiling has R3.5 insulation installed in the form of a combination of an anti-condensation blanket under the metal roofing, double sided foil with air spaces both sides, and bulk fibreglass (re-installed from existing ceiling). It is important to get the insulation correct in roofs and ceilings, as most heat is gained and lost there. [See: 4.7 Insulation]

Glazing

North-facing glass has been maximised. About 60 per cent of the north-facing wall area is glass (75 per cent including the window frame) to allow winter solar gain.

The one south-facing window is a tall narrow slot, just 400mm wide. This shape minimises the amount of glass at the top of the room (closest to the ceiling), where the warm air rises and collects. There are no west or east facing windows.

Existing north-facing windows were removed and larger openings provided. Constraints of existing ceiling heights and window head heights meant that there was as little as 200mm for a new lintel, which had to span over 3m.



Engineered timber allows these longer spans to be handled with minimal member depth. A laminated 200 x 45mm timber beam called a Hyne Edgebeam LGL was used in this instance.

Double glazing has been used on all major external glass. The north-facing windows and door have double glazing with a low-e coating to the inner glazed face of the inside sheet (facing into the air space of the double glazing).

Low-e (low-emittance) coatings prevent heat from being radiated or emitted from one side of a pane of glass to the other. Thus, they can limit the heat entering or leaving a building. For this reason they must be used appropriately, or they may actually work against you.

In winter, the double glazing allows sun to enter deep into the room and prevents the welcome heat from escaping again. The air gap in double glazing does little to inhibit the sun's radiant heat from passing through, but provides a barrier to conducted heat losses from inside to outside. The low-e coating prevents that captive heat from re-radiating out on winter nights. [See: 4.10 Glazing]

In summer, the glazing is shaded from direct sun. During long hours of intense heat, all windows and doors are kept closed and the thermal mass of the walls and floor works like a 'coolness battery' to keep the occupants comfortable. Heat dissipates from the room by opening the windows in the evening. [See: 4.6 Passive Cooling]

Shading

In this case, the seasonal shading angles provided by the existing roof overhang to the north were already near perfect, admitting winter sun to the north facing windows and excluding summer sun.

There are no east or west-facing openings in the lounge room, so the existing roof overhang on those walls has remained untouched, reducing costs.

Additional shading, if required, need not mean a new roof. Separate shading devices such as louvres or pergolas are an easy and lifestyle-enhancing alternative.

Active (moveable) shading devices enable the occupant to select how much heat is admitted on a daily basis: a cold snap in November can be treated like winter (sun admitted) and a heat wave in August can be treated like summer (sun excluded).

The shade of the surrounding trees is used to advantage. There is a deciduous tree immediately to the north, which provides copious summer shade, yet lets winter sun directly in to the lounge room. The owner opposes the planting of exotic trees, but where established and useful they are tolerated.

Native trees to the east and west such as tallow wood and melaleucas provide morning and afternoon shade. [See: 4.4 Shading]

Ventilation

The north facing windows are casements, which are side-hinged like a door. They open towards the nor'east sea breeze, effectively scooping it into the room. The windows are timber framed and all windows and doors have draught seals.



Criteria for window selection included the need for good sealing when closed, permanent flyscreening and partial opening in a locked position so the house could be left unattended but 'breathing'. Stegbar AT2000 series were selected.

Cross-ventilation in the lounge room is maximised by the use of a south-facing floor-to-ceiling louvre window. Louvres allow 100 per cent of the window area to be opened and have the added benefit of allowing ventilation to occur during rain.

Louvres with good seals must be used in southern climates. Breezway Altair louvres, which have a better seal than any other type to date, were selected. [See: 4.6 Passive Cooling; 4.10 Glazing]

APPLIANCES AND SERVICES

Heating and cooling

A high efficiency wood burning heater fitted in a brick hearth is installed in the centre of the house. This burns only waste timber, typically old hardwood fences supplied by a local fencing contractor. This ensures carbon neutrality. [See: 1.4 Carbon Neutral; 6.2 Heating and Cooling]

A hybrid solar thermal collection and storage system is planned for the near future. This will collect heat from the back of the solar panels to be stored in a heat bank for use in the evenings.

There is no artificial cooling system in the house, which has been designed to optimise natural ventilation.

Lighting and daylighting

All lighting commonly used for more than five minutes at a time is either tubular fluorescent or compact fluorescent. Some fittings have been specially coloured to make the light value warmer.

Vented downlights have been replaced with non-vented fittings that accept the longer enclosed, compact fluorescents. These provide a suitably warm light, are much more efficient than low voltage halogen downlights and have a less uncomfortable effect on peripheral vision.

It should be noted that low voltage is not the same as low current – in fact 12 volt halogen lights are generally inefficient.

The wall lights in the lounge room use compact fluorescent bulbs with a warm white colour (2700k light temperature) and translucent glass covers. These covers allow a softer diffusion of light to the whole room.

Translucent wall light covers should be used in preference to solid covers. Solid covers only allow light to be reflected off the wall immediately above the fitting, shielding a large proportion of the light produced. [See: 6.3 Lighting]

Skylights have been provided to internal bathrooms. These have operable venting built in. The dining room on the south side has a Velux skylight at its southern end to increase natural lighting.

Two clerestory windows are both double glazed with a 100mm sealed air space between the glass. Because hot air accumulates near the ceiling, creating a large temperature difference across the window, some heat leakage to the outside still occurs through the double glazing.

Electricity generation

Three grid-interactive photovoltaic arrays provide a total of 1.76kw peak power:

Two building-integrated photovoltaic (BIPV) systems are built into the roof, and oriented with the house to 22° east of north.

A third array mounted in a tilting frame is oriented to true north, allowing for seasonal adjustments. There is provision for an extra tilting array in the future to bring the total peak power capacity up to 2.35kwp.

The photovoltaic arrays produce 110 volt DC that is changed to 240 volt AC by an inverter. The inverter, located in the first floor office for easy access, is mounted in a ventilated cupboard to reduce background noise. It has a cooling fan for periods of high load. [See: 4.11 Skylights]



The inverter records the instantaneous output in amps and volts, the total productive hours, total produced for the day, running totals and the last 31 days' history. [See: 6.10 Batteries and Inverters]

Energy Australia has a straightforward buy back arrangement using a reversing meter to measure the amounts imported and exported. The meter is electronic and records the amounts separately. The billing is easy to read and has always correlated with the owner's readings.

One common misconception is that solar electricity gives a building a stand-alone ability in case of blackouts. This is not presently the case with grid interactive systems. If the grid goes down, the inverter senses this and shuts down the PV system. This prevents power flowing back out to the grid, electrocuting an unsuspecting linesman.

Future systems will isolate from the grid without shutting down but current safety regulations prevent this.

PRODUCTION FIGURES	
Total building consumption	4367 kWh
Total production from PVs	1753 kWh
Total export to grid	774 kWh
Total import from grid	3563 kWh
Net import from grid	2789 kWh
Percentage produced on site	40.14%

(from 2000 calendar year records)

Electricity produced is available for consumption on site before any excess is sold back to the grid. The slight limiting factor affecting the production rate is the less than ideal orientation of the building integrated PV arrays. [See: 6.7 Photovoltaic Systems]

Despite limited use of high efficiency lighting and energy saving computers, electricity consumption is satisfactory.

Several factors cause the high electricity consumption rates. The fridge is 30 years old and due for replacement when the kitchen is upgraded and a busy design office is operating 15 hours a day 6 days a week.

WATER

Rainwater harvesting

Rainwater is collected from the roof for use in the house. Leafguards on gutters provide initial filtration and screened diverters are fitted at the inlets to each of three tanks. These trap sediment and debris and are emptied after each rainfall.

First flush devices are common in urban areas where atmospheric contaminants are high. In rural areas they are rarely necessary.

The atmosphere over Elanora is generally the cleanest in the Sydney region, as it receives fresh air from the Tasman Sea in summer and from the Richmond/Colo area northwest of Sydney in winter. For this reason, first flush devices were not used because of the volume of water they waste.

The tanks are located under the timber deck on the north side of the house and are partly buried. They are inter-connected by default but can be individually isolated by remote operated valves.

Polyethylene was the material of choice for the tanks, however at the time of building no tanks were produced in the optimal sizes to maximise storage capacity.

The alternative was to compromise the embodied energy and recyclability preference and use fibreglass tanks. There is one 9,000L tank and two 4,500L tanks, giving an effective usable total capacity of 16,000L.

According to CSIRO figures, 16,000L would provide 80 per cent certainty of supply. This has proved accurate over an 18 month period. Reserve supply is still from the mains. Future additional capacity of 4,000L will be via an above ground tank located under the pergola.

The system is pressurised by an electric pump housed in an acoustically dampened box adjacent to the house. The box is constructed from 150mm thick AAC Hebel blocks and has a removable lid made of Ritek panel: a foam sandwich panel with two skins of corrugated colorbond steel.

An 80 micron filter is on the outlet of the pump. Initially there were three additional filters, down to 20 microns but, after much sampling and debate, these were bypassed.

Flow restrictors were fitted to every tap before fitting the rainwater system. They have since been removed due to lower operating pressures compared to mains supply. [See: 7.3 Rainwater]

Water heating

The hybrid system comprises an un-boosted 300L Edwards Stainless solar heater and a high efficiency 130L Rheem Stellar gas storage heater. [See: 6.5 Hot Water Service]



Earlier experimentation used a low pressure solar heater but it was incompatible with the pressure pump system and had to be abandoned. Others have had mixed success with these units, which are cheap to buy.

The preferred design choice was to use an instantaneous gas heater in line after the solar pre-heater but the manufacturer advised that the lower pump pressures were unsuitable.

A manually operated bypass valve allows the storage heater to be taken out of the system, thus using unboosted solar heating whenever the conditions allow; about 75 per cent of the time in summer. The gas heater is left on pilot at these times and its efficiency is such that the pilot maintains a water temperature of over 50°C.

Greywater system

Greywater is used to flush toilets and irrigate the garden. The holding tank allows a small electric pump to fill the cisterns of all three toilets in the house. Overflows run off to a drip system feeding two garden beds.

This system has reduced total household water demand by approximately 16 per cent. Wastewater from the shower, handbasin and laundry is treated in this system. Kitchen and toilet wastewater proceeds separately to the local sewage treatment plant.

Treatment is via a three tank gravity-fed reed bed system, which runs into a holding tank. Each treatment tank has the infeed water entering under a galvanised mesh grid, which supports a coarse fabric with a gravel filter bed on top. Selected reeds grow in the moist top layer of this gravel, consisting mainly of Acorus gramineus 'Variegatus'.



The wastewater is fed up through this matrix, overflowing at one end into the bottom of the next tank, where the same process is repeated, and again into the third tank.

A small solar powered pump recirculates about 40 per cent of the water stored in the holding tank as a means of preventing putrification.

The system is in its initial testing phase, and if the quality of the treated water exceeds the expected standard for a 12 month period, it will be tested for use in the clothes washing machine. This would reduce demand by a total of 27 per cent. [See: 7.4 Wastewater Re-use]

EVALUATION

The owner/ designer has made the following comments:

> Given an unlimited budget, we would do many things differently, but since that was not an option, the outcome is generally very satisfactory. Greater automation of things like the hot water would be nice, but doing it manually keeps you in touch with what the weather has been doing.

> The benefits of Reverse Brick Veneer are many, and considering the relative lack of pain and expense in achieving such a startling result for the lounge room, it should become a regular option in renovations.

> The walls of the first floor within the lower roof need a higher level of insulation. There is a single layer of foil with R1.5 batts behind. The batts appear useless to stop radiant heat and will have to be replaced with double sided foil, which is far more effective for this purpose.

> The acoustic performance of a timber framed, brick veneer house is not as good as a masonry house and with teenagers and their music this is a concern.

PROJECT DETAILS	
Architecture:	Dick Clarke, Envirotecture Projects
Builder:	Dick Clarke
Engineer:	Stewart McGeady NB Consultancy Engineers

Principal author:
Dick Clarke

Chippendale NSW

RENOVATION

ZONE 5: Warm temperate



Topics covered
Passive heating and cooling
Renewable energy use
Rainwater harvesting
Water treatment/re-use
Greenhouse gas reductions
Sustainable materials use
Waste minimisation/recycling
Indoor air quality
Food production

AccuRate (thermal comfort)	Existing 3.2 (regulatory)
AccuRate (thermal comfort)	Renovation 3.6 (regulatory)

'Sydney's Sustainable House' is one of Australia's best-known examples of an attempt at sustainable urban living. It was the result of renovations in 1996 to an inner city terrace, with the goal of making the home self-sufficient in water and energy.

At the time, the focus was on creating a healthy environment, capturing solar energy, improving appliance effectiveness and treating wastewater; rather than improving the passive design which would have further reduced energy demand and assisted the achievement of sustainability.

The main components of the renovation were:
> A renewable energy system
> A rainwater collection system
> A wastewater treatment system

As a result of the renovations, the house's sewage is now treated on-site and no longer pollutes the ocean. The rainwater and sunlight which fall naturally onto the site are utilised as a precious resource.

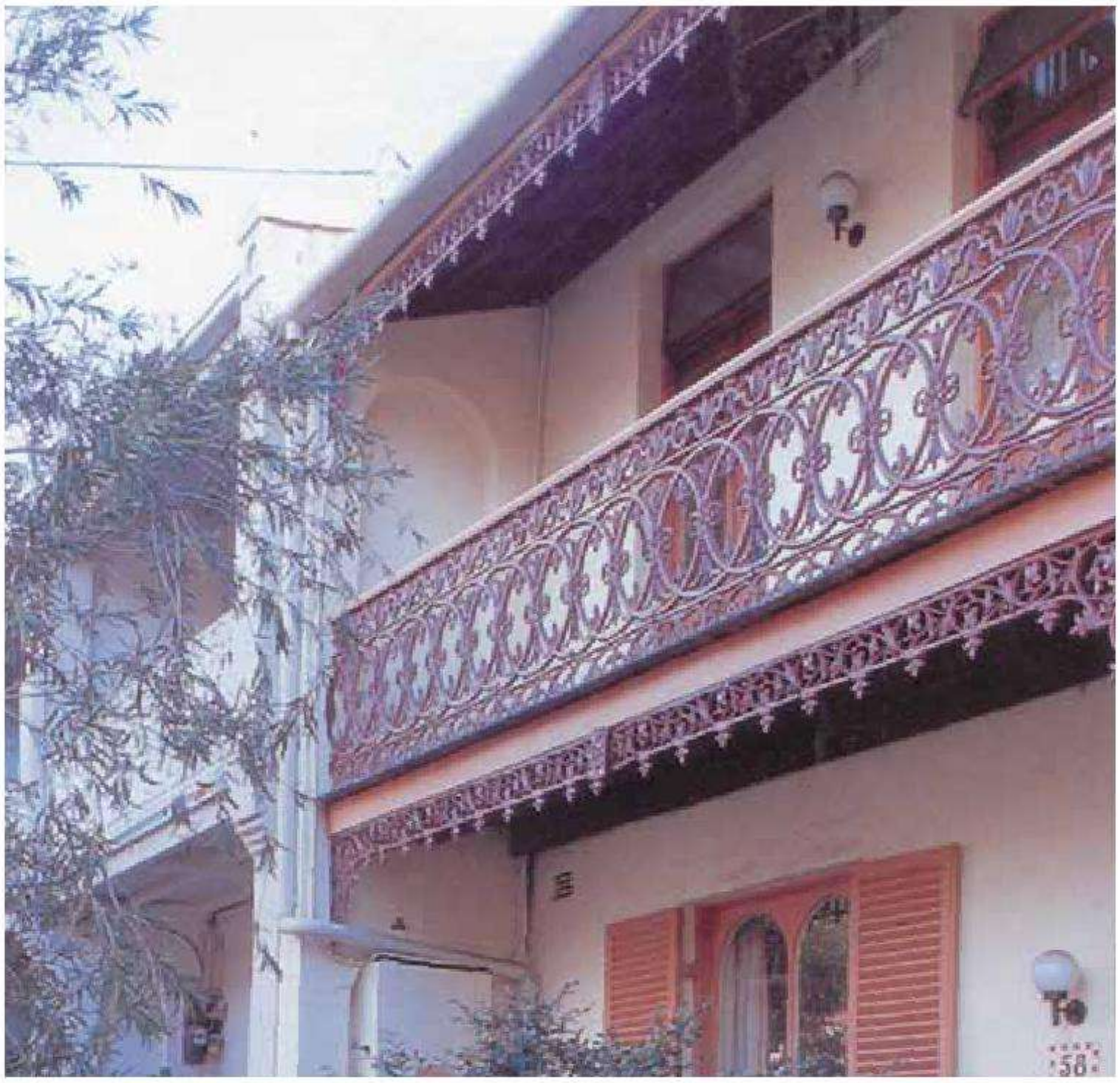
The original project was well documented in the owners' book, *The Sustainable House, 1998*. This case study focuses on the successes and the lessons learnt.

The significance of the project

Several factors made 'Sydney's Sustainable House' unique when it was completed in 1996. It showed that it was possible to create an almost entirely autonomous house on a compact, inner city site and within a relatively modest budget.

The greatest contribution of the project is that it has made the concept of sustainable home design more accessible, largely due to excellent publicity and the detail with which the renovation process was documented.

'Sydney's Sustainable House' is the subject of a book and an ABC online feature, and features in the Ecologic Exhibition at the Powerhouse Museum in Sydney. In addition, over 15,000 people have visited the house on the tours run weekly.



BACKGROUND

Design goals

When the kitchen and bathroom of an existing terrace house were renovated in 1996, the owners, Heather Armstrong and Michael Mobbs, set a goal of making the house self sufficient for water and energy.

In addition, the owners wanted their house to feel like any other house to live in, and to be suitable for sale on the mainstream housing market.

The existing home

The two storey inner city terrace was built in the 1890s. It sits on a 150m^2 site (5m wide and 30m deep), located 2km from Sydney's central business district and 10 minutes walk from Darling Harbour. The precinct is a heritage conservation area under the local council planning controls, so all renovations must fit in with the existing character of the streetscape. [See: 2.3 Streetscape]

The renovation

The scope of the renovations limited the opportunity to consider issues like passive design and materials use. Even so, this simple renovation was able to make a significant difference.

THE SOLAR ENERGY SYSTEM

Renewable electricity generation

The grid-interactive photovoltaic system uses 18 x 120 watt photovoltaic panels located on the north-facing roof area. These generate up to 2555 kilowatt hours per year and provide around 70 per cent of the electricity used in the house. [See: 6.6 Renewable Energy; 6.7 Photovoltaic Systems]

An inverter converts this electricity to 240V so it can be used within the house or diverted to the main grid. The main grid acts as 'storage' for the electricity produced, replacing the need for bulky battery storage. [See: 6.10 Batteries and Inverters]

Surplus solar electricity is exported to the main grid during the day, putting the household bills into credit with the local power company. At night, electricity is imported from the main grid.

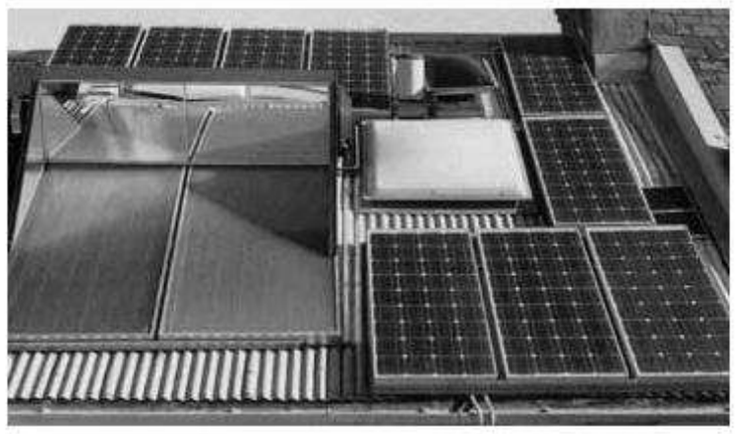
This system supports all the home's electricity requirements, including refrigerator, fax, photocopier, video, television, computer, stereo, clothes dryer, front-loading washing machine, and dishwasher.

The house was to be a net exporter of clean electricity to the main grid. The inefficient refrigerator, prevented this from happening. The owners have replaced it with a more efficient model. [See: 6.4 Appliances]

Solar hot water service

Reflector devices were added to the existing solar hot water service, increasing its efficiency during winter by around 17 per cent. These reflectors are positioned at the sides and top of the existing solar hot water panels, to capture low angle winter sun and reflect it onto the solar hot water panels.

A gas booster was installed to replace the existing electric booster on the solar hot water service. In most cases, natural gas produces only about a third of the greenhouse gas emissions of conventional electricity. The booster can be set to operate only at nominated times. It can be turned off when there is sufficient sun to keep the water hot without boosting.



Reducing household energy demand

Before the renovation the house used 24 kwh of electricity a day on average. Now, after the use of energy efficient appliances and lighting, and the switch to gas for cooking, hot water boosting and space heating, it uses about 10kwh. Of that, the refrigerator is using over 3 kwh. [See: 6.1 Energy Use Introduction]

Energy and water efficiency were the main criteria for appliance selection.

A gas cooktop and oven/grill are used, along with a water-efficient dishwasher and washing machine.

The washing machine is a front loading model. The cold water tap is connected to recycled water, and the hot water tap is connected to the rainwater.

The newer and smaller fridge has a 4.5 star rating. It is designed to use 340kWh/year, but actually uses less energy as it is switched off when not in use.

Ventilating the space behind the fridge was considered as a way of improving its energy efficiency. Good air flow behind the fridge allows the heat pump to dissipate energy more quickly, reducing its running time. [See: 6.4 Appliances]

Energy efficient lighting is also used in the renovated areas to reduce energy demand. Five individually switched compact fluorescent ceiling lights, which together use less energy than one conventional incandescent light bulb, were placed to shine directly onto bench work surfaces in the kitchen. [See: 6.3 Lighting]

Reducing water demand

To reduce water demand, water-efficient appliances and fixtures are used. These include:

> Toilet 3/6 litre dual flush

> Showerhead WELS 3 Star rated

as well as the water-efficient dishwasher and washing machine previously described. [See: 7.2 Reducing Water Demand]

Rainwater collection

The house is almost self sufficient in water. Rainwater is collected and used for drinking, cooking, showers, baths and hot water.

Roof materials and finishes need to be carefully chosen when collecting rainwater. Avoid lead-based and tar-based paints. Suitable materials include galvanized steel, Colorbond, Zincalume, slate and tiles.

Specially designed gutters, which are covered to exclude sediment, leaves and pollutants, collect the rainwater which falls on the galvanized steel roof.

A rainhead attached to the downpipe excludes any leaves and other debris that may have somehow entered the covered gutters. Whilst not essential, these reduce maintenance and the likelihood of blocking of the first flush diverters.

A diverter ensures that the first 8-10L of first flowing, dirty rainwater are automatically diverted to the garden. This is particularly important in cities like Sydney where air quality can be poor, leaving the roof covered in pollutants between rain periods.

Clean rainwater is diverted to a 10,000L concrete storage tank located in the back garden, beneath the deck. A sump between the first flush diverter and the rainwater tank contains a fine stainless steel mesh grate to ensure no further sediment enters the tank.

A small pump delivers the stored rainwater to the house when a tap is turned on. This pump is required to achieve the necessary water pressure, and is housed in an acoustic hood at the back of the garden. [See: 7.3 Rainwater]

The stored rainwater is pumped on demand when a tap is turned on. Overflow is contained in a small wetland which transpires some of the excess into the atmosphere, reducing the load on the stormwater system. [See: 7.5 Stormwater]

Sophisticated water quality tests (2002) show that, despite the inner city location, with planes flying overhead and traffic congestion, the rainwater contains no hydrocarbons and none of the by-products of chlorine decay present in town water.

Wastewater treatment

To stop sewage leaving the site, wastewater is treated and recycled using a wet compost system. This process treats all types of wastewater, whether it be from a toilet or kitchen sink, by filtering it through compost beds. There is also a carbon filter and UV disinfection.

The wastewater treatment system treats washing, kitchen and household waste to tertiary quality levels for treatment and re-use.

Treated water is used to flush the toilet, wash clothes and water the garden. The system uses a natural, self-adjusting biological process. Yet the house appears the same as any other, having a conventional dual flush toilet, and typical water efficient appliances.

Wastewater is piped from the house to a concrete tank beneath the garden deck which houses a series of filter beds, collectively known as a 'biolytic filter'.

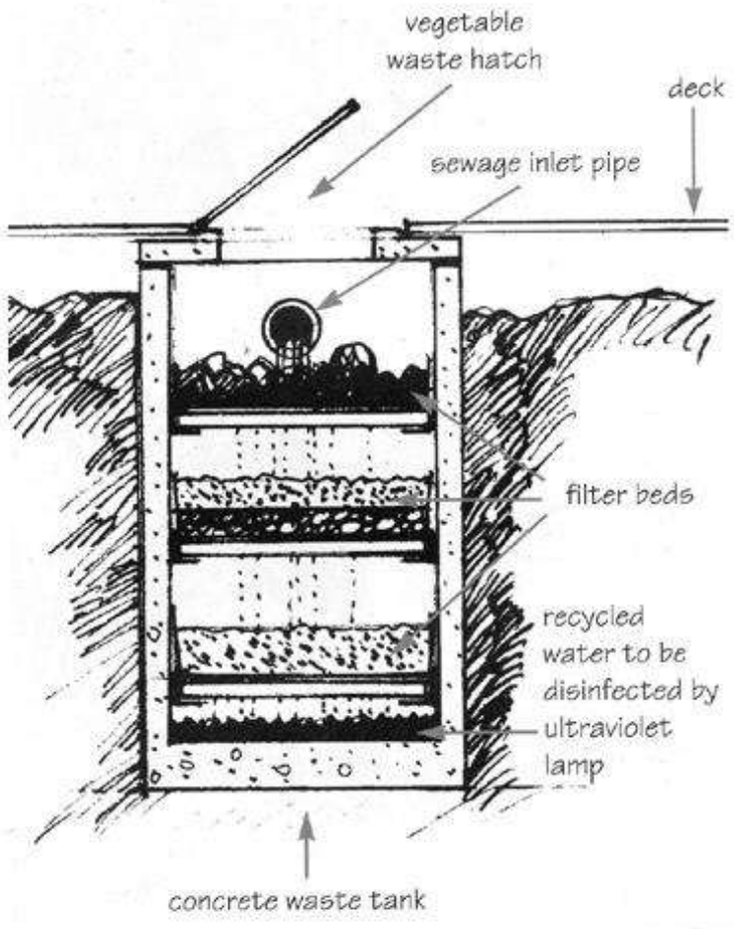
A hatch located near the inlet to the tank allows vegetable scraps, waste paper and other biodegradable household waste to go into the wastewater treatment system.

In the tank a series of filter beds consisting of sand and peat, worms, insects and microorganisms break down the waste present in the water. A carbon filter removes any remaining odour and colour from the filtered wastewater.

An ultra violet (UV) lamp provides a final stage of treatment, disinfecting the filtered wastewater as it is pumped to the house for re-use. This is the only system component that needs regular replacing (approximately once every 12-18 months). [See: 7.4 Wastewater Re-use]

Excess filtered wastewater is discharged into a wetland at the side of the garden, where it is absorbed by the plants and released to the atmosphere through evapotranspiration. This wetland also provides habitat for frogs and native birds.

The owner has made some modifications to the system. Since this system was installed there has been significant research and development in the area of on-site wastewater systems. Many reliable systems are now available.



Materials and indoor air quality

Only plantation or re-growth timbers were used in the renovation. Re-growth timber comes from forests that have re-grown after logging many years ago. As the original ecology never completely returns to a logged forest, this type of native forest has lower conservation and biodiversity value than an old growth forest, whilst still yielding some of the durability characteristics of old growth native timbers. [See: 5.4 Biodiversity Off-site]

Polished timber floors were used in the renovated kitchen and living area, as carpet can be a source of irritants for those allergic to dust mites.

A tung-oil based floor sealer was specified for the timber floor, but the contractor used an oil-modified urethane product. While this is not as harmful as polyurethane, it still contains volatile organic compounds (VOCs) and is moderately toxic.

Plantation hoop pine was used for the kitchen joinery. The kitchen joinery incorporates a specially designed waste sorter under the sink, a pull-out bin system which allows easy separation of waste for recycling.



Good ventilation in the kitchen and living area was achieved by use of louvre windows and external glazed doors opening to the garden. If too little fresh air enters a home, pollutants can accumulate to levels that can pose health and comfort levels.

Radially-sawn plantation hardwood timber was used for the outdoor deck. This technique reduces the amount of waste generated by traditional saw-milling, provided that the rhomboid shaped sections it produces can be used efficiently. Decking is an ideal use.

Avoiding the use of PVC was difficult at the time, as information could not easily be found on viable alternatives. The first flush diverter, the electrical wiring, the dishwasher and the paint to the interior all had PVC content. Greenpeace have since compiled a guide of alternative materials which can be found on their website.

Water-based paints were specified as they are generally environmentally preferable to oil-based paints. Plant or mineral based 'bio-paints' are environmentally preferred, with 'low VOC' conventional (synthetic) water-based paints being the next best option.

Sustainable Landscapes

The newest addition to the 'sustainable house' are a pair of free range chooks for egg-laying. The owners are now also growing 7 types of vegetable and various herbs in the back garden.

WAS IT EXPENSIVE?

Up-front costs

The costs (in 1996) were:

> water system	$11,000
> waste system	$11,000
> energy system	$26,000

These costs could be reduced by about 30-50 per cent on a bigger site, a sloping site or a new site.

If they were to do the same renovation in 2008, costs would be significantly lower. This is due to improved technology and increased availability of products. In the case of the energy system, this also takes into account increased installation efficiency and the government rebates available.

EVALUATION

Following is a summary of the most important things the owners learnt through the process of renovating and living in their sustainable house, and what they would do differently if they had the chance again.

> Link payment to the delivery of design goals so that design professionals, builders and tradespeople understand that these goals are not negotiable and to seek creative solutions.

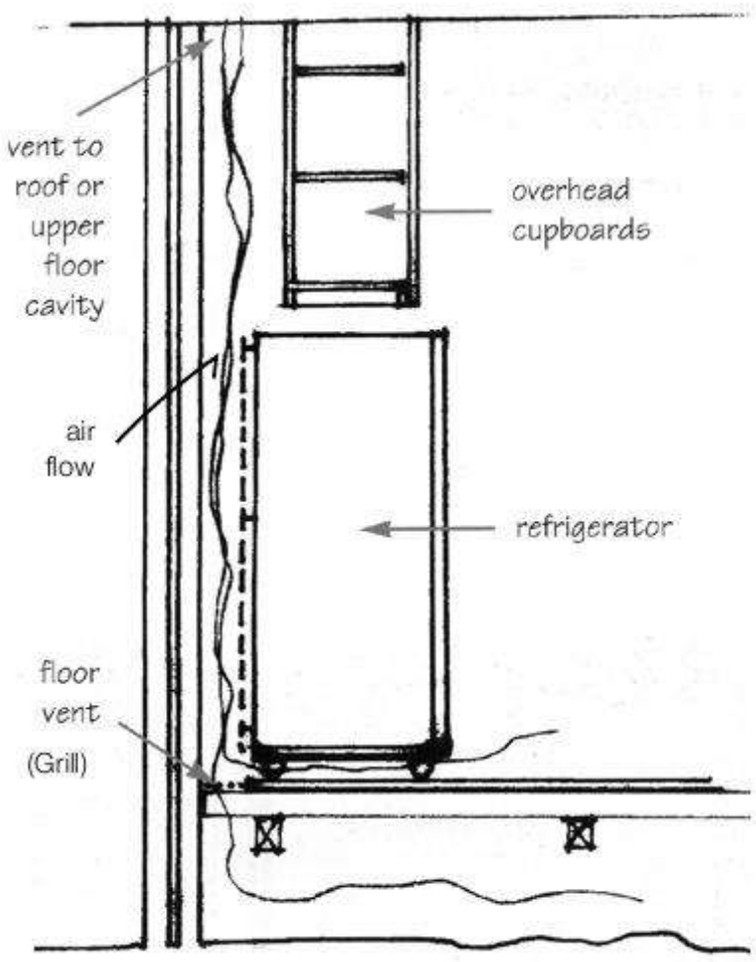
> Ensure that all consultants work as a team right from the beginning of the project, as good communication is essential for achieving optimum, workable solutions.

> Designers and purchasers of wastewater systems should consider systems that are as modular as possible to allow easy maintenance and replacement of parts. Ask to see performance data before purchasing a system. [See: 7.4 Wastewater Re-use]

> Ensure that solar panels are not overshadowed (by chimney stacks, roof ventilators, adjacent buildings, etc), as this will reduce their efficiency. The owners discovered that the overshadowing of one panel was reducing the efficiency of all the panels in the array. [See: 6.7 Photovoltaic Systems]

> Pay careful attention to glazing location and type. The west-facing wall in the kitchen and living area was extensively glazed to let in plenty of natural light. Unfortunately, this makes the space too hot in summer and too cold in winter. Use of a removable shadecloth outside the windows improves summer performance. Use of double glazing would be one way to improve winter performance. [See: 4.3 Orientation; 4.4 Shading; 4.10 Glazing]

> The use of toxic materials came about largely due to the lack of easily available information on alternatives. Since that time, many resources have been developed on materials use and indoor air quality. [5.1 Material Use]



PROJECT DETAILS

Designer: Michael Mobbs

ADDITIONAL READING

Mobbs, Michael (1998), *Sustainable House: Living for our future* CHOICE Books.
www.choice.com.au

Sydney's Sustainable House
www.sustainablehouse.com.au

Principal author:
Caitlin McGee

Clovelly NSW

RENOVATION

ZONE 5: Warm temperate



Topics covered

Passive heating and cooling
Accessible design
Reduction in greenhouse gas emissions
Reduction in water use
Rainwater harvesting
Greywater treatment
Materials use
Indoor air quality

AccuRate (thermal comfort)	Existing 2.7 (regulatory)
AccuRate (thermal comfort)	Renovation 3.4 (regulatory)

This award-winning Sydney renovation turns site constraints into opportunities, creating a spacious, light-filled home that is a showcase for leading-edge domestic water management. The renovation reduces the existing home's environmental impact and incorporates innovative technologies as an integral part of the architectural expression.

In pursuit of their philosophy of making the principles of sustainability an essential element of the design approach, the designers extended their concerns to incorporate the principle of universal access and adaptability with the home designed to accommodate an occupant with limited mobility.

BACKGROUND

Location and site

The house is in Clovelly, an inner coastal suburb of Sydney. Located within a warm temperate climate zone, it enjoys mild winters and warm summers moderated by cooling sea breezes. Rainfall is relatively high at around 1,200mm per annum. The architect describes the site as 'complex and constrained' due to its tight 234m² area and east-west orientation, which limits the potential for easy solar access. The existing house was a small, 'dark and poky' semi-detached dwelling with its long façade facing south.



Bart Maiorana

Design brief

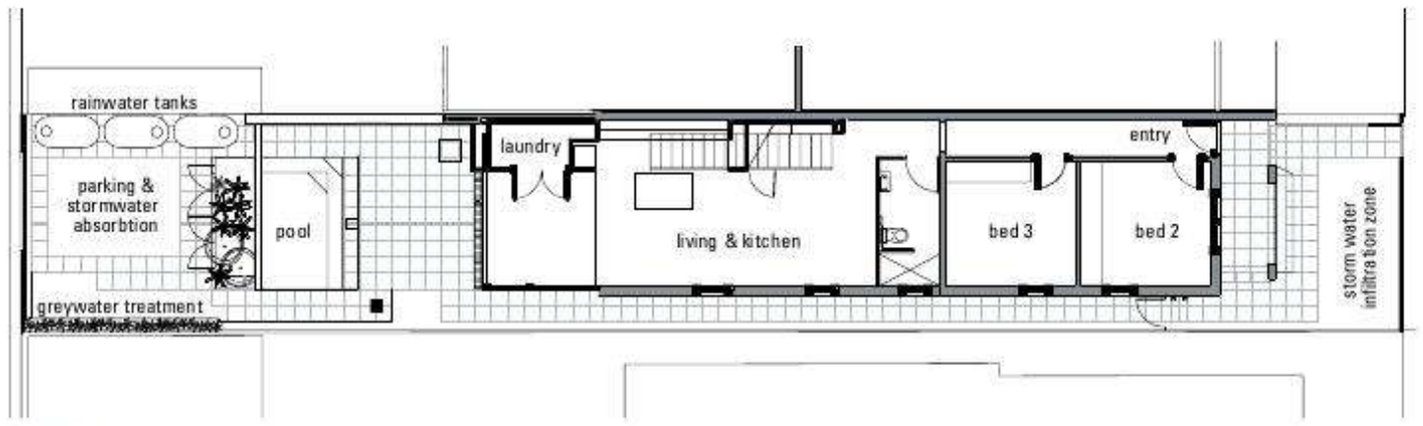
The owners wanted to open the house up to the garden and to natural light, a typical requirement for many inner-city renovations. Less typical was the need to meet the spatial and accessibility needs of an occupant with an ambulant disability. The owners were also keen to address key environmental issues and push boundaries where possible. They were particularly keen to 'do something significant' in response to Australia's pressing need to conserve water. [See: 7.2 Reducing Water Demand]

DESIGN RESPONSE

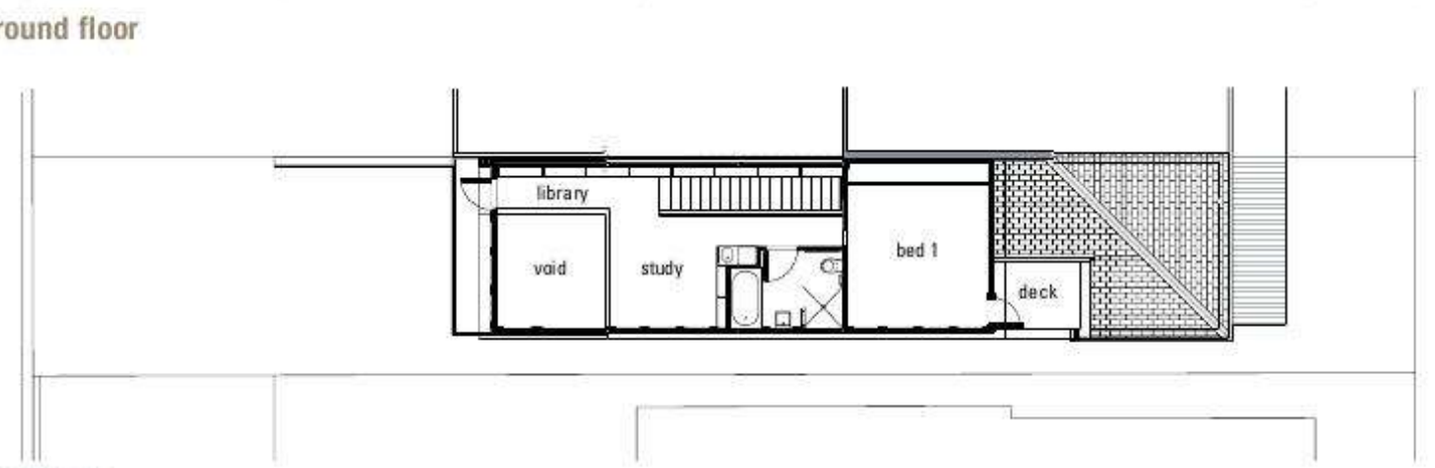
The key design challenges were to manage the site's poor solar access, maximise spaciousness on a tight site, and integrate the resulting open plan format with thermal and acoustic comfort.

Whilst the majority of the structure of the existing house was retained, the entire back wall was removed to accommodate a two storey addition. The addition encompasses a living area on the ground floor, and a home office, main bedroom, bathroom and kitchenette on the upper floor. At its centre are a staircase and void, creating a pivot around which the home operates. The northern wall along the staircase accommodates an extensive library.

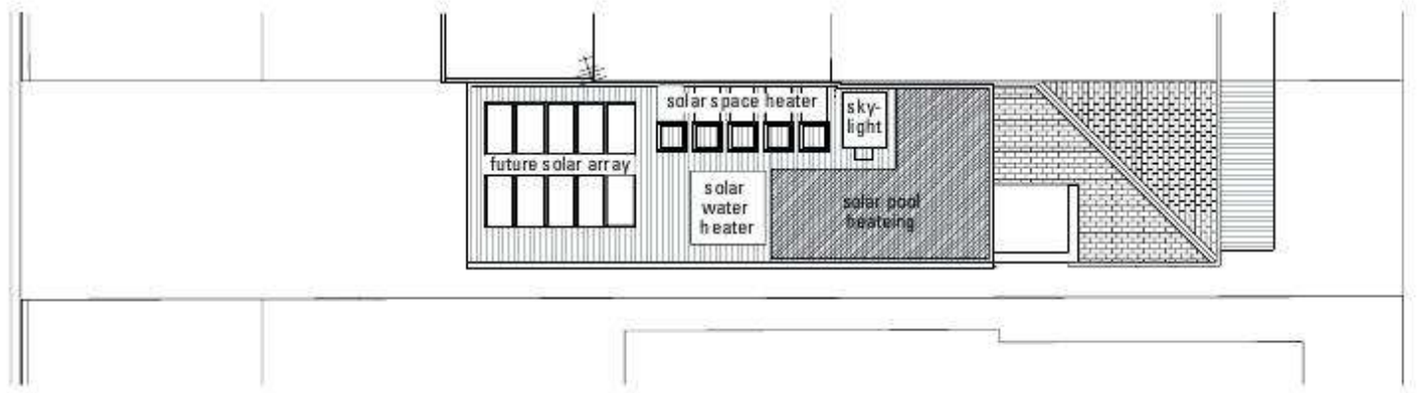
The geometry of the addition is based on a series of solid and open intersecting cubes, carried through into the design of the landscape. This underpinning design theme helps to provide a sense of unity, clarity and space. Urban design issues of privacy, scale and massing were respected and the approvals process was relatively straightforward. The house integrates a range of innovations including a vertical 'green wall' for greywater treatment, the first of its kind in Australia. [See: 5.13 Green Roofs and Walls]



Ground floor



First floor



Roof top

Natural cooling in summer is achieved through strategic placement of openings for cross ventilation. The double height void, as well as providing a sense of space, creates natural ventilation through the 'chimney effect'. Warm air is exhausted through high-level glazing and skylights, which in turn pulls fresh cooler air through the house at ground level. The west-facing wall can be opened up at night to encourage heat loss.

Shading on the west-facing glazing minimises unwanted heat gain in summer. On the ground floor, a deep recess provides protection. At a higher level, adjustable external louvres screen out low angle western sun in summer whilst admitting it to warm the living areas in winter. [See: 4.6 Passive Cooling]

Thermal insulation under the roof and above the ceiling is an important part of the passive design strategy, minimising unwanted heat loss and gain.

The concrete ground slab is covered with a battened timber floor. This reduces utilisation of the slab's heat storing properties, but allows quicker warming and cooling of the space. Similarly, the metal-clad brick veneer wall construction reduces the ability of the bricks to store heat but allows quicker warming and cooling of the space. [See: 4.9 Thermal Mass]

Light-coloured internal walls, skylights and clerestory glazing minimise the need for artificial lighting during the day.

Passive design strategy

The renovated house is designed to minimise the need for artificial heating, cooling and lighting and avoids reliance on mechanical systems like air conditioning in order to achieve ongoing cost savings and environmental benefits.

Double height voids and large glazed areas can be particularly problematic in terms of heat loss. This is counteracted to an extent by the solar powered heating system, however in retrospect the architect would have decreased the amount of south-facing glass and incorporated double-glazing to improve winter comfort. Draught protection on doors and windows helps to retain heat in winter. [See: 4.5 Passive Solar Heating]

'ACTIVE' SOLAR ENERGY SYSTEMS

Space heating and cooling

A proprietary solar-powered heating and cooling system is used to enhance indoor comfort without creating any greenhouse gas emissions. The system is a recent Australian invention and consists of two solar-powered fans and a heat collector on the roof. The heat collector is a metal and glass box, similar in principle to a solar hot water panel. The system works by raising the ambient indoor temperature in winter and extracting hot air in summer.

In winter the fans draw air from ceiling level, heat it to about 50° Celsius in the collector, and pump it back to floor level via insulated ducts. In summer the fans draw hot air from ceiling level out through an opening flap on the collector. For this home, one heat collector panel was installed as a trial, however in retrospect two panels would have been more appropriate. The cost of the system was approximately $2,500. Ceiling fans are also used to keep the home cool in summer. There is no air-conditioning or auxiliary heating used.

Water heating

The home uses an electrically boosted solar hot water system located on the roof. Heating for the small therapeutic pool is provided by a solar pool heating system, consisting of a series of heat-absorbing collector pipes located on the roof.

WATER MANAGEMENT

One of this project's special attributes is its treatment of sustainable water management technologies as an integral part of the design rather than aesthetic or conceptual 'add-ons'.

The owners were particularly committed to reducing their mains water use, firstly through a high level of water efficiency, and secondly through the capture and treatment of alternative water sources. The latter added approximately $20,000 to the cost of the renovation but enabled an estimated 80 per cent reduction in mains water use.

The different qualities of water available are carefully matched to appropriate uses. Mains water is used for drinking and cooking only. Rainwater is used to supply showers, baths, bathroom taps and the small pool. Greywater is collected from the bath, basin and shower and treated for use in toilets, the washing machine and garden irrigation. Water from the toilet, kitchen and washing machine is discharged to the sewer.

The home has a 'triple pipe' reticulation system for mains water, rainwater and greywater. Installing this was relatively easy given the significant scale of the renovation.



Water efficiency

Water demand is reduced through the use of water efficient taps and showers, dual flush toilets, a water efficient washing machine and outdoor planting with low water needs.

Rainwater collection and use

Three rainwater tanks with a collective capacity of 9,000L were specially manufactured to fit the limited space available and form a 'wall' along the northern boundary of the garden. Rainwater is collected from a roof area of approximately 100m^2 for use in showers, baths, basins and the pool. When asked about tank capacity, the architect suggests engaging a hydraulic engineer to do a water balance report. This takes into account factors such as the uses for rainwater, the roof area for rainwater collection and the amount of local rainfall to determine suitable storage capacity. The inclusion of a greywater system as part of the sustainable water management strategy allowed the storage capacity for rainwater to be reduced, compared to using rainwater only.

The rainwater system is outperforming expectations in terms of water quality. Analysis suggests the rainwater is of potable standard, but Sydney Water and NSW Health do not support the use of rainwater for potable purposes. [See: 7.3 Rainwater]

Greywater treatment and re-use

The 'green wall' system for greywater treatment was developed in association with environmental engineers ENVDS. It combines the popular European concept of 'green walls' as landscape elements with greywater treatment technology to produce a system appropriate for small urban lots – claimed to be the only vertical greywater system of its type in the world.

Water from the bath, shower and bathroom basin is stored in a holding tank and then pumped to the top of the green wall. Using gravity, the water trickles through a series of three planter troughs which act as filters, removing nutrients, polluting compounds and organic matter from the water. The sand in the filters does most of the work, whilst the plants are selected partially to enhance the treatment process and partially on the basis of being able to survive in a nutrient-rich sand base. The final stage of treatment is UV filtration, which was a requirement for approval of the system but has been found through monitoring to be unnecessary. The treated water is stored in a tank underneath the green wall for re-use in toilets, the washing machine and the garden. Any excess greywater overflows to the sewer.



The green wall is approximately 6m long, 2.1m high and 400mm wide. It consists of a galvanised steel frame and 3 horizontal folded steel sheet trays, and is designed specifically to save space and utilise gravity feed. The green wall is not yet an 'off the shelf' product, and expert input is required to determine the size and composition of the filters relative to the specific situation.

The treated greywater is non-potable, and regular testing confirms it meets NSW Health requirements for use in the toilet and washing machine. The green wall does not have the capacity to treat the nutrient-laden water generated by the washing machine, so this is discharged direct to the sewer. The green wall cost around $10,000. Because it was a

prototype, future versions are likely to cost less and be smaller. [See: 5.13 Green Roofs and Walls; 7.4 Wastewater Re-use]

Stormwater management

Excess stormwater not captured by the rainwater system is directed to underground absorption pits in both the front and rear garden, to recharge the aquifer and ensure that there is virtually no run-off from the site. [See: 7.5 Stormwater]



RENEWABLE ENERGY

Suitable roof space was incorporated into the design to facilitate future installation of a photovoltaic system, recognising that the costs of installing such a system are likely to decrease over time.

LIGHTING AND APPLIANCES

Energy efficient compact fluorescent lighting is installed throughout the home. LED (light emitting diode) lighting, another very energy efficient technology, is also used in selected locations. Appliances have been chosen for their energy and water efficiency ratings. The fridge has a 5 star energy rating and an external clothesline prevents the need for an energy-hungry clothes drier. [See: 6.4 Appliances]

CONSTRUCTION MATERIALS

Attention has been paid to the ecological and health impacts of materials and finishes. Plant-based 'bio paints' have been used for internal walls and ceilings. These bio paints improve indoor air quality, as they do not off-gas toxic volatile organic compounds (VOCs). Similarly, floors have been finished with natural vegetable-based oils instead of polyurethane, to avoid VOCs.

Sustainable timbers, including spotted gum timber flooring, have been selected for use in the home. Databases such as Ecospecifer now make the task of researching the sustainability credentials of such timbers much easier.



Because of their lower embodied energy, polypropylene pipes are used for water supply plumbing rather than copper.

External pavers have been selected for their low embodied energy and are laid so as to allow stormwater infiltration through the paving joints. [See: 5.2 Embodied Energy]

ACCESSIBLE 'UNIVERSAL' DESIGN

The home demonstrates an important aspect of social sustainability – the ability to accommodate occupants with varied levels of mobility. In response to the needs of a client with an ambulant disability, the bathroom, master bedroom, home office, stairs, kitchen and living spaces are all wheelchair accessible. The bathroom has the generous door width and layout needed for compliance with AS1428.1. The kitchen contains an island bench on castors that can be moved to make more space.

The home office is upstairs in the centre of the house, overlooking the living area and garden, and has been cleverly designed to reduce the need for physical movement. It includes a control for the front door, and is adjacent to a kitchenette and bathroom. A wide staircase with a gentle gradient, fitted with a stair-climber, provides easy access to the upper level. [See: 3.2 The Adaptable House]

LANDSCAPE

The rear garden is divided into two equal courtyard spaces, based on the same geometry as the home extension. The courtyard closest to the house is designed as an extension of the living space. It contains a 7,500L therapeutic pool, supplied exclusively with rainwater. The rear courtyard functions as a garden and service area, accommodating water storage and treatment and an off-street car parking space. It is flanked by rainwater storage along one boundary wall and the 'green wall' along the other – both of which are treated as a vibrant part of the landscape design rather than hidden from sight.

An intermediate wall between the two courtyards houses pumps and other equipment to support the pool and water treatment. It incorporates a feature wall, a fountain and a slate-covered planter box. The fountain, pool and water wall help to condition the air on hot dry days through evaporative cooling, dropping the temperature outside the living areas by several degrees.

Local native plants and groundcovers are used throughout the garden, chosen in part for their low water needs. It includes native trees such as Blueberry Ash and Lilli Pilli which both grow rapidly and afford considerable shade to the west facing windows. The expectation is that the combination of these trees plus the substantial trees on the adjoining property will mean that within a few years the windows will receive very little summer heat load. [See: 2.4 Sustainable Landscapes]

EVALUATION

The renovation was completed prior to the implementation of BASIX, however retrospective scoring using BASIX estimates the home uses 25 per cent less energy and 54 per cent less water than the average NSW home. Onsite metering and records kept by the occupants show the home is achieving a reduction of 75-80 per cent in mains water use, compared to the home's consumption before the renovation. The occupants are pleased with the radical cuts in water consumption, claiming that they have never run out of tank water despite being in a period of almost constant drought since the house was occupied.

Although there were some teething problems associated with the renovation's innovative approach, the experience was largely a positive one. The plumber initially contracted was not receptive to the sustainable water management initiatives, so a new more committed plumber was found. After initial caution, the builders became interested in trying a fresh approach. Local Council staff were enthusiastic and helpful, and the mayor has since visited the house and showcased it in presentations.

Completed in 2004, the house has won a range of awards including the Gold Medal at the NSW Green Building Awards and the Royal Australian Institute of Architects' Sustainable Architecture award, and it has featured in print publications and television news and lifestyle programs.

The home is proving easy to maintain, meeting the goal of making its owners' lives easier rather than harder.

PROJECT DETAILS	
Architects:	Steve Kennedy, Simon Anderson and Erin Owens, Kennedy Associates
Environmental Engineer:	Toby Gray, ENVDS
Hydraulic Engineer:	Javid Nasseri, Nasseri Associates
Structural Engineer:	Cosmo Farinola, Low and Hooke Partners
Landscape Architects:	Mike Horne, Turf Design Studio
GreyWater System:	Garden Saver – Ken Pepyat

Principal author:
Caitlin McGee



Bart Maiorana

Marion SA

RENOVATION

ZONE 5: Warm temperate



Topics covered

Passive design
Renewable energy
Energy efficiency
Rainwater harvesting
Sustainable materials
Construction waste avoidance

AccuRate (thermal comfort)	Existing 3.8 (regulatory)
AccuRate (thermal comfort)	Renovation 4.7 (regulatory)

This study shows how a conventional suburban project house has been renovated to provide a comfortable and efficient home that fits within the context of its surroundings.

The aim of the design was to improve the home's liveability, minimise environmental impact during construction and operation, and harmonise with the natural surroundings.

The original budget of about $120,000 was continuously reviewed to balance needs and desired outcomes with 'value for money'. The final cost of the renovation was $155,000.

The clients' idea of cost effectiveness was informed by their environmental awareness, their concern for minimal use of resources, their desired lifestyle, the long-term viability of the building and advice from the architect and council.

Of particular concern was enhancing natural lighting, cross ventilation and linkage to the natural surroundings. The inherent characteristics of the existing building were utilised and improved, along with creative 'grafting' of a low environmental impact addition.

The house has attracted considerable publicity, highlighting its great performance in terms of low energy use and low running cost.

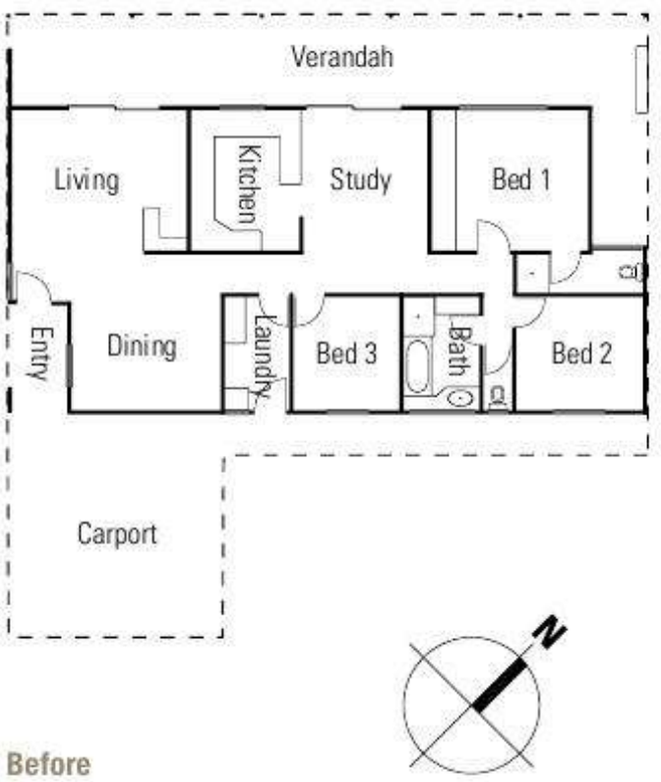
The flow between outdoor and indoor spaces has resulted in a new relationship between occupants and passers-by. Many visitors have been attracted to the house by its appearance and the tangible application of passive and renewable energy measures.

The existing house

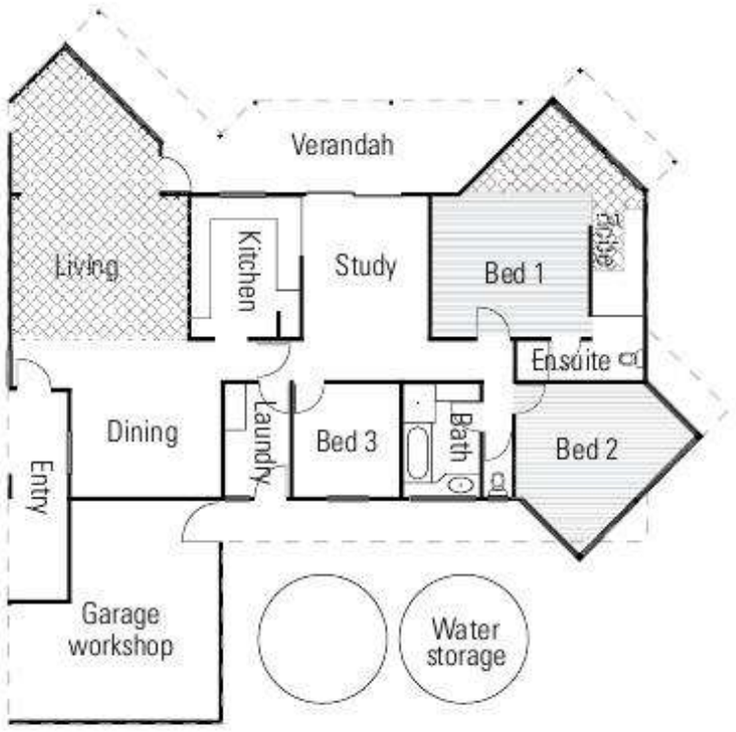
The house is a conventional 1970s spec-built double brick home in suburban Marion, SA. It is situated alongside a park reserve, with school grounds across the creek.

It is located in a suburban environment, and surrounded by contemporary typical brown brick dwellings featuring bottle glass and concrete roof tiles.





Before



After

Site and climate

Marion is about 4km inland from the coast, in a mild to warm temperate climate zone, with cool wet winters and hot dry summers. The temperature range is around 15-28° in summer and 3-17° in winter.

Cooling breezes come from the south west in summer. In winter, cold winds come predominantly from the north east.

Solar access to the block is excellent, limited only by tall eucalypts on the east and west boundaries. Open areas to the north and east of the block increase its exposure to wind.

PROJECT AIMS

The main aims of the project are summarised below:

Amenity – Enhance views to the reserve and creek and provide the clients with an improved living space, a more direct relationship with outdoors, and improved cross ventilation and natural lighting.

Energy – Achieve good passive solar design, maximise energy efficiency, use materials with low embodied energy and use renewable electricity.

Water – Harvest rainwater to supply all household uses.

Materials – Use plantation timber, to design for 'long life, low maintenance' and re-use and recycle construction waste.

DESIGN SOLUTIONS

Orientation and windows

The alignment of the original house was 45° to the North-South axis. The additions are angled in plan and elevation to enable the most effective solar access, and to provide interesting spatial relationships between existing 'pokey' spaces and external areas.



The new living area contains a significant amount of north facing glazing. Windows which were not practical to curtain were double glazed for improved insulation.

In winter, the double glazing allows sun through to heat the thermal mass, while preventing conducted and convected heat from escaping back to the outside.

Internal spaces are airy and flooded with natural light during the day. [See: 4.3 Orientation; 4.10 Glazing]

Shading

Eave overhangs and angled western red cedar solar oriented slats in pergolas control sunlight penetration on the north facade.

East and west facing windows are partially screened by the eucalypts along the boundaries. In addition, east facing windows are screened with external blinds and west facing windows are tinted with metallic film. [See: 4.4 Shading]

Thermal mass

Concrete slab on ground has been used as the flooring system for the extensions, to provide additional thermal mass. The existing suspended timber floor in the lounge was also replaced with a concrete slab.

Concrete floors are tiled, not carpeted, to enhance the thermal performance of the concrete. Passive solar design allows as much winter sun as possible into the house to heat up the thermal mass. [See: 4.5 Passive Solar Heating; 4.9 Thermal Mass]

Structure, envelope and insulation

The new roof over the living area was raised and angled to provide the optimal angle for the roof mounted photovoltaic array and solar hot water system. This popped up metal roof also provides a light and airy atmosphere to the internal space.

The new walls are framed with plantation timber and clad in 'eco-ply' pine plywood.

The new floors are concrete slab on ground with a tiled surface.

Reflective insulation is used in the roof, with R2.5 bulk insulation to external lightweight walls and R3.0 bulk insulation to ceilings. [See: 4.7 Insulation]

Ventilation

Narrow louvre windows maximise use of breezes and provide security. Placed in strategic locations, the louvred windows allow controllable natural cross-ventilation.

South facing clerestory windows above the living area provide views of surrounding trees and can be opened for ventilation in summer. They are designed to encourage natural ventilation by exhausting warm air and catch cooling breezes. [See: 4.6 Passive Cooling]

Day lighting

The north facing glazed areas result in vastly improved natural daylight from several different directions at once, which adds to the open, airy feel of the rooms.

The living area has dynamic natural lighting, utilising a mix of small, large and clerestory windows that allow light in from different directions.

South facing rooms have 'solar-tubes' installed in the roof to add more daylight.

Landscape

The house sits well in its context, allowing visual connection to the native vegetation reserve. It 'welcomes' visitors because of its openness, while providing security for its occupants through creative use of the boundary line in the extension, and simple pool type fencing.

A vegetable patch has been cultivated to supply the house occupants with fresh produce.

Pre-settlement native vegetation seedlings have been raised and planted in the garden and along the edge of the reserve. Removal of existing trees was avoided. [See: 2.4 Sustainable Landscapes]

Paths are made of concrete lattice rather than full concrete to minimise run-off. [See: 7.5 Stormwater]

SERVICES AND APPLIANCES

Renewable electricity generation

A 1.05 kW grid-connected photovoltaic array comprising 6 Sharp 175W panels and a 1200W inverter was mounted on the roof. Power exported to the grid (795kWh) was 72 per cent of power imported from the grid (1109 kWh) in 2002 / 2003. [See: 6.7 Photovoltaic Systems]

Hot water

A solar water heater is used to pre heat water, which is then passed through an efficient 5-star gas instantaneous hot water system. [See: 6.5 Hot Water Service]

Heating and cooling

To minimise the need for artificial cooling, louvre windows are placed to maximise cross-ventilation in the house.

An evaporative cooler provides supplementary cooling in summer. The unit is located at ground level in a shady spot on the south of the building. The inlet air drawn into the unit is cooler than if it were on the roof in direct sunlight, and hence requires less energy to cool.

An efficient 5.5-star rated gas space heater is located in the living room for winter use. Yearly gas consumption is around 4700MJ. [See: 6.2 Heating and Cooling]

Lighting

Compact fluorescent lights are used throughout the house. The design allows for plentiful natural lighting. [See: 4.11 Skylights; 6.3 Lighting]

Natural gas is used for all cooking, and energy and water efficient white goods have been selected. Background electricity usage of appliances and consumer electronics in the house, including standby, is approximately 3kWh. [See: 6.4 Appliances]

WATER

Rainwater harvesting

Rainwater is expected to supply the house's water needs for most of the year, depending on the length of the dry spell in summer. In 2003, no mains water was used between March and September.

Enviro-flow gutters prevent leaves and bark from nearby trees entering the system, and an in-line mesh filter is fitted to the 21,000L semi-submerged storage tank. The system uses a 550W multi-stage pump used for low noise and high performance.

Toilets are dual plumbed to enable switching to mains if necessary in summer.

Water efficient fixtures such as WELS rated low-flow showerheads and 3/6 L toilets have been incorporated. The washing machine is a front-loading water efficient model. [See: 7.2 Reducing Water Demand; 7.3 Rainwater]

MATERIALS USE

When selecting materials for the renovation the following issues were taken into account:

> The context and location of the existing house.

> Thermal properties that contribute to the energy efficiency of the building envelope. Double glazing and high mass floors are an example of materials used primarily for their thermal benefit. [See: 4.9 Thermal Mass]

> Low embodied energy of materials. Materials with high embodied energy (such as concrete) have only been used where there is a clear thermal benefit. The new lightweight timber-framed walls have low embodied energy. [See: 5.2 Embodied Energy]

> Sustainable sourcing of materials. Renewable resources such as plantation timber have been used where possible. [See: 5.4 Biodiversity Off-site]

> Impact on health and indoor air quality. Materials with no or low toxicity have been selected where possible. For example, an 'Enviro-pro' finish was used to timber and cork floors in place of conventional polyeurethane.

> Durability and longevity of materials, including reduced need for ongoing maintenance.

> Recycled content of materials. Windows, a sliding glass door, timber flooring and bricks were salvaged from the demolition for use in the renovations. [See: 5.3 Waste Minimisation]

EVALUATION

The lightweight timber additions were effective for simple, quick, low-cost construction, avoiding use of heavy machinery, with minimal disturbance to the surroundings.

This project has contributed considerably to public awareness of ESD. Its site, context and occupants' willingness to welcome onlookers with their direct experience and information is exemplary. Adelaide Greenhouse Office's Solar House Day tours have attracted attention to the renovated building's application of active and passive energy initiatives.

Most importantly, the clients possess a genuine sense of achievement and pride in their new home.

The renovated building and its enhanced performance demonstrate that low impact housing is achievable in the most ordinary situation, affordable, exciting and desirable for a high quality of life.

Awards:

Royal Australian Institute of Architects South Australian Chapter Commendation in Sustainable Architecture 2003

Housing Industry Association GreenSmart Renovation of the Year 2003

PROJECT DETAILS	
Architect:	John Maitland, Energy Architecture
Builder:	Daryl Stanton, Gage Constructions

Principal author:
Geoff Milne

Hawthorn VIC

RENOVATION

ZONE 6: Mild temperate



Topics covered
Orientation
Design for climate
Passive heating
Passive cooling
Insulation
Thermal mass
Glazing
Shading
Reduced water demand
Water harvesting
Water re-use
Material selection
Energy use
Hot water
Lighting

AccuRate (thermal comfort)	5.6 (regulatory)

This project is an excellent example of how the performance of an ordinary Victorian terrace can be transformed while still working within the tight parameters of a small site with stringent heritage regulations. The post-renovation house achieves self-sufficiency in terms of energy use, incorporates low embodied energy materials and generates a large portion of its own water needs.

PROJECT BACKGROUND

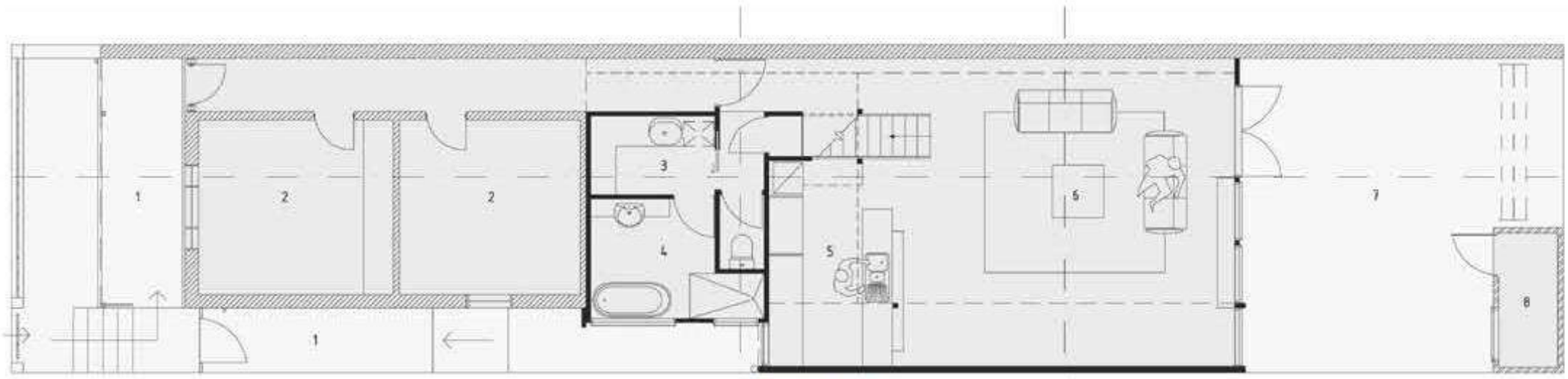
The clients, both professionals in an environmental field, had a high level of awareness of sustainability issues. Their brief was to renovate their semi detached single fronted Victorian home in an inner city Melbourne suburb in a way that considered not only the rearrangement of functional areas and the local planning and heritage codes, but also the delivery of outstanding environmental, occupant health, energy and water efficiency.

An initial feasibility study was commissioned to accertain water catchment potentials, as well as the extent of the sustainable features and their costs. A two bedroom small family home with a study, north-facing living room and kitchen were the specified spatial requirements.

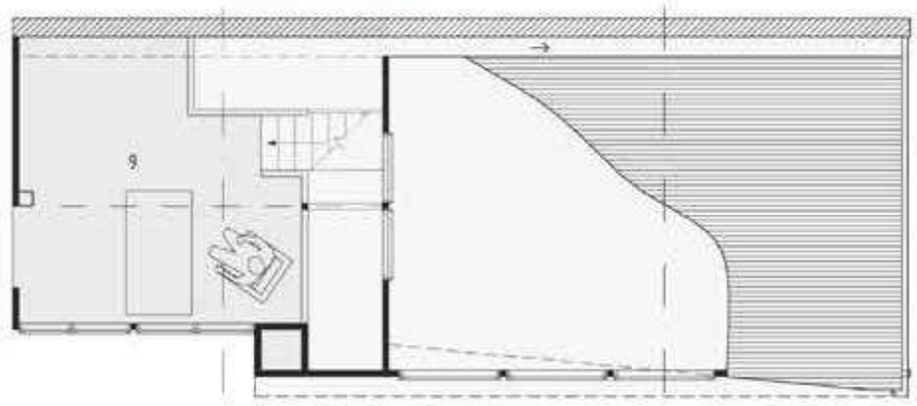
Heritage overlay

The property is covered by heritage overlay control. The streetscape has a local significance as an illustration, of the influence of the brick industry, workers housing and of the garden suburb ideal for the less affluent. The new design restores the 1890's style verandah and picket fence and includes appropriate heritage colours. The solar panels and solar hot water service, water collection and greywater systems had to be hidden from the streetscape. This was quite a challenge for a very small site of 203m^2.





Ground floor



Upper level

PLANNING PROCESS

The planning approval was prolonged, with the application process taking eleven months. Not all of the delay was due to the environmental features proposed by the design. One issue was the neighbours' concerns about the noise that might be associated with the pumps and the way in which the greywater was treated on site. The council health officer was also initially concerned about potential health risks with the use of greywater, but persistence from the design team was successful in allaying these fears.

Overlooking was also a major issue for the neighbours and it was solved with cleverly designed screens and louvers and extensions to fence heights. There appeared to be no concern about the PV power system on the roof. The height of the building was kept to a minimum so that the extension was not visible from the street.

The council's planners were initially ambivalent towards the project as an example of best practice sustainable design for a difficult inner city block. However, persistence eventually made the overall benefits of the innovative design features apparent to the authorities and planning approval was achieved. So successful was the project that the council recognised the renovation with an environmental award.

DESIGN SOLUTION

A warm, comfortable small family home was provided that works both spatially and environmentally for the clients. The rear wall of the house faces north on its short axis.

The original unrenovated house had a rear wall with a smattering of outhouses and no north facing windows. The new rear wall had to be setback sufficiently from a neighbouring 8 metre high tree that would have interfered with northern sun entering the building.

A mezzanine level was created to house a generous study with roof storage access. The additional height was used as an inlet point for a heat shifter that takes additional warmth from the north rooms via a fan into the south rooms that receive no sun.

Highlight windows were created on the east facade to provide additional heat gain and natural day lighting. These windows had to be sufficiently high to avoid overlooking of neighbour's private open spaces.

The extension was constructed on an on ground slab and the old timber floors to the front 2 rooms and hallway were insulated with reflective foil insulation under the external joists to improve thermal performance.

The active sustainable features designed into the home include a grid interactive PV system, greywater treatment and recycling, water catchment tanks, a gas boosted solar hot water system, and use of recycled and plantation timbers.

Cladding: the external walls are a combination of rendered fibre cement sheet, cypress macrocarpa weatherboards and AAC block work. Cypress macrocarpa is sustainably sourced from windbreaks. Both products were chosen for their low embodied energy and in the case of the AAC block work its inherent insulation properties. The unique nature of AAC also contributes to some thermal mass. The external walls were bagged and painted with a cement-based paint with a minimum 20-year life.

Recycled materials: the internal timber posts were made from recycled ironbark. Recycled jarrah and mountain ash was used on bench tops in the kitchen with New Age Veneer in Tassie Oak on the cabinets. The mezzanine floor is recycled messmate. Three thousand bricks were cleaned and re-used for the party wall and rear battery room. The original house Baltic pine floorboards were also re-used. The turned verandah heritage posts were custom made from recycled ironbark because off the shelf heritage posts are made from virgin imported rainforest or native timbers.

ARC steel was used for slab reinforcement which is 100 per cent recycled and the concrete was Slag Blend used for its recycled content.

The sewage pipes are made from PVC and the metal roof has a component of recycled scrap steel.

A porus piping, made from recycled car tyres, has been adapted into the greywater tank as part of the aerator system.

The kitchen also has a recycling system installed for compost and general garbage.

Thermal mass and insulation

Thermal mass is provided by the concrete slab, AAC and recycled brick walls from the demolished section.

Wool/polyester batts were installed in the walls and ceiling to provide R1.5 to walls and R3.5 to ceiling. Reflective foil insulation was used as a roof blanket, and due to its excellent reflective properties, increased the R rating by up to R1.5.

Reflective foil insulation was also used under the existing joists in the old section of the house. [See: 4.7 Insulation Installation]



Glazing

All windows and glazed doors are double glazed with 6-10mm argon gas space between panels and weather stripped to prevent draughts. The existing front Victorian windows were reglazed with higher performing laminated single glazed units. The existing traditional frames could not accommodate double-glazing so the nearest equivalent product in single glazing was used. A fixed eave shades the east facing windows in summer. The west wall is a party wall and has no windows. [See: 4.10 Glazing]

Shading

The PV panels and solar hot water collectors on the roof also provide significant heat reductions. Sail shades have been provided to the north facing deck. They are removed in winter to allow maximum solar gain. A fixed eave on the east shades the windows from summer sun.



Ventilation

Maximum cross-flow ventilation has been allowed through strategic window placement and by most windows utilising casement mechanisms that increase the size of the openable space. [See: 4.6 Passive Cooling]

APPLIANCES AND SERVICES

The home is heated with a flued gas space heater, a gas wall console heater and a smaller unit for the bathroom/laundry area. This system emits only 1.0 nanograms of NO^2 per joule of gas compared with 5.0ng/j for a typical unflued gas heater. No supplementary cooling is required for summer. After one year there has been a ten per cent reduction in gas consumption compared to the pre-renovated house. The occupiers were most surprised to discover that the old house used 11,000MJ of gas to heat one 14.5m^2 room, compared to the sustainable design of 15,000MJ to heat four rooms with total floor area of 103m^2.

All light fittings have been designed to accommodate compact fluorescent globes to reduce energy usage. Low voltage halogen lights have been avoided. [See: 6.3 Lighting]

Photovoltaic system

18 x 75 watt photovoltaic modules were installed to generate electricity to the local grid (net metering allows the electric meter to run forwards and backwards). After one year the system has produced about 1,600kWh of renewable electricity, which equates to 88 per cent of the total household use. The owners have signed a contract with an electricity retailer for 30c cash in hand for every kWh generated in excess of onsite consumption. [See: 6.7 Photovoltaic Systems]





Greywater

A Garden Saver 1,000L greywater system has been installed to take all greywater from shower/bath and washing machine and is used for non-edible garden use and to flush the toilet cistern. The tank is hidden under the rear deck.

The problem of water odour was overcome with an air blower. The water is clear and odour free and can be stored for months. The owners have applied for a grant to monitor the water usage and savings over a 12 month period as well as testing of water quality in both the greywater and rainwater tanks. WELS rated water efficient appliances and showerhead have been installed and the best available dual flush toilet. [See: 7.4 Wastewater Re-use]

Rainwater collection

The house has a roof area of 120m^2 and rainwater is channelled into storage tanks hidden under the front verandah and tanks down the side of the building. The optimum water storage capacity was calculated in relation to annual rainfall statistics. So far this roof harvesting, combined with the greywater system, has provided 65 per cent of domestic water needs. In an average (non-drought affected) year this is expected to be more than 75 per cent, a great result for such as small roof area.

Toxicity studies on the type of metal roof used indicated it was the best choice for catching rainwater used for drinking. A specially designed guttering system was also installed to minimises debris and pollution and its compatibility with the chosen metal roof contributes to maintaining quality drinking water. The system includes a first flush process with a twin water filter on the kitchen tap. Due to the restricted nature of the site nine smaller tanks were installed under the front verandah and down the side of the house particually innovative response to a tight space situation. [See: 7.3 Rainwater]





Solar hot water

A solar hot water unit with three panels and 14 risers was installed. The electric element was removed. The system is now boosted by an instantaneous natural gas unit in winter. Due to limited roof space to accommodate the PV panels and the hot water service it was installed facing west and an extra panel was installed to compensate for the reduced efficiency. The position was also limited by heritage visibility issues from the street, but despite this, solar energy has provided 90 per cent of hot water needs for a family with young baby.

Low toxicity finishes

The new concrete floors are covered in marmoleum sheet flooring which is a totally biodegradable product made from natural fibres. It also has low allergen properties. The walls are painted with low toxic paints, commonly available at hardware stores.

Conclusion

Overall, the project demonstrates a considerable enhancement to an otherwise ordinary performing building, despite the considerable constraints placed on the design process by minimal site space and other regulations. The renovated house not only provides excellent health benefits for its occupants but also has a significantly smaller impact on the environment.

PROJECT DETAILS	
Designer:	Andreas Sederof and Ryan Strating, Sunpower Design
Builder:	Brett Richards, Everbuild
Engineer:	Andreas Sederof, Sunpower Design

Principal author:
Caitlin McGee

Surrey Hills VIC

RENOVATION

ZONE 6: Mild temperate



Topics covered

- Passive heating and cooling
- Efficient envelope design
- Renewable energy use
- Efficient appliance use
- Rainwater harvesting
- Greywater treatment/re-use
- Reducing embodied energy
- Greenhouse gas reductions
- Sustainable materials use
- Waste minimisation/recycling
- Indoor air quality

AccuRate (thermal comfort)	5.1 (regulatory)

This extensive renovation of a 1930s duplex in Surrey Hills, Melbourne, incorporates the latest technology in solar efficient design, water collection, greywater re-use, and photovoltaic grid-interactive power systems. It also uses forest friendly timber products and low toxicity finishes.

The owners, a young couple, wanted to renovate their 1930's brick duplex. The existing home was a maze of small pokey rooms.

Their brief called for the existing home to be upgraded to a solar efficient 2-bedroom home with large living areas, two separate studies and two bathrooms. They were keen to incorporate the latest technologies in sustainable home design.

The climate is cool temperate. The prevailing winds come from the southwest in winter and from the northwest in summer. The diurnal (day/ night) temperature range normally exceeds 8°C. [See: 4.2 Design for Climate]

The site is a long urban block, 48 x 10m wide, running east-west. Northerly access was limited by the presence of the neighbouring half of the duplex, situated directly north and sharing a party wall. The neighbours' proposed extension also had to be taken into account. [See: 2.2 Choosing a Site; 4.3 Orientation]

DESIGN SOLUTIONS

General planning

The existing home was partly demolished and re-planned. The front living room was converted to a master bedroom with ensuite attached, and the rear of the building was removed and rebuilt. Only two rooms remained intact by the completion of the project.

Maintaining the streetscape and the connection to the neighbouring duplex was seen as important by the owners. This was achieved by leaving the street facade of the house intact to match the neighbouring duplex and to fit in with the character of the street. [See: 2.3 Streetscape]







The extension was built with a suspended concrete slab for thermal mass and an AAC blockwork party wall for its excellent fire rating and good sound insulation properties.

The pitch of the north-facing roof was designed to accommodate solar panels and a solar hot water service. [See: 6.7 Photovoltaic Systems]



Courtyards were located to the north of the building to maximise solar gain, with an extensive area of double glazing in the roof over the dining/ living area. [See: Passive Solar Heating]

The open-plan kitchen, dining and living spaces opening onto an external north-facing deck and internal courtyard which facilitates natural ventilation and is conducive to a relaxed lifestyle.

Maximum cross-flow ventilation was achieved with carefully positioned windows. A window was placed above the stairs to create a thermal chimney for stack ventilation. [See: 4.6 Passive Cooling]

A basement is located below the living room to accommodate a battery room (for the photovoltaics), storage, a dog shower and a cellar.



Cladding

External walls are a combination of rendered fibre cement sheet and AAC blockwork. Both products were chosen on an environmentally preferred basis for their low embodied energy and more sustainable manufacturing processes. [See: 5.1 Material Use]

Boundary walls are AAC (autoclaved, aerated concrete) blockwork. The fire rating and insulating properties of this material made it an ideal choice for a boundary wall.

Thermal mass and insulation

A new suspended concrete floor slab at the rear of the house and the brick walls which have been retained at the front of the house provide the majority of the thermal mass required to even out day/night temperature variations. [See: 4.9 Thermal Mass; 5.12 Concrete Slab Floors]

Concrete slab insulation is provided by 50mm thick RMAX L grade foam insulation with an R-value (insulating value) of at least R1.0. This insulation was placed on the underside of the entire suspended slab. [See: 4.7 Insulation]

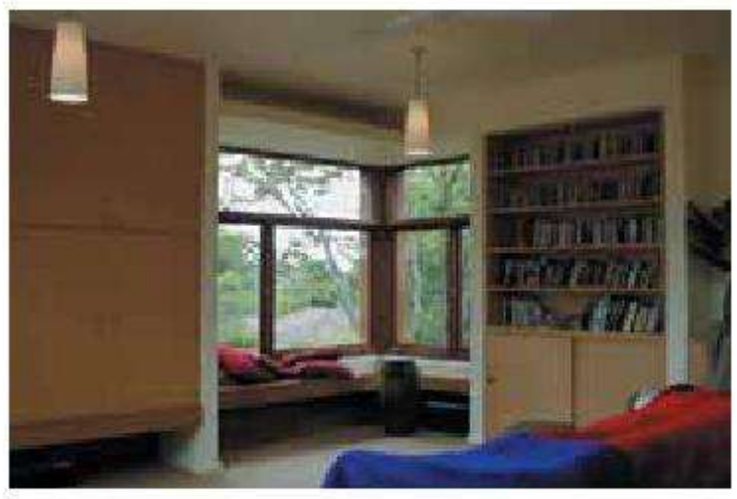
AAC walls in the dining area provide reasonable thermal insulation (R1.5 for 200mm thickness) due to the trapped air bubbles within the blocks. They also contribute moderately to the thermal mass of the structure due to the masonry component. [See: 5.5 Construction Systems]

Wool/ polyester bulk insulation batts were installed in the walls and ceiling. The R-value of the batts was R1.5 to walls and R3.0 to ceiling.

'Air-cell' (an innovative insulation product that combines the benefits of reflective and bulk insulation by trapping bubbles of still air inside reflective foil) was used in addition to bulk insulation in the roof. This increases the total summer roof R-value by around R2.2 and provides a sarking layer.

Glazing

Double glazing (insulating glass units or 'IGU') is used for all windows and glazed doors.



Roof glazing is an argon-filled double glazed assembly with a low-e coating on the inside face of the glass. A 12mm spacer bar is used between the glass sheets to increase the R-value and minimise heat loss. [See: 4.10 Glazing]

There are no west-facing windows in the new extension.

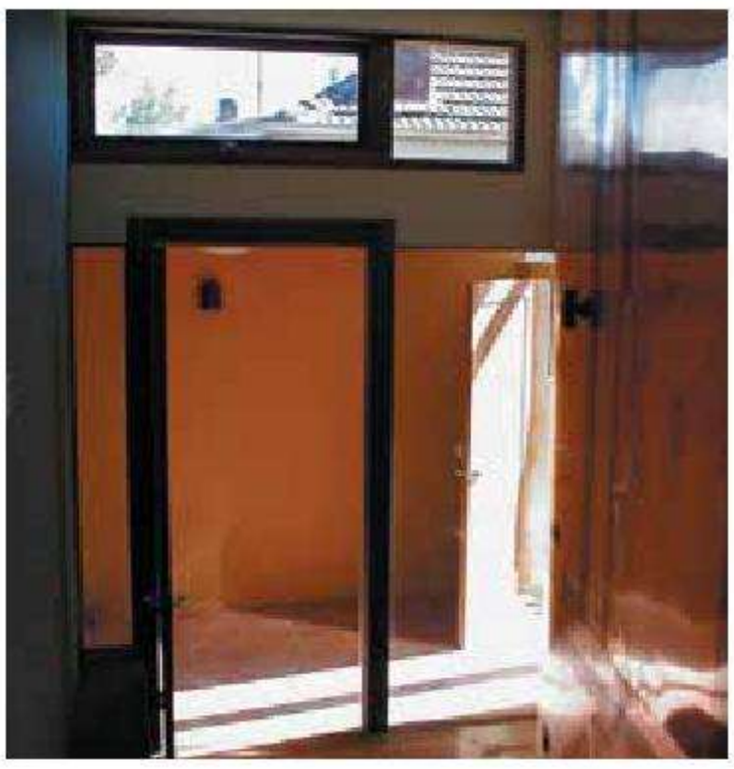
Shading

An acrylic canvas shade sail protects the north facing courtyard and deck from summer sun. It is removed in winter to allow maximum solar penetration into the building.

This adjustable shading system allows maximum flexibility in Melbourne's unpredictable climate. It is particularly useful in spring and autumn when fixed shading is unable to respond adequately to hot or cold snaps.

Roof glazing is shaded by blinds on auto spring loaded rollers. As the roof glazing can allow serious overheating in summer, the designer experimented with the unique method of using a version of Air-cell for the blind. This should reduce heat gain by up to 95 per cent in summer.

Additionally, photovoltaic panels on the roof will provide significant heat reduction by shading large areas of the roofing material from direct sun. In effect, this creates a partial fly roof for the building. [See: 4.4 Shading]



Natural ventilation

Windows have been carefully placed to facilitate maximum cross-flow ventilation.

Casement mechanisms, which increase the openable area of the window, assist ventilation on the majority of the windows.

Stack ventilation (drawing rising hot air out of the building) is facilitated via a high window above the stairwell. This is also known as a 'thermal chimney' effect. [See: 4.6 Passive Cooling]

Recycled materials

Existing materials were re-used wherever possible: [See: 5.1 Material Use Introduction; 5.3 Waste Minimisation]

> Timber framing and flooring were salvaged during demolition for re-use in the renovations.

> Bricks were salvaged from the demolished garage, cleaned, and re-used in the basement walls and base brickwork.

> Recycled timber was used for internal flooring to the second story, overlay flooring to the first floor and external decking. Refer to the section on 'timber usage' for further information.

> Slab reinforcement was 100 per cent recycled Smorgons ARC steel.

> GB Slag Blend concrete was chosen for its recycled content.

> Recycling bins were built into the back of the pantry unit with sliding doors to enable easy removal of recycling.

> A Kitchen King recycling system is installed in the kitchen for composting and general garbage.

> The existing gas heating system was serviced and retained.

Timber usage

Plantation pine was used for framing. External stairs are constructed from treated plantation pine.



All cabinet timber veneers were made from New Age Veneers, produced in Europe from refigured plantation poplar.

Recycled ash or jarrah were used for flooring. Recycled jarrah was used for internal stairs and external decking. Recycled ash was used for internal timber posts.

Western red cedar (WRC) sourced from Canada was used for doors and windows. WRC is a high- grade joinery timber with high durability (durability class 1). Whilst this timber comes from old-growth source, the Canadian government reports that the producers have a reasonably managed harvest program in place and new plantations are being cultivated. [See: 5.4 Biodiversity Off-site]



Timber joinery was environmentally preferred for windows and doors for the following reasons:

Aluminium frames have very high embodied energy and, unless thermally separated, conduct heat. This reduces the overall energy performance of the window.

PVC frames provide adequate thermal separation because the material has good insulation properties. [See: 5.1 Material Use Introduction]

Low toxicity finishes

Flooring was sealed with Feat Watson Floor Seal which is Tung Oil-based. It has very low levels of di-isocyanate compared with 2-pack polyurethane finishes.

Internal walls and ceilings were painted with Berger low VOC water-based paint, and Limewash was used on feature walls.

Air infiltration and ventilation is tightly controlled in a well designed and built passive solar design during the winter months. This places even greater importance on reducing the level of toxins emitted by finishes and materials.

APPLIANCES AND SERVICES

Space heating

Supplementary heating is by a gas central heating system. No supplementary cooling is required for summer. The study has been provided with ceiling fans for airless days. [See: 4.6 Passive Cooling; 6.2 Heating and Cooling]

Appliances

A gas cooker was selected by the owners because gas cooking generates approximately 33 per cent less greenhouse gas than electric cooking. [See: 6.1 Energy Use Introduction]

The dishwasher is water efficient and 4.5 Star energy-rated. It is connected to the hot water tap to avoid use of electric heating elements.

The washing machine is a 4 Star Galaxy award-winning model.

The refrigerator is 6 Star energy rated, and uses 1080 watt-hours per day at 32° ambient temperature. This is only 1/3 of the energy use of an average refrigerator, particularly significant because a refrigerator can contribute to around 25 per cent of a house's energy consumption.

No electric clothes dryer has been installed. A drying rack has been provided for natural drying of clothes internally. [See: 6.4 Appliances]

Lighting

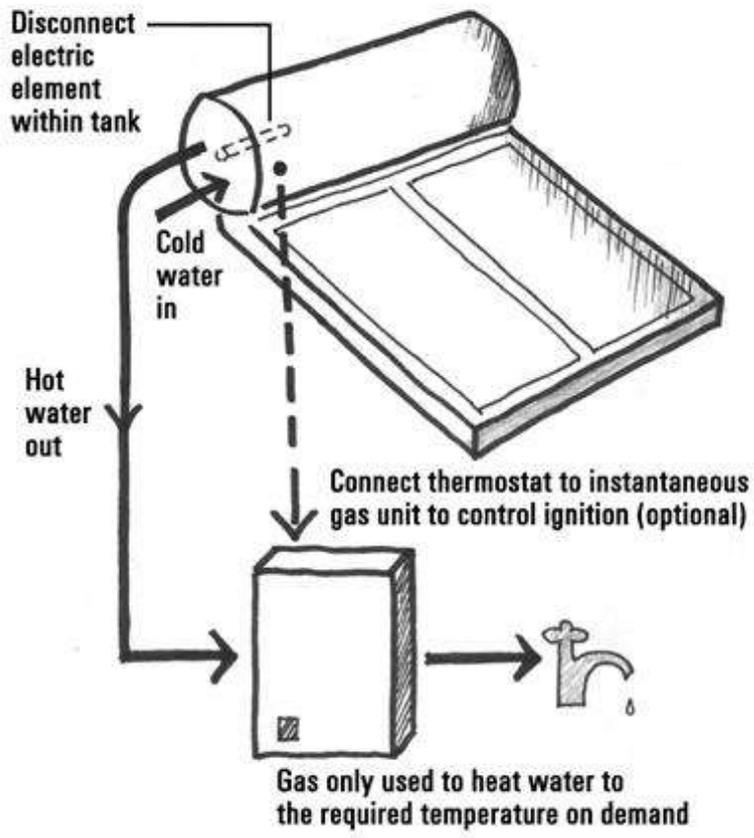
Natural daylight levels are high throughout the house interior, reducing energy use.



For night lighting, surface-mounted and pendant lights were selected exclusively, to eliminate holes in the insulation necessitated by low voltage transformers. 98 per cent of lights have energy efficient compact fluorescent or circular fluorescent globes. [See: 6.3 Lighting]

Hot water heating

A solar hot water unit with 2 panels was installed, boosted by an instantaneous gas unit.



The electric element has been removed from the solar hot water service to reduce greenhouse gas emissions. The solar hot water service and the instantaneous gas unit have been connected in series so that gas is only used to boost water temperature when it is actually required. [See: 6.5 Hot Water Service]

PHOTOVOLTAIC SYSTEM

A grid-interactive photovoltaic electricity generating system was installed, including 20 75watt BP modules and a 3kVA PSA inverter.

The system utilises a two-way meter that allows electricity to be drawn from the grid when the system is not producing enough, and to be fed into the grid during times of excess production. The grid is effectively used as a battery system.

A battery backup system is also installed to eliminate the inconvenience of grid supply interruptions. A solar / grid / battery interactive sinewave inverter controls this process. [See: 6.6 Renewable Energy; 6.7 Photovoltaic Systems; 6.9 Batteries and Inverters]

How the system works:

Non-essential loads are wired as grid interactive (ie. with no battery backup).

Essential loads are grouped in the switchboard and are wired to the inverter, so that in the event of a main grid failure the inverter will drive these loads from batteries. The larger the battery system, the greater the load the system can supply.

Typical essential loads would include, but not be limited to: lights, water pumps, gas hot water electronics, alarm and intercom systems, computer equipment and equipment with digital clocks (to avoid re-setting).

Under normal operation with mains supply available:

> During the night (no solar power), all loads are running from the main grid supply. The inverter is in an idle state synchronised to the grid, with a battery charger maintaining the batteries in a charged state for essential systems.

> During the day (with solar power), the solar power generated will raise the battery voltage above that set by the inverter battery charger. The energy thus created is converted to 240V and fed into the switchboard. If it is not used within the house it is fed back into the grid. A solar regulator is required for the sole purpose of protecting the batteries from overcharge in the event of the grid failing.

> In the event of main grid failure the inverter will disconnect itself within two seconds from the grid (this is a legal requirement). Essential loads then run off the battery supply. Non-essential loads are in blackout until the grid supply is restored. The inverter senses when the grid is restored and reconnects these circuits.

WATER USE



Rainwater harvesting

Two 4,500L water tanks have been installed under the deck to supply showers, vanity basins, toilets, laundry taps, the washing machine and the hot water service.

Town water is used for drinking in the kitchen only. There is a switch-over from town supply to rainwater supply by the appropriate check valves should this be required. Tanks are fed from all roofs and augmented by town supply. A third tank of 13,500L has been installed in the rear of the garden to handle the overflow.

An electric pump powered by the PV panels is used to supply water at adequate pressure to the house. [See: 7.3 Rainwater]

Greywater collection

Greywater is collected from showers, basins, and the bath.

Note: Whilst less likely to contain pathogens than greywater from laundry and kitchen wastes, it must be assumed that pathogens may still be present. Ideally, all greywater should be disinfected before storage or re-use.

A 2,000L polyethylene septic tank is used for storage, and an electric pressure pump powered by the photovoltaics delivers greywater to toilet cisterns for re-use. Greywater is also used for sub-surface irrigation in the garden.

Note: In many local government jurisdictions, strict rules apply to the collection and re-use of greywater. Direct application of untreated greywater onto inaccessible garden areas is permitted by some health authorities.

Check with your Council before installing a system. When stored, greywater can degrade quickly due to the presence of bacteria and pathogens and high levels of nutrients from detergents and soaps.

A small reed bed or wetland will aerate the water and remove some of the nutrients. These wetlands are quite small, don't require fencing (there is no exposed water) and can be made into a garden feature.

A sand filter further aerates and removes contaminants.

An ultraviolet filter will finally disinfect water ready for re-use for garden watering or toilet flushing. [See: 7.4 Wastewater Re-use]

Landscaping

An inner-city permaculture-based garden is being established by the owners at the rear of the property. [See: 2.4 Sustainable Landscapes]

Low-water planting and porous surfaces (to minimise stormwater run-off) have been used in the internal courtyard. [See: 7.5 Stormwater; 7.6 Outdoor Water Use]

Greywater will be the sole source of water for the garden.

PROJECT EVALUATION

This project is a stand out example of how home owners with a strong commitment to sustainable ideals can significantly reduce the environmental impact of their home whilst increasing comfort levels and reducing operating costs.

No cost benefit analysis has been performed on the project to date and, whilst this would be of great interest to many, the owners of this home have clearly decided to take a whole of life cycle approach to their home.

The owners realise that the small additional investment in the sustainable features of their home will continue to deliver economic and environmental benefits, long after the initial cost has been made insignificant by appreciation in the value of their property.

This outstanding success has been achieved through the strong commitment of the owners and their choice of a design team with specialist skills in sustainable design and construction.

Many of the principles described in *Your Home* have been applied with great skill in this project, and as a result the house is a good model of how sustainable design and construction can be considered 'mainstream' rather than a specialist skill.

PROJECT DETAILS	
Designer:	Andreas Sederof and Ryan Strating, Sunpower Design
Builder:	David Smith, SolarCon
Engineer:	Andreas Sederof, Sunpower Design

GENERALLY			NOTES
The home is large enough to meet the occupants requirements, but not too big to increase energy use for heating, cooling and cleaning.	☐ YES	☐ NO	

SUSTAINABLE COMMUNITIES			
The site allows for good solar access.	☐ YES	☐ NO	
The character of surrounding streetscape has been addressed.	☐ YES	☐ NO	
Sustainable landscaping and plant selection have been included.	☐ YES	☐ NO	
Biodiversity impacts on the site have been addressed.	☐ YES	☐ NO	
Transport and its implications on design have been addressed.	☐ YES	☐ NO	
Noise issues around the home have been addressed.	☐ YES	☐ NO	
Erosion and sediment control on the site have been addressed.	☐ YES	☐ NO	

DESIGN FOR LIFE			NOTES
The home is adaptable for future changes in occupant lifestyles and accessible for all.	☐ YES	☐ NO	
Safety and security issues around the home have been addressed.	☐ YES	☐ NO	
Indoor air quality has been addressed with the choice of non toxic materials and finishes.	☐ YES	☐ NO	
Bushfire risks have been addressed.	☐ YES	☐ NO	

PASSIVE DESIGN			NOTES
The main living areas are orientated north to maximise winter sun and minimise summer sun.	☐ YES	☐ NO	
Rooms are zoned or grouped and divided up as needed for economical heating and cooling.	☐ YES	☐ NO	
The house is sited in a suitable location to avoid overshadowing problems from neighbouring buildings.	☐ YES	☐ NO	
Eaves or other shading devices have been incorporated to provide shading from summer sun and allow winter sun to enter.	☐ YES	☐ NO	
Windows located on the east or west have been avoided or minimised and provided with adequate shading.	☐ YES	☐ NO	
Windows and doors are located to get good natural cross ventilation and to ventilate bathrooms and wet areas.	☐ YES	☐ NO	
Windows are located and sized appropriately to provide natural daylight and winter sun penetration, while avoiding summer overheating.	☐ YES	☐ NO	
Living area windows (minimum) or all windows are double glazed.	☐ YES	☐ NO	
Maximum insulation has been provided in the roof, walls and floor.	☐ YES	☐ NO	
There is appropriately designed thermal mass internally to moderate indoor air temperatures.	☐ YES	☐ NO	
Ceilings are high enough to accommodate ceiling fans.	☐ YES	☐ NO	

MATERIALS USE			NOTES
Materials used have low environmental impact and/or embodied energy.	☐ YES	☐ NO	
Recycled materials or materials with recycled content have been included.	☐ YES	☐ NO	
Local materials and suppliers have been included.	☐ YES	☐ NO	
Building materials and appliances are durable and low maintenance.	☐ YES	☐ NO	
Materials are designed efficiently to minimise waste, and are designed for recycling, re-use and/or disassembly.	☐ YES	☐ NO	
Materials have been included that moderate indoor temperatures – thermal mass – and improve indoor air quality.	☐ YES	☐ NO	
Light and dark coloured materials have been included to reflect and absorb heat as appropriate.	☐ YES	☐ NO	
Demolition materials from existing structures have been designed for re-use, recycling or disposing of appropriately.	☐ YES	☐ NO	

ENERGY USE			NOTES
Draughts and air leakage have been adequately sealed.	☐ YES	☐ NO	
Heating and cooling systems are energy efficient and appropriately sized.	☐ YES	☐ NO	
The star rating of the home is more than the minimum 5 star required.	☐ YES	☐ NO	
The amount of lighting has been minimised and is energy efficient.	☐ YES	☐ NO	
Appliances (whitegoods, TVs, DVDs, computers etc) are energy efficient.	☐ YES	☐ NO	
Solar hot water has been included.	☐ YES	☐ NO	
The hot water system has been sized appropriately for the number of occupants.	☐ YES	☐ NO	
Renewable energy sources (such as PV) have been included.	☐ YES	☐ NO	

WATER USE			NOTES
Taps, hot water systems and other appliances are water efficient.	☐ YES	☐ NO	
Hot water pipes are insulated and lengths of pipes kept to a minimum.	☐ YES	☐ NO	
Rain water storage tanks have been included.	☐ YES	☐ NO	
Stormwater capture or retention systems have been included.	☐ YES	☐ NO	
Outdoor surfaces and vegetation to retain water have been included.	☐ YES	☐ NO	
Outdoor areas with water retaining finishes and vegetation are being appropriately considered to ensure no detrimental impacts from construction ie. compacted grass areas.	☐ YES	☐ NO	
Greywater recycling systems have been considered.	☐ YES	☐ NO	
Low water use toilets have been considered.	☐ YES	☐ NO	

Index

Page numbers in this Index indicate the principal topical discussions in the text. Case studies are indicated by bold page numbers.

A

AAC (autoclaved aerated concrete), 149, 169–71
ACA (Australian Consumers' Association), 196
access roads, 25–6
accessibility, 52–4, 63, **249**
  in bushfire areas, 67
  in multi-unit dwelling design, 131
  see also adaptable house
AccuRate software, iii, 16–17, 18, 119, 243
adaptable house, 51, 52–6, **247–50**
Adelaide SA
  apartments and mixed community housing, **233**, **298–302**
  energy and water efficient apartments, **303–6**
adobe, 149, 151–3
air conditioners, 187, 188–9
  as noise sources, 44
  suitable location, 44
air conditioning, 10, 97–8, 188–9
air leakage *see* draught sealing
air locks, 89–90
air movement, 88, 95–6 *see also* ventilation
air pollution
  indoor air pollutants, 51, 57–61
  motor vehicle pollution, 38
  see also air quality
air quality, 33, 51, 57–61, 85, **249–50**
airborne noise, 42, 43 *see also* noise control
American Indian cliff dwellings, 7
angle of incidence (solar radiation), 121
apartment buildings, 70, 130–3
  energy and water efficient apartments, Adelaide SA, **303–6**
  medium density, mixed community housing, Adelaide SA, **233**, **298–302**
  medium density, sustainable design, Clayfield QLD, **295–7**
  transport related considerations, 40
  water sensitive urban design, **233**
appliances, 182, 193–6
  automated control, 217
  and combustion products, 58, 60
  energy efficiency rating, **19**
  energy efficiency ratings, 15, 16, 17, 18, 182, 183, 194
  energy sources, 181
  energy use, 13, 180, 182–3, 190, 193
  entertainment equipment, 183, 194, 196
  for heating and cooling, 182, 185–9
  white goods, 193–6
  see also hot water systems
architects, 3
architects, role in sustainability, 5
asbestos (pollutant), 58
audiovisual appliances *see* entertainment equipment; television sets
Australian Capital Territory
  exemplary environmental house, **292–4**
Australian climate zones *see* climate zones
Australian Consumers' Association, 196
Australian Council of Built Environment Design Professions (BEDP), 20
autoclaved aerated concrete, 149, 169–71
automation *see* home automation
awnings, 83 *see also* shading of buildings and outdoor areas

B

Bairnsdale VIC
  autonomous house, **278–80**
BASIX (Building Sustainability Index), 18
bathrooms, 55, 62–3
batteries and inverters, 213–15
batts *see* insulation
BEDP (Australian Council of Built Environment Design Professions), 20
bedrooms, 55
BERS (Building Energy Rating Scheme) software, 16, 17, 119
bicycle storage, 40
biodiversity conservation, 22, 35–7
biodiversity impacts off-site, 135, 144–6
biodiversity impacts on-site, 22, 35–7
biophilia, 34
blackwater, 219, 227–8 *see also* wastewater
body heat (human) *see* thermal comfort
brick veneer, 104, 111–12, 118, 150, 167–8 *see also* cavity walls
brick walls, 9, 43, 92, 100, 148, 167, 168
  installing insulation in, 104, 111–12
  insulation types and properties, 106–7
bricks and brick construction, 148, 166–8 *see also* mud brick
builders, role in sustainability, 5
building a new home *see* home building strategies; new homes
building codes, iii, 15, 41–3, 110
Building Energy Rating Scheme (BERS) software, 16, 17, 119
building envelope
  defined, 69
  and air conditioning, 97–8
  and bushfire resistance, 67–8
  and passive cooling, 93–4
building environmental performance rating tools, 15–18, 75, 119, 133
  see also energy efficiency rating
building materials *see* materials
building orientation *see* orientation
building sector, and sustainability, 5
building sites *see* site issues

building sustainability *see* house design; passive design; sustainable design
Building Sustainability Index (BASIX), 18
building waste, 140 *see also* waste minimisation
buildings
  design for climate *see* design for climate
  house design *see* house design
  new homes *see* new homes
  renovations *see* home renovation
  sustainability *see* sustainable design
  zero energy buildings *see* zero energy buildings
bulk insulation *see* insulation
bushfires, 26, 51, 65–8
buying a home *see* home buying

C

Canberra ACT
  exemplary environmental house, **292–4**
car dependency, 22, 38, 40 *see also* transport
carbon dioxide emissions, 11–14 *see also* greenhouse gas emissions
carbon neutral, *defined*, 11
carbon neutral schemes, 11–14
carbon offset schemes *see* carbon neutral schemes
carbon positive, 14
carpeted floors *see* floor coverings
case studies
  explained, 243
  published in 'Environment Design Guide', 20
  specific examples of sustainable design:
  apartments and mixed community housing, Adelaide SA, **233**, **298–302**
  autonomous house, Bairnsdale VIC, **278–80**
  autonomous house, Little Green Island QLD, **244–6**
  autonomous house, Tanja NSW, **269–73**
  biodiversity impacts off-site, **145**
  challenging site, Fremantle WA, **50**
  development in remnant rainforest, **36–7**
  EcoHome, Sunbury VIC, **274–7**
  ecologically oriented renovation, Mt Ommaney QLD, **307–9**
  energy and water efficiency, **19**
  energy and water efficient apartments, Adelaide SA, **303–6**
  energy efficient home, Dandenong Ranges VIC, **285–8**
  energy efficient home, Perth Hills WA, **265–8**
  environmentally friendly home, The Gap QLD, **251–4**
  exemplary environmental house, Canberra ACT, **292–4**
  healthy home, Gold Coast QLD, **241**, **255–6**
  heritage terrace (renovation), Hawthorn VIC, **329–32**
  NABERS HOME energy and water rating tool, **19**
  passive design house, Kangaroo Island SA, **289–91**
  passive solar house, East Perth WA, **258–60**
  passive solar house, Rockhampton QLD, **247–50**
  passive solar house, Subiaco WA, **261–4**
  solar efficient duplex renovation, Surrey Hills VIC, **333–7**
  suburban project home renovation, Marion SA, **326–8**
  suburban house (minimal impact), Yarra Junction VIC, **281–4**
  sustainability and accessibility (renovation), Clovelly NSW, **321–5**
  sustainable design apartments, Clayfield QLD, **295–7**
  sustainable house renovation, Northern Beaches NSW, **310–16**
  Sydney's Sustainable House, Chippendale NSW, **317–20**
  Termeil Guesthouse, **36–7**
  water sensitive urban design, **233**, **240–2**, **321–5**
cavity walls, 9, 167, 171
  installing insulation in, 104, 109, 111–12
  see also brick walls
ceiling fans, 63, 96, 100, 187
ceilings
  insulation installation, 104–5, 110–11
  insulation types and properties, 106–7
central heating, 185 *see also* heating and cooling
CFLs (compact fluorescent lamps) *see* fluorescent lamps
challenging sites, 23, 48–50, **295–7**, **321–5**
Chippendale NSW
  'Sydney's Sustainable House' (renovation), **317–20**
Christie Walk, Adelaide SA, **233**, **298-302**, **303–6**
cladding, 150
clay bricks *see* brick walls; bricks and brick construction
Clayfield QLD
  medium density, sustainable design apartments, **295–7**
cleaning products, 61
climate change, 2, 11, 218
  appropriate landscaping, 34
  design issues and principles, 28, 83, 117
  see also design for climate
climate zones, iv
  design for climate, 6–7, 69, 71–4
  effective use of thermal mass, 117
  glazing design guidelines, 126
  insulation levels, 102–3
  key design responses, 71–4
  and landscaping choices, 33, 34
  passive cooling design principles, 94–5
  shading options, 84–5
  specific zones:
  Zone 1: High humid summer, warm winter
    autonomous house, **244–6**
  Zone 2: Warm humid summer, mild winter
    ecologically oriented renovation, **307–9**
    environmentally friendly house, **251–4**
    healthy home, **241**, **255–6**
    passive solar house, **247–50**
    sustainable design (apartments), **295–7**
  Zone 5: Warm temperate
    energy and water efficient apartments, **303–6**
    energy efficient home, **265–8**
    mixed density community housing, **298–302**
    passive solar house, **258–60**
    passive solar house (two storey), **261–4**
    suburban project home (renovation), **326–8**
    sustainability, accessibility, adaptability (renovation), **321–5**
    'sustainable' house renovation, **310–16**
    'Sydney's Sustainable House' (renovation), **317–20**
  Zone 6: Mild temperate
    autonomous house, **269–73**, **278–80**
    EcoHome, **274–7**
    improved thermal performance (renovation), **329–32**
    passive design house, **289–91**
    solar efficient duplex (renovation), **333–7**
  Zone 7: Cool temperate
    exemplary environmental house, **292–4**
    high energy efficient house, **285–8**
    suburban house (minimal environmental impact), **281–4**
clothes dryers, 195

Clovelly NSW
sustainability and accessibility (renovation), **240**, **321–5**
cockroaches, 61
colonial buildings, 6
colour of external surfaces, 100
see also design for climate
combustion products, 58
community housing projects, **298–302**
compact fluorescent lamps *see* fluorescent lamps
compost heaps, 61, 222
composting toilets, 237–9
computers *see* home office equipment
concrete blocks, 149 *see also* autoclaved aerated concrete; earthcrete
concrete slab floors, 105, 113, 115, 172–5, 185
see also thermal mass
condensation, 97–8, 125
condensation barriers, 104, 108, 109
conduction, 120 *see also* heat gain and loss
conservation *see* biodiversity conservation; environment protection
construction codes *see* building codes
construction materials *see* materials
construction systems, 135, 147–50
for apartments and multi-unit buildings, 133
composite systems, 150
and embodied energy, 138
heavy and lightweight systems, 147–8
materials selection tool, 135
planning for waste minimisation, 142–3
roofing and flooring, 149–50
specific systems *see* adobe; autoclaved aerated concrete; bricks and brick construction; concrete slab floors; green roofs and walls; lightweight timber construction; mud brick; rammed earth (pisé); straw bales; timber framed structures
consumers, role in sustainability, 5
consumption of energy *see* energy use
convection, 88, 96, 120
Coober Pedy dwellings, 7
cooking and cookers, 182
energy use, 13, 180
cooking spaces, 54–5, 58, 60, 61, 62
cool light, 127
cooling *see* heating and cooling
costs
common myths about cost, 8
of good design, 2, 4
crime prevention through environmental design, 64
see also safety and security
cycling *see* bicycle storage; transport

D

Dandenong Ranges VIC
energy efficient home, **285–8**
daylight, 127–8, **249**
sunhours, 209
see also light transmittance
design
common myths, 8–10
good design principles, 2–3
historical perspective, 6–7
design for climate, 6–7, 69, 71–4
and climate change, 11, 28, 83, 117, 178, 218
landscaping strategies, 33, 34
passive cooling design principles, 94–5
passive solar heating design principles, 87
see also climate zones
designers, role in sustainability, 5
developers, role in sustainability, 5
difficult sites *see* challenging sites
dishwashers, 195, 222
door frames *see* frames
doors, 63, 99
double brick *see* brick walls
double glazing *see* glazing
draught sealing, 9, 89, 105
ducted systems, 185, 188
dust *see* house dust

E

earth
mud brick *see* mud brick
rammed *see* rammed earth (pisé)
earth bermed construction, 149, **286–8**, **289–91**
see also underground dwellings
earth coupling, 97, 149, 172, **290**
earthcrete, **299**, **300**, **302**
East Perth WA
passive solar house, **258–60**
eaves, 74, 78, 79, 80, 82–3
EcoHome, Sunbury VIC, **274–7**
EcoSpecifier materials selection tool, 135
ecosystem restoration, 34
see also biodiversity conservation
electric hot water systems, 197–201
electrical appliances, 180–3
electric heaters, 185–6, 187
energy use, 182–3
electrical wiring, 63
electricity, 180–1
automation and electricity demand, 217
GreenPower, 207
embodied energy, 134, 136–8, **249**
energy consumption *see* energy use
energy efficiency rating, 15–18, 183, 194
mandatory disclosure, 15
see also house energy rating tools
energy generation
grid connected renewable systems, 206, 213, 214
on-site *see* zero energy buildings
from renewable sources, 205–12
stand alone power systems, 206
energy sources, 180–1
ENERGY STAR® logo, 183
see also energy efficiency rating
energy use, 180–3
rating tools, 15–18, **19**
by households, 2, 13, 74, 86, 180–3
by lighting, 190–2
operational energy and embodied energy, 136–8
standby energy consumption, 183
strategies to reduce use, 207
see also zero energy buildings

entertainment equipment, 183, 194, 196, 217
environment protection, 27–8
ecosystem restoration, 34
see also biodiversity conservation
environmental design
case studies *see* case studies
common myths, 8–10
and crime prevention, 64
see also passive design
erosion *see* sediment control
evaporative cooling, 96, 187–8
exhaust fans, 60
external surfaces, colour of, 100
extractive industries, and biodiversity impacts off-site, 145–6

F

fact sheets, explanations of, 3
fading (interior furnishings), 125
fans, 63, 96, 100, 187
films (window films), 123
fire risk and prevention, 26, 63–4
in bushfire areas, 26, 51, 65–8
characteristics of materials *see* construction systems; materials
skylights, 129
downlights, 109
fireplaces, 186 *see also* wood burning heaters
FirstRate software, 17, 18, 119
fittings, 63–4 *see also* appliances
floor coverings, 60
floor insulation, 105, 106–7, 112–13
floors, 43, 63
concrete slab floors, 105, 113, 115, 172–5, 185
construction materials and systems, 149–50
glass to floor area ratios, 90–1
fluorescent lamps, 8–9, 183, 190–1
see also lighting
flyash, in wall construction, **248**, **300**
frames
timber framed walls *see* timber framed structures
window frames *see* window frames
freezers, 194–5
Fremantle WA
challenging site, **50**

G

The Gap QLD
environmentally friendly house, **251–4**
water use (housing development), **233**
garden design, 32–4, 234 *see also* outdoor water use
gas, 180–1
gas appliances, 60, 181–2, 186, 187
gas water heaters, 197–204
generators, 213, 215
geothermal exchangers, 188–9 *see also* air conditioners
glazing, 70, 92, 119–26
climate considerations, 124–6
common myths, 9
glass to floor area ratios, 90–1
lifecycle costing, 126
in multi-unit dwelling design, 133
and noise control, 43–4
rating systems, 17, 124, 125
skylights, 124, 125, 127–9
specifying and documentation, 124
and thermal performance, 119
thermal properties of glass, 119–23
types, 122–3
global warming *see* climate change
Gold Coast QLD
healthy home, **241**, **255–6**
governments, role in sustainability, 5
grass *see* lawns
green roofs and walls, 7, 32–3, 149, 176–9
greenhouse gas emissions, 2, 11–14
associated with construction materials, 152, 155, 158, 164, 175
and climate change, 2, 28
and electricity generation, 205, 207
generated by cars, 38–40
and hot water services, 199–200, 201, 203
produced by Australian homes, 2, 13–14, 38, 105, 180–8, 194, 197
rating systems, 18, 19, 194
see also carbon dioxide emissions
GreenPower, 207
greywater, 218–19, 227–30, **240–2**, **246**, **264**, **273**
defined, 218, 227
see also wastewater
Gross Energy Requirement, 137

H

Hawthorn VIC
heritage terrace (renovation), **329–32**
health issues
composting toilets, 238
greywater re-use, 228–30
indoor air quality and health issues, 51, 57–61, 85
psychological health, 34
rainwater tanks, 223–4
see also safety and security
healthy home, Gold Coast, **241**, **255–6**
heat exchangers, 188–9 *see also* air conditioners
heat gain and loss, 75, 87, 101, 119, 124–5
heat transmission, 119–23
and skylights, 127–9
see also insulation; passive cooling; passive solar heating; shading of buildings and outdoor areas
heat shifters, 187
heating and cooling, 184–9
automation, 216
central heating, 185
common myths, 9–10
efficient energy use, 182
energy use, 13, 180, 184, 189, 190
heater location, 88, 184
heaters (electric), 185–6, 187
heaters (gas), 60, 181, 182, 186, 187
heaters (solar), 100
heaters (wood burning), 60, 61, 181, 186–7
mechanical cooling devices, 187–9
passive cooling *see* passive cooling
passive solar heating *see* passive solar heating
practical tips, 189
safety, 63

solar air heaters and cooling systems, 100
see also air conditioners; appliances
heavyweight construction *see* construction systems
heritage significance, **329–32**
HERS *see* house energy rating tools
home automation, 216–17
defined, 216
home building strategies, 2–4, 338–9
see also home renovation; house design; new homes
home buying, 3–4, 27 *see also* new homes
home design *see* house design
home entertainment equipment *see* entertainment equipment
home improvements *see* home renovation
home office equipment, 183, 196
home renovation
health and safety issues, 59, 61
home improvement strategies, 4
house orientation, 78–80
insulation retrofit, 103–5
passive cooling, 98–100
passive heating, 91–2
thermal mass, 118
transport related considerations, 40
tropical houses, 99
see also house design
case studies:
ecologically oriented renovation, Mt Ommaney QLD, **307–9**
heritage terrace, Hawthorn VIC, **329–32**
solar efficient duplex, Surrey Hills VIC, **333–7**
suburban project home, Marion SA, **326–8**
for sustainability and accessibility, Clovelly NSW, **321–5**
sustainable house renovation, Northern Beaches NSW, **310–16**
Sydney's Sustainable House, Chippendale NSW, **317–20**
water saving measures, **240–2**, **321–5**
home size *see* house design
hot water systems, 63, 197–204
automation, 217
energy use, 13, 180, 181
house construction codes *see* building codes
house design, 6–10, 196
adaptable house, 51, 52–6
bushfire resistance, 26, 51, 66–8
case studies *see* case studies
for challenging sites, 48–50
checklist, 338–9
for climate change, 11, 28, 83, 117, 218
climate sensitive design, 6–7, 69, 71–4 *see also* passive design
for healthy living, 51, 57–61
historical perspective, 6–8
multi-level housing, 55–6, 88, 117
myths and misunderstandings, 8–10
noise control, 22–3, 41–4, 125, 173–4, 178
orientation *see* orientation
passive design *see* passive design
plans (house plans), 26
principles and strategies, 2–4, 28
renovations *see* home renovation
safety and security, 51, 62–4
shade *see* shading of buildings and outdoor areas
size of house, 26
social impact, 27
streetscape *see* streetscape
transport related considerations, 40
tropical houses, 7, 94, 98, 99, 117, **244–6**
visual impact, 26, 40, 130
waste minimisation and use of recycled materials, 141–3
water saving measures, **240–2**, **321–5**
see also construction systems; home renovation; materials; new homes
house dust, 58, 60
house energy rating tools, 15–18, 75, 119, 133
see also energy efficiency rating
house fittings, 63 *see also* appliances; floor coverings
house plans, 26
household energy use *see* energy use
housing developments, **233**, **298–302**, **303–6**
see also house design
housing industry impact on biodiversity, 22, 35–7, 135, 144–6
human thermal comfort, 74–5, 98, 114, 117, 119
humidity *see* climate zones; thermal comfort
hybrid cooling systems, 97–8
hydronic systems, 185

I

impact noise, 42–3 *see also* noise control
incandescent lamps, 190
see also lighting
indigenous plants, 33, 37
defined, 33
indigenous species *see* biodiversity conservation; sustainable landscapes
Indonesian vernacular buildings, 7
indoor air quality *see* air quality
indoor temperature, 10 *see also* thermal comfort
information sources
Australian Consumers' Association, 196
EcoSpecifier materials selection tool, 135
Environment Design Guide, 20
see also rating tools and schemes
Inkerman D'Lux sub division, Melbourne (water management), **233**
instantaneous water heaters *see* hot water systems
insulation, 70, 89, 100, 101–7
in apartment buildings, 132
for climate types, 102–3
common myths, 9
installation of, 103–5, 108–13
insulated concrete construction, 149
location of, 103–7
requirements, iii, 103
types and properties, 102, 106–7
interior spaces *see* adaptable house
inverters *see* batteries and inverters

J

journey to work *see* transport

K

Kangaroo Island SA
  passive design house, **289–91**
kitchens, 54–5, 58, 60, 61, 62
knowledge bases *see* information sources; software tools
Kogarah town centre, Sydney (water management), **233**

L

labelling *see* energy efficiency rating; Smart Approved Water Mark; Water Efficiency Labelling and Standards (WELS) Scheme; Window Energy Rating Scheme (WERS)
landfill, 140, 146
landscaping
  common myths, 10
  materials, 33
  in multi-unit dwelling design, 133
  sustainable landscapes, 22, 32–4, 130–1
  see also plants; vegetation
laundries, 55
lawns, 33, 235 *see also* plants; vegetation
lead (pollutant), 58, 61
leaks (water wastage), 221
Life Cycle Assessment, 139, 140
lifecycle approaches
  to cost of glazing, 126
  in identifying biodiversity off-site impacts, 144–6
lifestyle adaptations, 98 *see also* adaptable house
light
  cool light, 127
  daylight, 127–8, 191, **249**
  sunhours, 209
  see also light transmittance; lighting
light emitting diodes, 191
light transmittance, 122, 125, 128 *see also* glazing; skylights
lighting, 190–2
  automation, 217
  common myths, 8–9
  costs, 191
  energy efficiency, 183, 191–2
  energy use, 180, 190
  see also light
lightweight timber construction, 138, 147–50, 162–5
  see also construction systems
Lismore NSW
  wastewater management retrofit, **242**
Little Green Island QLD
  autonomous house, **244–6**
'living' roofs *see* green roofs and walls
living spaces, 54 *see also* home renovation; house design
louvres, 83
low impact toilets *see* toilets
low water use vegetation *see* xeriscaping

M

maintenance, 148
  and bushfire resistance, 68
  skylights, 129
manufacturers, role in sustainability, 5
Marion SA
  suburban project home, **326–8**
marketing agents, role in sustainability, 5
material use, 134–5, 144–6 *see also* waste minimisation
materials, 147–50
  and biodiversity impacts off-site, 144–6
  EcoSpecifier materials selection tool, 135
  embodied energy of, 136–9
  for landscaping, 33
  re-use and recycling, 139–41, **277**, **300**
  sourcing (guidelines), 146
  waste minimisation in construction, 140–3
  see also construction systems
Mawson Lakes SA (water management), **233**
mining industries, and biodiversity impacts, 145–6
motor vehicle pollution, 38 *see also* car dependency
Mt Ommaney QLD
  ecologically oriented renovation, **307–9**
mud brick, 9, 149, 151–3
mulching, 47, 235
multi-level housing, 55–6, 88, 117
multi-unit housing, 130–3 *see also* apartment buildings
myths and misconceptions about environmental design, 8–10

N

NABERS HOME rating tool, 17, **19**
Nationwide House Energy Rating Scheme (NatHERS), 16, 18, 119
  NatHERS software, 16, 18
  see also house energy rating tools
native plants, *defined*, 33
natural gas water heaters, 197–204
neighbours (good neighbours), 27, 31, 40, 64
Nepalese dwellings, 7
new homes
  design checklist, 338–9
  home building strategies, 2–4
  see also home renovation; house design
  case studies:
  autonomous house, Bairnsdale VIC, **278–80**
  autonomous house, Little Green Island QLD, **244–6**
  autonomous house, Tanja NSW, **269–73**
  EcoHome, Sunbury VIC, **274–7**
  energy efficient home, Dandenong Ranges VIC, **285–8**
  energy efficient home, Perth WA, **265–8**
  environmentally friendly house, The Gap QLD, **251–4**
  exemplary environmental house, Canberra ACT, **292–4**
  healthy home, Gold Coast QLD, **241**, **255–6**
  passive design house, Kangaroo Island SA, **289–91**
  passive solar house, East Perth WA, **258–60**
  passive solar house, Rockhampton QLD, **247–50**
  passive solar house (two storey), Subiaco WA, **261–4**
  suburban house (minimal impact), Yarra Junction VIC, **281–4**
New South Wales
  autonomous house, Tanja, **269–73**
  sustainability and accessibility (renovation), Clovelly, **321–5**
  'sustainable' house renovation, Northern Beaches, **310–16**
  'Sydney's Sustainable House', Chippendale, **317–20**
  wastewater management retrofit, Lismore, **242**
  water sensitive urban design, Kogarah, **233**
noise control, 22–3, 41–4, 125, 173–4, 178
Northern Beaches NSW
  sustainable house renovation, **310–16**

O

offset schemes (carbon neutral schemes), 11–14
open fireplaces, 186 *see also* wood burning heaters
orientation, 69, 76–80, 92, **245**, **252**, **271**, **274**, **278**, **296**, **299**
  see also shading of buildings and outdoor areas
outdoor water use, 33, 219, 229–30, 234–6
  see also rainwater tanks

P

paint, 61
panel systems (construction systems), 149
panel systems (solar) *see* photovoltaic systems
parking provision, 40 *see also* car dependency
passive cooling, 70, 79–80, 93–100
  case studies *see* case studies
  climate specific design principles, 94–5
  cooling systems, 96–8
  and renovations, 98–100
  and shading, 34, 81–5, 99
  thermal mass *see* thermal mass
passive design, 6–7, 8, 12–14, 86–7
  defined, 69
  apartments and multi-unit housing *see* apartment buildings
  case studies *see* case studies
  design for climate *see* design for climate
  glazing *see* glazing
  insulation *see* insulation
  orientation, 69, 76–80, 92
  passive cooling *see* passive cooling
  passive solar heating *see* passive solar heating
  in renovations *see* home renovation
  shading, 34, 81–5, 99
  skylights, 70, 125, 127–9
  thermal mass, 70, 90–1, 97, 100, 114–18, 132
passive solar heating, 69, 76–8, 86–92
  case studies *see* case studies
  convective air movement, 88
  heat loss prevention, 88–90
  in multi-unit dwelling design, 132
  in renovations *see* home renovation
  thermal mass *see* thermal mass
performance rating tools *see* building environmental performance rating tools
pergolas, 83 *see also* shading of buildings and outdoor areas
Perth WA
  energy efficient home, Perth Hills WA, **265–8**
  passive solar house, East Perth WA, **258–60**
  passive solar house (two storey), Subiaco, WA, **261–64**
pest control, 59, 61
photovoltaic panels, 12, 13, 132, 205
photovoltaic systems, 205, 208–10
pipes, 9, 44
pisé (rammed earth), 149, 154–6, **258–60**
plans (house plans) *see* house plans
plants
  and erosion control, 47
  indigenous, *defined*, 33
  native, *defined*, 33
  for reduced water use, 22, 235
  reducing fire potential, 67
  for shade, 82, 85, 99
  in sustainable landscapes, 33
plumbing and waste pipes, 9, 44
pollution
  greenhouse gas emissions, 2, 11–14
  indoor, 51, 57–61
  motor vehicle pollution, 38
  sediments *see* sediment control
ponds (landscaping) *see* landscaping
pools (swimming pools) *see* swimming pools
potting mix, 61
power outlets *see* electrical wiring
precast concrete construction, 149
predictive rating tools *see* house energy rating tools
privacy, 31
Process Energy Requirement, 137
project homes, 27, 78, 79, **326–8**
property developers, role in sustainability, 5
psychological health, 34
PV panels, 12, 13, 132
  see also photovoltaic systems

Q

Queensland
  autonomous house, Little Green Island, **244–6**
  ecologically oriented renovation, Mt Ommaney, **307–9**
  environmentally friendly home, The Gap QLD, **251–4**
  healthy home, Gold Coast, **241**
  healthy home, Gold Coast QLD, **255–6**
  passive solar house, Rockhampton, **247–50**
  sustainable design (apartments), Clayfield, **295–7**
  water use (housing development), The Gap, **233**

R

radiation and radiant heat, 120–2
rainforests, development case study, **36–7**
rainwater tanks, 218, 223–6, **248**, **268**, **280**, **283**, **323**, **328**
rammed earth (pisé), 149, 154–6, **258–60**
ramps, 63
rating tools and schemes
  for apartment buildings, 133
  for building sustainability, 15–19
  energy efficiency, 15–19, 119, 124, 183, 194
  for skylights, 124, 125
  thermal comfort rating, 75
  water efficiency, 10, 181, 182, 218, 220–2
  for windows and glazing, 17, 124
rebates
  for rainwater tanks, 223
  for water efficient products, 222, 236
recycling and re-use of building materials, 134, 139–43, *see also* waste minimisation
reflective insulation *see* insulation
reflectivity, and passive cooling, 100
refrigerated coolers *see* air conditioners
refrigerators, 13, 193–5
regulators, role in sustainability, 5
remote sites, 25–6, **244–6**, *see also* site issues
renewable energy, 13–14, 180–1, 205–12, **276**, **294**, **306**, **315**
  in multi-unit dwelling design, 132
  photovoltaic systems, 12, 13, 132, 205, 208–10
  solar hot water systems, 197–204
  storage (batteries and inverters), 213–15

wind generators, 205, 211–12
see also passive design; zero energy buildings
renovation *see* home renovation
restoration ecology, 34 *see also* biodiversity conservation
reverse brick veneer, 92, 100, 104, 118, 148, 167
see also brick veneer; brick walls
reverse cycle air conditioners *see* air conditioners
Rockhampton QLD
passive solar house, **247–50**
Roman vernacular buildings, 7
roofs
insulation installation, 104–5, 110–11
insulation types and properties, 106–7
roofing materials and systems, 149
siting of solar modules, 209–10
ventilation, 10, 108
rural and remote sites, 25–6 *see also* site issues

S

safety and security
building design tips, 51, 62–4
in multi-unit dwelling design, 130
outdoors, 63
security measures, 64
when installing insulation, 109
when working with batteries, 214
see also health issues
sediment control, 23, 45–7
shading of buildings and outdoor areas, 34, 69, 81–5, 87, 99, 132
showerheads, 10, 181, 220–1
site issues
access and mobility, 25–6, 56
biodiversity impacts on-site, 22, 35–7
biodiversity impacts off-site, 135, 144–6
bushfire prevention and safety, 26, 51, 66–8
challenging sites, 23, 27, 48–50
choosing a site, 21, 24–8
efficient land use, 25
noise control, 22–3, 41–4
rural and remote sites, 25–6
sediment control, 23, 45–7
streetscape, 21, 29–31, 130
sustainable landscapes, 22, 32–4
topography, 27
transport, 22, 26, 38–40, 131
size of home *see* house design
skylights, 70, 125, 127–9
slab floors *see* concrete slab floors
sleeping spaces, 54 *see also* house design
slow combustion stoves and heaters, 60, 61, 186–7, 189
Smart Approved Water Mark, 236
social amenity, 27, 30, 130
software tools *see* house energy rating tools; information sources
soil stabilisation, 47
soil types, 234–5
solar air heaters and cooling systems, 100
see also passive solar heating
solar heat gain *see* heat gain and loss; passive solar heating
solar hot water systems, 197–204
solar panels *see* photovoltaic panels
solar radiation (glazing), 120–2
solid fuels, 186 *see also* wood burning heaters
sound insulation *see* noise control
sound levels (design recommendations), 41–4
see also noise control
South Australia
apartments and mixed community housing, Adelaide SA, **233**, **298–302**
energy and water efficient apartments, Adelaide SA, **303–6**
passive design house, Kangaroo Island, **289–91**
suburban project home (renovation), Marion, **326–8**
water sensitive urban design, Mawson Lakes, **233**
space heating, 185–7 *see also* heating and cooling
stairs, 63
star ratings *see* energy efficiency rating; rating tools and schemes
steep sites *see* challenging sites
storage water heaters *see* hot water systems
stormwater, 27, 45–7, 133, 219, 231–3
defined, 231
straw bales
as construction material, 89, 104, 149, 157–61, **298–300**
for sediment control, 47
streetscape, 21, 29–31, 130
structure borne noise, 42 *see also* noise control
Subiaco (WA) passive solar house (two storey), **261–4**
sun angles (shading), 82, 83
Sunbury (VIC) EcoHome, **274–7**
sunhours, 209 *see also* daylight
Surrey Hills VIC
solar efficient duplex (renovation), **333–7**
sustainability, and building sector, 5
sustainable design (historical perspective), 6–7
see also house design; passive design; rating tools and schemes
sustainable development, *defined*, 5
sustainable landscapes, 22, 32–4, 130–1
swimming pools
evaporative losses, 236
as noise sources, 44
synthetic grass, 33 *see also* lawns

T

Tanja NSW
autonomous house, **269–73**
taps (leaks), 221
television sets, 183, 194, 196, 217
temperature control, in humans *see* thermal comfort
Termeil Guesthouse, **36–7**
termites, 59
terrace house renovation, **317–20**, **329–32**
thermal bridges, 108
thermal comfort, 74–5, 98, 114, 117, 119
thermal insulation *see* insulation
thermal lag, 90
thermal mass, 70, 90–1, 97, 100, 114–18, 125
additions and renovations, 118
climatic considerations, 117
in multi-unit dwelling design, 132
water filled containers, 150
thermal properties of glazed elements, 119–22
tight sites *see* challenging sites
tiltup concrete construction, 149
timber construction, 104, 138, 149, 162–5

timber framed structures, 104, 138, 168, 171
adding thermal mass, 92, 100, 118
cost comparison with AAC walls, 170
toilets, 55, 218, 219, 221, 237–9, **242**, **246**
topography, 27 *see also* site issues
tourist accommodation, **36–7**
townhouses, **298–302** *see also* apartment buildings
traffic noise, 22, 41, 44 *see also* noise control
transport, 22, 26, 38–40, 131
tropical areas
awnings and pergolas, 83
house design, 7, 94, 99, **244–6**
thermal comfort, 74–5, 98, 117
see also climate zones
Turkey, vernacular buildings, 7

U

underground dwellings, 7, 117
see also earth bermed construction
universal house, 52–3
see also adaptable house
urban transport, 22, 38–40
urban villages, 38–9
usability *see* the 'universal house'

V

vapour barriers *see* condensation barriers
vegetable gardens, 33
vegetation
and erosion control, 47
fire prevention role, 67
on roofs *see* green roofs and walls
see also biodiversity conservation; plants; sustainable landscapes
ventilation, 59, 125, **262–3**, **266–7**, **276**, **300**, **304**, **327**
air movement for passive cooling, 95–6, 100
see also air quality
vernacular buildings, 6–7
Victoria
autonomous house, Bairnsdale, **278–80**
EcoHome, Sunbury, **274–7**
energy efficient home, Dandenong Ranges, **285–8**
heritage terrace (renovation), Hawthorn, **329–32**
solar efficient duplex (renovation), Surrey Hills, **333–7**
suburban house (minimal impact), Yarra Junction, **281–4**
visible light *see* light; light transmittance
visual impact of home, 26, 40, 130
see also streetscape
volatile organic compounds, 58–9, 61

W

Wales
vernacular buildings, 7
walls, 9, 43, 150
installing insulation in, 103–4, 109, 111–12
insulation types and properties, 106–7
materials and construction systems, 148–50
waste flyash in wall construction, **248**, **300**
see also adobe; brick walls; cavity walls; green roofs and walls; mud brick; timber framed structures
washing machines, 195, 221
waste
building waste, 140
flyash in wall construction, **248**, **300**
waste water *see* wastewater
waste management plans, 143
waste minimisation, 134, 140–3
wastewater
and multi-unit dwelling design, 133
re-use, 218–19, 227–30, **240–2**, **274**, **331**, **337**
volume calculation, 228
see also stormwater
Water Efficiency Labelling and Standards (WELS) Scheme, 10, 181, 182, 218, 220
see also water use
water filled containers, for thermal mass, 150
water heating *see* hot water systems
Water Sensitive Urban Design (WSUD), 232–3
urban water design case studies, **233**, **240–2**, **323–4**
water use, 218–19
rating tools, 17–19
cost of leaks, 221
efficiency case study, **19**
outdoor water use, 33, 219, 229–30, 234–6
rebates for water efficient products, 222
reducing demand, 218, 220–2, 236
in sustainable landscaping, 33
urban water design case studies, **233**, **240–2**, **323–4**
wastewater re-use *see* wastewater
see also hot water systems; rainwater tanks
weather proofing, 9
weatherboards, 111, 138, 162
Western Australia
energy efficient home, Perth Hills, **265–8**
passive solar house, East Perth, **258–60**
challenging site, Fremantle, **50**
passive solar house (two storey), Subiaco, **261–4**
wet areas *see* bathrooms; kitchens; laundries
white goods, 193–6 *see also* appliances
wind generators, 205, 211–12
Window Energy Rating Scheme (WERS), 17, 124
window frames, 123
windows, 9, 43–4, 63, 99, 119–5, 133
see also glazing; ventilation
wiring *see* electrical wiring
wood burning heaters, 60, 61, 181, 186–7
wood (energy source), 181

X

xeriscaping, 22, 33

Y

Yarra Junction VIC
suburban house (minimal impact), **281–4**

Z

zero carbon, *defined*, 12
zero emission, *defined*, 12
zero energy, *defined*, 12
zero energy buildings, 12–14