LOW CARBON LIVING CRC

Guide to Low Carbon Residential Buildings – New Build

Acknowledgements

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Guide to Low Carbon Residential Buildings – New Build

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Cover photo:
Josh's House,
Acorn Photography

Contents

Glossary

Building envelope
The part of the house structure that separates the inside from the outside and provides the opportunity to create safety and comfort inside the home–typically the walls, doors and windows, roof and ground floor.

Carbon account
An annual statement of the greenhouse gas (GHG) emissions sources, quantities, and any offsets made during that year.

Carbon offset
A demonstrated reduction of GHG emissions achieved outside the project that is used as a credit on the project Carbon Account to reduce nett emissions. This process is referred to as 'offsetting'.

Embodied emissions
The GHG emissions that have arisen in the supply chain of building materials and components required for a project. There are two main approaches to embodied emissions: Cradle-to-site, which is limited to emissions related to extraction of raw materials, their subsequent processing, and assembly into usable products, and their transport to the construction site; and Cradle-to-grave, which includes all emissions throughout a building's construction and life.

Emission (or carbon) intensity
The GHG emissions per unit of a resource or service. For example, the carbon intensity of electricity would be expressed in kilograms of carbon dioxide equivalent released per kilowatt-hour of electricity delivered to a consumer (kg CO2-e / kWh).

Greenhouse gases (GHGs)
Also known as 'carbon emissions'. Gas emissions that have a heating effect leading to an increase in atmospheric temperatures. GHGs include carbon dioxide (CO2), methane (CH4), Nitrous dioxide (NO2), and synthetic gases (HFCs, SF6, CF4, C2F6). GHG emissions are generally expressed in units of kilograms-CO2-equivalent (kg CO2-e) to acknowledge they are figures based on a mix of gases.

National Carbon Offset Standard for Buildings (NCOS-B)
A voluntary standard to manage greenhouse gas emissions and to achieve carbon neutrality.

Operational emissions
GHG emissions that arise from the operation of a building. These include: Direct emissions due to fuel use onsite (Scope 1 emissions); Indirect emissions due to consumption of energy services such as electricity (Scope 2 emissions) and; Indirect emissions due to consumption of other resources such as water onsite (Scope 3 emissions).

Passive design
Design that takes advantage of the climate to maintain a comfortable temperature range in the home. Passive design reduces or eliminates the need for auxiliary heating or cooling.

Renewable Energy Certificate
A measurement of renewable energy that can be traded or sold. Australia's Renewable Energy Target (RET) requires energy retailers to purchase a set number of certificates each year.

Thermal mass
The measure of the ability of a material, usually stone, brick or concrete, to absorb heat.

Abbreviations

Abbreviation	Meaning
GHG	Greenhouse Gases
kWh	Kilowatt-hour (unit of energy equal to 3.6 megajoules)
kW	Kilowatt (unit of power)
kWp	Kilowatt peak (relates to the rated size of a PV system)
kL	Kilolitre
EF	Emissions Factor
PV	Photovoltaic
REC	Renewable Energy Certificate
Unit	In electricity bills, a unit is equal to 1 kilowatt-hour
CRCLCL	Cooperative Research Centre for Low Carbon Living
NCOS-B	The National Carbon Offset Standard (NCOS) for Buildings

Emissions and the built environment

Buildings, in all their forms, have a huge impact on the environment. Globally, the United Nations Environment Program estimates they are responsible for **30–40%** of all primary energy used.

In Australia, buildings are responsible for one quarter of all greenhouse gas emissions.

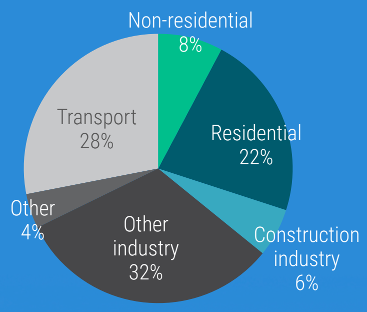
This presents a **significant challenge** as well as a **valuable opportunity** for the built environment sector to contribute to emissions abatement and mitigation.

In 2016, the Australian Government ratified the **Paris Agreement** within the United Nations Framework Convention on Climate Change, pledging to work alongside other developed nations to achieve net zero emissions by 2050 and a 26–28% reduction in emissions relative to 2005 levels by 2030.

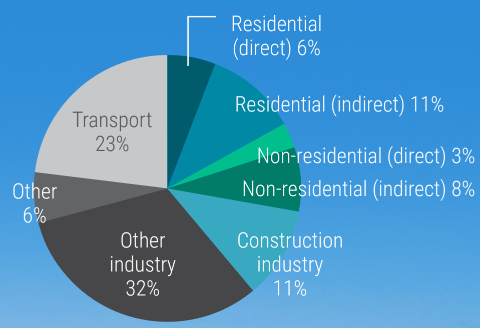
It is clear that if Australia is to achieve these targets, curbing emissions from **the built environment will play a central role**. And with more than 75% of the world's population predicted to be living in cities by 2050, the decisions and actions taken now will have effects decades into the future.

Global share of buildings and construction final energy and emissions, 2017

Energy



Emissions



Source: Derived from IEA (2018a), *World Energy Statistics and Balances 2018*, and *IEA Energy Technology Perspectives* buildings model

About the CRCLCL

The **Cooperative Research Centre for Low Carbon Living** (CRCLCL) is a national research and innovation hub for the built environment. It aims to influence policies and practices to reduce carbon emissions, improve energy efficiency and realise other co-benefits while driving competitive advantage for Australian industry. It has undertaken more than 100 research projects with industry and government partners and supported almost 100 PhD and Masters students.

Supported by the Australian Government and almost 40 industry and government participants, it links leading Australian researchers to organisations across all sectors involved in the built environment. When it ceases operations in mid-2019, the CRCLCL will leave a legacy of research outputs, policy and practice innovation, and enhanced national capacity. This Guide and others in the Low Carbon Guides series form part of that legacy.

A guide for every situation

Each Low Carbon Guide summarises best practice in various phases of the building lifecycle—construction, retrofit, operation—for a range of building types in the residential and commercial sectors and at the level of precincts. The series includes:

Guide to Low Carbon Residential Buildings – New Build
Options for homeowners, builders and designers during the planning and construction of new homes.

Guide to Low Carbon Residential Buildings – Retrofit
Retrofit solutions for existing homes, tailored for homeowners and their contractors.

Guide to Low Carbon Households
Advice to homeowners and renters on operating households using low carbon living approaches.

Guide to Low Carbon Commercial Buildings – New Build
The design and construction of low carbon commercial buildings.

Guide to Low Carbon Commercial Buildings – Retrofit
Methods for retrofitting commercial buildings to improve performance while reducing energy and carbon use.

Guide to Low Carbon Precincts
Frameworks and options to assist councils and developers with strategic planning decisions when implementing low-carbon neighbourhoods.

Further Guides cover Landscape, Urban Cooling, Value-chain and other topics.

For further information go to: builtbetter.org/lowcarbonguides

Introduction

A new house is an opportunity; not only to ensure affordability and the best possible liveability for future occupants, but to create high-performance dwellings that actively 'give back' by generating more power than they use, collecting and recycling water and reducing the built environment's carbon footprint.

This document offers practical advice to developers and owner builders on how to achieve these objectives through the conception and realisation of a new home.

In Australia the residential housing sector alone contributes around 9% of the country's total reportable greenhouse gas emissions. Intervening in new-build constructions to encourage low carbon choices, therefore, helps Australia meet its international emissions commitments to combat dangerous climate change.

The time to take advantage of these opportunities is now—homes built after the next update of the national building code in 2019 will comprise around half the dwellings in existence by 2050. Yet the pace of change has been slow—in the last 12 years, less than 1% of new residential buildings have achieved a zero-carbon footprint.

This Guide's focus is on reducing the carbon footprint in all phases of planning, design, construction and system (fixed appliance) selection. It also touches on embodied emissions and some operational phase considerations such as waste and low carbon transport options.

The target audience is architects and building designers, contractors and drafters, state and local government planning agencies, and private developers and owner builders. While the approach and language assume some familiarity with the technical aspects of new-build housing projects, the information here is also suitable for general audiences who are seeking an understanding of effective low carbon approaches and a synopsis of the research that underlies them.

The types of new housing referred to in the Guide span single dwellings up to group housing schemes and small multi-residential developments such as 'walk-ups'. The selected case studies are related to CRCLCL projects and cover all the country's major climate zones, representing what can be achieved in a typical Australian home.

The Guide does not address large multi-residential developments as these are on a scale and complexity that demand a different design approach and servicing needs. For advice on neighbourhood-scale developments, refer to the **Guide to Low Carbon Precincts**. For advice on the construction of new commercial buildings refer to the **Guide to Low Carbon Commercial Buildings – New Build**.

Key principles

The central aim of this Guide is to help homeowners, builders and developers reduce the greenhouse gas (GHG) emissions associated with the construction and eventual operation of a new home.

However, carbon consciousness is not the only measure of success in pursuit of sustainability in the housing sector. Other important principles include:

- **Affordability** – a home's low carbon sustainable status should take into account the ongoing cost of its operation.
- **Green building** – low GHG emissions should not be achieved at the expense of good social, economic and other environmental outcomes.
- **Efficiency** – access to low carbon and/or renewable energy does not remove the imperative to use that energy optimally.
- **Behaviours** – buildings don't use energy, people do. The way occupants use a house will have a large impact on its GHG emissions, regardless of the low carbon principles employed in its design and construction. Assessment of operational emissions should be based on actual measured performance.
- **The big picture** – the dangerous impacts of climate change cannot be reduced through low carbon housing alone, but rather by tackling emissions from all human activities.

In the highly specialised field of low carbon building and design, some use of jargon and abbreviations is unavoidable. If you see an unfamiliar term or idea, please refer to the **Glossary** for an explanation and to the 'Zero Carbon Footprint' box on the following page.

Design and construction are important factors leading to low carbon impact. Photo: JBA

How to use this guide

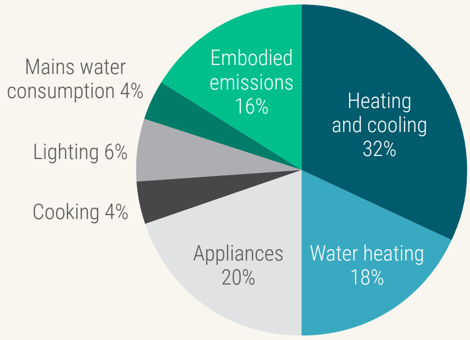
The following pages offer practical advice on low carbon building choices, while also setting out the principles and context for those recommendations. While it is written as a stand-alone document, this Guide can be used as a companion text to other guides in the Low Carbon Series, especially the **Guide to Low Carbon Households** and **Guide to Low Carbon Precincts**.

The document is loosely structured into three parts:

- **Getting started** – how to plan a project, set goals and apply frameworks that ensure targets and objectives are met and measured.
- **Building** – practical advice on building a home according to low carbon principles. Includes recommendations for site orientation, materials and landscaping, heating and cooling, and the sustainable use of energy and water.
- **Occupancy and operation** – how to track home performance once occupants move in. This section includes a carbon inventory and a simple matrix to collect and examine annual data.

Each section lists certain **principles**, describes a number of **strategies**, and provides **further information** and a **summary**.

Annual Emissions Breakdown – New Build Housing



Source: JBA 2019, adapted from Residential Baseline Study for Australia 2000 - 2030, National Performance Reports - Urban water utilities (BOM 2017), Clarkson, S. and Bengtsson, J., Cradle to Grave Assessment and Benchmark of the CSR House

The information in this Guide is informed by research undertaken by the CRC for Low Carbon Living and more details of the specific research projects can be found in the **Appendix**.

Zero carbon footprint

A net zero carbon footprint, or **carbon neutrality**, is commonly defined as achieving net zero carbon emissions by measuring the amount of carbon released and balancing it with an equivalent amount of carbon that is sequestered or offset, or buying enough carbon credits to make up the difference. Most new housing projects will not seek formal certification as ‘carbon neutral’, as this requires a documentation and auditing load that may not be appropriate for the scale of the project. Goals for low carbon housing typically rest on annual performance in net emissions, or energy performance, as a close substitute for carbon emissions.

Even with the best intentions and planning, it will generally not be possible to achieve carbon neutrality or a zero-energy home in its own right–people and their homes use energy and create emissions. However, building a home that *approaches* zero emissions is still a good result since remaining carbon emissions can be ‘offset’. **Carbon offsets** are demonstrated reductions in GHG emissions that are achieved outside the project. These are then used as a credit against the project’s Carbon Account to reduce net emissions.

Carbon offsetting can be achieved through retiring certified offsets. The National Carbon Offset Standard for Buildings (NCOS-B) provides some guidance on selecting offsets. This guide also suggests another option–exporting renewable energy from the site – as suitable offset in some cases. As a general principle, however, a low carbon housing project should first reduce emissions as much as is practical within the parameters of the project itself, and then use offsetting to achieve stated emissions targets if required.

Renewable energy as an offset

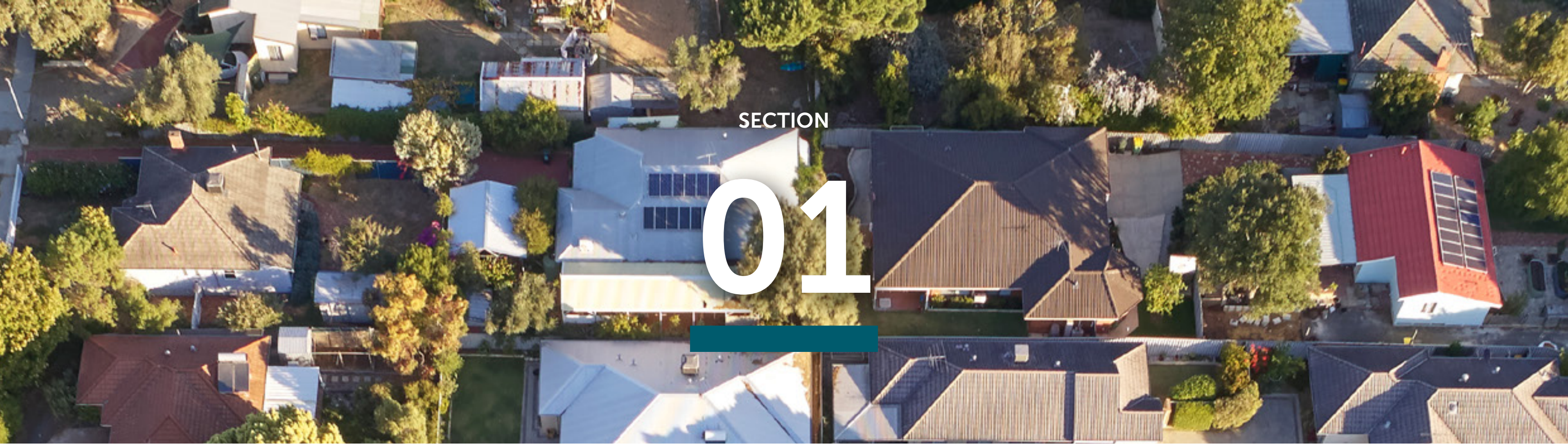
Though a worthwhile addition to any low carbon project, export of renewable energy is not an eligible offset under the NCOS-B so projects that are seeking a formal carbon neutral certification cannot use this method of offsetting. However, for owners or developers who are not aiming for a formal carbon neutral status for their project, renewably sourced electricity exported into the grid can still be claimed an 'emissions reduction' in their own carbon accounting records, as set out in other sections of this guide.

On a larger scale, the exports from small, distributed renewable energy systems such as rooftop solar and wind energy generators are emerging as a key mechanism for decarbonising electricity grids. For this reason, this Guide encourages homes to install renewable energy systems to meet energy demand in the home and to export any excess energy generated to the grid.

The use of gas

Natural gas consumption in any home results in carbon emissions at the site. These emissions can be reduced through efficiency and can be offset. However, they remain a source of GHG emissions at some level and so can have no legitimate place in a future de-carbonised economy. Replacement of natural gas with hydrogen gas may represent a future solution to decarbonising the reticulated gas system, but this is a long-term proposition at the time of writing. It is expected to require the replacement of appliances built for natural gas with new versions built to burn hydrogen gas. Similarly, some projects may have access to gas sourced from bio-digesters, or other potentially renewable resources. However, at present, these are not common and are not discussed in this Guide.

Using electricity for all services is the most viable alternative to gas because it enables a home to be powered from onsite renewable energy and/or certified Green Power through the electricity grid. It involves no real compromise on amenity or cost in most cases. In most situations, designing an all-electric home also makes good financial sense.



SECTION

01

Getting started

In any complex project, good preparation can help ensure goals are met. Planning should be comprehensive and include early stage thinking. When low carbon is a project goal, this involves understanding context, examining motivations and setting targets and objectives.

Photo: Acorn Photography

Context analysis

Before beginning any kind of design process, and preferably before even settling on a site, developers should undertake a basic ‘context analysis’.

This is a study of all the opportunities and constraints that the project design needs to consider. Along with any site peculiarities, it should address the following elements:

- **Regulations** – In all states of Australia, there are planning codes that seek to guide housing developments. Generally, these are implemented though local government, but there are other State or even Commonwealth development authorities that may have jurisdiction. Planning and building regulations can have an impact on low carbon design and may limit some options, but should not be seen as a barrier.
- **Development controls** – There may be design guidelines or other controls in effect on a site including conditions within the contract of sale.
- **Local vernacular** – Understanding why existing housing around the site has a particular form can provide clues to important local considerations. It is not always desirable to simply emulate what has gone before, but understanding what has driven local housing construction in the past is a wise starting point.
- **Infrastructure** – What infrastructure is available and the cost of connecting to it will inform decisions around the need for alternative systems such as onsite renewable energy generation and storage, or microgrids.
- **Existing trees and vegetation** – How will the design harmonise with the natural and living elements of the site?
- **Climate** – Understanding the climate zone of the site, as well as prevailing winds and seasonal weather patterns, will inform design. The Australian Building Codes Board (ABCB) publishes a map of the climate zones that apply to the National Construction Code (NCC), which is a useful starting point. The case studies throughout this Guide are drawn from across a range of climate zones, showing that low carbon, high-performance housing is viable in all parts of the country.

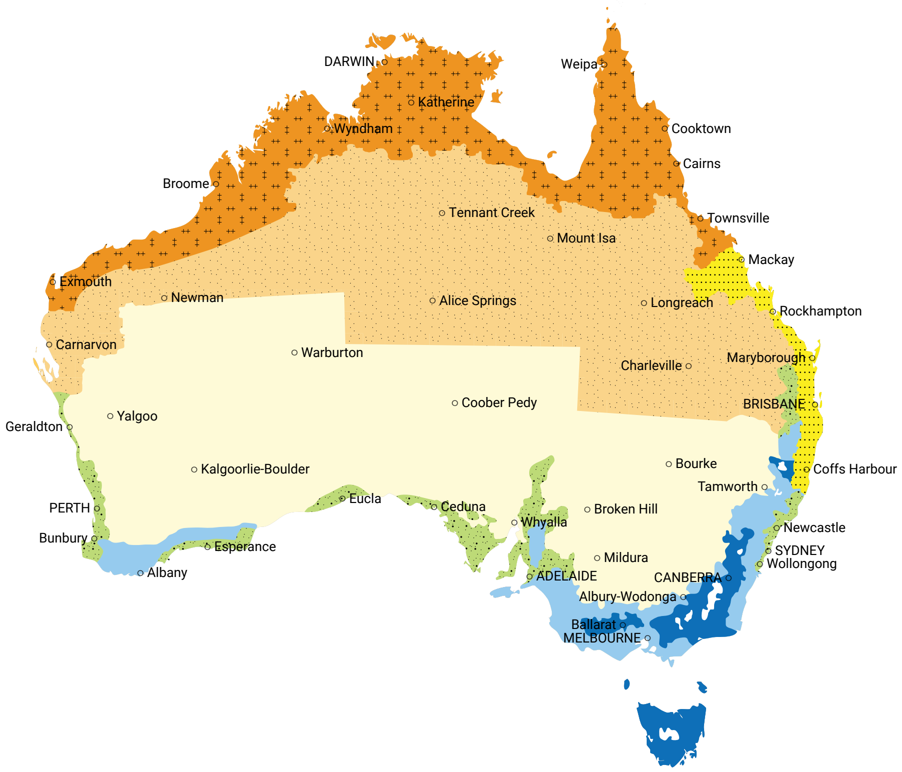


Figure 1 Climate Zone Map: Australia Wide

Zone		Description
	1	Hot 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

Source: Australian Building Codes Board

While low carbon features are important, a new home must also include features that are attractive to buyers. Photo: SJD Homes

Motivations

Another important early consideration is to understand market demand. What features do buyers really want? A smaller home will generally produce fewer carbon emissions, but the home must also satisfy what buyers are looking for. Understanding the needs of future residents and their appetite for technical complexity may affect the types of systems selected. For example, features that might be appropriate for a holiday house may not be well suited to a full-time residence.

Setting targets and objectives

Once context and motivation are understood and constraints and opportunities identified, project goals can be set. Goals are important in any successful project and will help designers and developers navigate the myriad options and alternatives available in a new build. For low carbon housing, best practice can be achieved by adopting one of the following benchmarks:

Zero Energy Home (ZEH) – Within the low carbon living movement, ZEHs are considered optimal and are designed to be energy neutral, that is, to generate at least as much energy as they use on an annual basis. Through good design and quality construction, ZEH buildings are highly energy efficient and include an appropriately sized roof-top solar power generation system. In a grid-connected ZEH, the total amount of excess renewable energy (in kWh) exported to the grid should equal or exceed the total kWh imported for household use. Gas consumption is limited. In an off-grid ZEH, all energy requirements are met from renewable energy. While not addressing carbon emissions directly, the ZEH approach uses energy as a proxy. It offers a very simple approach that supports low carbon housing and the transition to a low carbon economy. Utility bills are the means by which assessments are made and simple calculations over a year confirm whether a house meets ZEH status.

Greenhouse gas emissions reduced and offset 105% (Operational only) – In this target method, a credible carbon account is developed for the project and all operational carbon emissions, plus 5% (or more), are offset on an annual average basis. Operational carbon emissions include, at a minimum, emissions from gas, electricity, and any other fuel used onsite to directly service the home (see Scope 1 and 2 emissions on page 8), and emission resulting from mains water use in the home and garden (see Scope 3 emissions). The simple *Carbon Inventory Template* (page 9) can be used along with utility bills (electricity, gas and water) to determine the amount of offset required (if any) each year.

Greenhouse gas emissions reduced and offset 105% (Operational and embodied) – A credible carbon account is developed for the project and all operational carbon emissions, plus 5% (or more), are offset on an annual average basis as set out in the previous example. In addition, all embodied carbon emissions, plus 5% (or more), are offset over the first three years of the project using one of the embodied emissions tools listed on page 12.

These benchmarks are indications only for owners and builders who are planning to undertake proper carbon accounting. They are considered 'gold-standard' but are not mandatory for the construction and operation of low carbon housing. A further way to think about emissions is by classifying them as 'scopes'.

Emissions scopes

One way to understand a housing project's contribution to GHG emissions is to classify its emissions into 'scopes'.

Scope 1 emissions are those released to the atmosphere as a direct result of an activity, or series of activities, at a facility level. They are sometimes referred to as direct emissions. Examples relevant to housing projects are:

- Emissions from the burning of gas, wood, kerosene or any other fossil fuel in appliances such as stove tops, hot water systems and space heaters.
- Emissions from diesel or other fuel used in generators on site.

Scope 2 emissions are the 'indirect emissions' released to the atmosphere from the consumption of an energy commodity. Examples relevant to housing projects include:

- Consumption of electricity at the home. These emissions come from the burning of coal, gas or other fossil fuels at the generation facilities that supply the grid with electricity.
- Consumption of hot water or steam from a precinct system, which may burn fossil fuels to produce required heat.

Scope 3 emissions are indirect GHG emissions other than scope 2 emissions that are generated in the wider economy. The scope 3 emissions that are considered in this Guide are those from consumption of mains water by a housing project. The Guide also addresses the need to reduce construction waste, which is a source of Scope 3 emissions.

Emissions accounting

A simplified carbon account template, based on the National Carbon Offset Standard (NCOS-B), can be used to assist small-scale housing projects to quantify emissions.

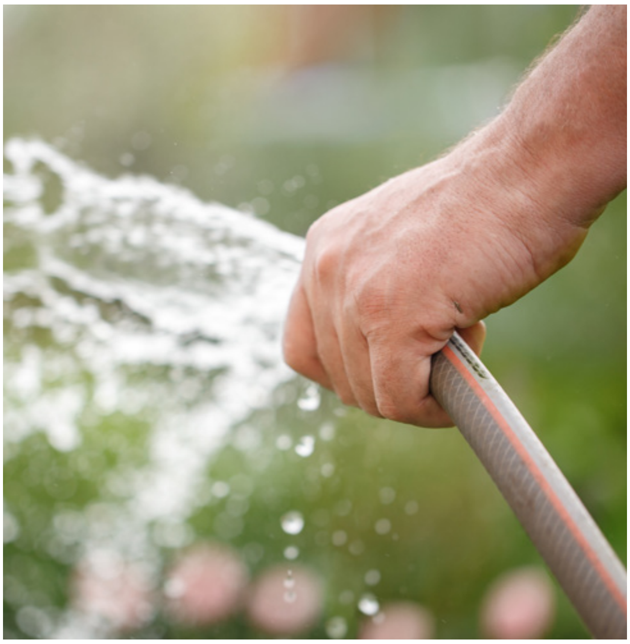
Larger projects may need to consider a more detailed account such as a detailed Life Cycle Assessment (LCA), to make a robust assessment suited to their scale.

Carbon Inventory Template: Operational Emissions
Projects that aim to offset operational carbon emissions can use the following table annually, once 12 months of energy and water bills have been collected. Note: projects that pursue the stricter carbon neutral certification should use the **NCOS template**.

Information from the table below can be transferred directly into the NCOS template if required.

Annual operational GHG emissions account template

Project	e.g. Our Low Carbon House			
Period	e.g. FY2018/19			
Emission Source	Quantity (appropriate units) A	Emissions Factor – Scopes 1, 2 and 3 ($kgCO_2e$/unit) B	Emissions Factor source for future reference	Total emissions ($kgCO_2e$) A*B
Electricity – total imports from grid (kWh)	Total from 12 months electricity bills (note that kWh are often referred to by utilities as 'units')	From current version of the *National Greenhouse Accounts Factors* (NGAF)	NGAF table of grid emissions by state OR Alternative source	e.g. 999,999
Gas – total consumption (kWh)	Total from 12 months gas bills (note that kWh are often referred to by utilities as 'units') OR total volume of bottled gas consumed based on metering or receipts from supplier.	From current version of the *National Greenhouse Accounts Factors* (NGAF)	NGAF table of natural gas or LPG emissions OR Alternative source	e.g. 999,999
Water – total consumption (kL)	Total from 12 months water bills.	See: 'Emissions due to Water Consumption' section of this Guide (next page)	BOM National Performance Reports - Urban water utilities OR from local water authority/supplier annual reports	e.g. 999,999
Total emissions in kg-CO_2e				e.g. 999,000
Total emissions in Tonnes-CO_2e				e.g. 999
Total offsets retired Tonnes-CO_2e				e.g. 999 + 5%



Emissions due to water consumption

Local water supply authorities routinely produce their own annual reports stating the GHG emissions intensity of their water supply. If no reports are available, an approximation can be made using information from the Bureau of Meteorology (BOM) published in their annual National Performance Reports on urban water utilities.

GHG Emissions due to water consumption – 2017

National Performance Reports – Urban water utilities (BOM 2017)	p17, Table 2.3	P19, Table 2.6	Resultant
Major urban centre	Average annual residential water supplied (kL/property)	Total net greenhouse gas emissions (net tonnes CO_2 equivalent per 1,000 properties)	EF (Water supply and wastewater processing) kg CO_2e/kL
Adelaide	171	250	1.46
Canberra	190	242	1.27
Darwin	361	179	0.50
Melbourne	149	266	1.79
Perth	223	828	3.71
Sydney	206	176	0.85

The above table summarises the water supply and processing emission factors for the six Australian capital cities that reported to the BOM for the 2016–17 edition of the report. These figures include both the supply of mains water and the removal and processing of waste water.

Where figures are available from individual suppliers, these should be used. Suppliers may report water supply and wastewater figures separately, enabling projects that use onsite waste water processing, or grey water systems, to more accurately estimate their water use emissions.

Sustainability frameworks

CRCLCL research has demonstrated that home buyers are strongly interested in a dwelling's energy and emissions performance and that a home with a clearly articulated energy rating, including some explanatory text, was as attractive or more attractive than other home features

There are various frameworks that consider energy efficiency and carbon emissions as well as other sustainability outcomes and generally provide a combination of design guidance and certification. These give some consideration to energy and carbon emissions and also address a range of 'green building' outcomes covering environmental, economic and social impacts. The most common include:

- **HIA GreenSmart**: developed by Housing Industry Australia.
- **The Built Environment Sustainability Scorecard (BESS)**: developed for Victorian councils by the Council Alliance for a Sustainable Built Environment (CASBE). BESS assesses energy and water efficiency, thermal comfort, and overall environmental sustainability performance of your new building or alteration and can be used as part of the application for Planning Permit process in Victoria. **BASIX** is a similar tool used in NSW.
- **One Planet Living**: an international tool, originally from the UK, that has been applied to individual houses.
- **Living Building Challenge**: a tool out of North America that is one of the most ambitious yet simple frameworks available.

These frameworks may or may not be of value for marketing or development approval purposes. Regardless, they ensure broader green building principles are considered at the beginning of the design process.

There are also precinct and land development-level sustainability frameworks that may be helpful, including some developed in Australia:

- **EnviroDevelopment**: administered by the Urban Development Institute of Australia (UDIA)
- **Green Star Communities**: administered by the Green Building Council of Australia (GBCA)
- **One Planet Communities**: administered by BioRegional.

It should be noted that sustainability frameworks are a constantly changing field, and new options and updates to older tools are regularly issued.

Home buyers are extremely interested in energy and emissions performance – information that sellers would do well to include in marketing materials. Photo: VAM Media

Carbon account: Embodied emissions

This Guide does not seek to provide a definitive pathway to achieving low embodied emissions in a housing project because the factors involved rely on a very detailed understanding of specific products and materials and the amount of information required is too large and too detailed. Projects that wish to offset embodied emissions are advised to use one of the following tools to assess their design and to quantify the required offsets:

- A Life Cycle Assessment (LCA) completed by an experienced professional. See the Australian Life Cycle Assessment Society's (ALCAS) list of certified practitioners.
- A robust online tool that can provide an approximate embodied emissions figure for the project, for example:
  eTool
  The Footprint Company
  CSIRO AccuRate (the ECO2 module can be added to enable a level of life cycle assessment of embodied emissions in this modelling tool that can also be used to complete the compliance for the energy requirements of the building code).

Record keeping

Developers and owner builders are encouraged to create a filing system that acts as a repository of information for every low carbon project. The system should include:

- a Statement of Intent, which can be as simple as an intention to "seek to minimise embodied carbon emissions and be carbon neutral in operation"
- carbon account templates that are progressively completed as information becomes available
- any supporting documents.

More information

The following agencies offer advice and resources to support housing projects that are targeting lower GHG emissions and more sustainable outcomes:

- National Construction Code (NCC)
- Nationwide House Energy Rating Scheme (NatHERS)
- Building Sustainability Index (BASIX)
- Green Building Council of Australia (GBCA)
- Housing Industry Association (HIA)
- Urban Development Institute of Australia (UDIA)
- Bioregional (OPL)
- Living Future Institute Australia (LFIA)
- Built Environment Sustainability Scorecard (BESS)
- The Australian Passive House Association

SECTION

02

Building & landscape

Once preliminary planning is completed and permissions gained, the next step is planning for construction. This section looks at strategies for building and landscape design that reduce carbon emissions. Advice includes: building orientation and passive design, material choices, construction type, and outdoor and green space design.

Photo: Joel Barbitta

Potential impact:
38%
of household emissions
(related to cooling, heating and lighting)

Orientation and passive design

Passive design uses characteristics of the surrounding climate to maintain a comfortable temperature range inside the home. Good passive design reduces or removes the need for artificial heating, cooling and lighting, which accounts for about 40% of energy use in the average Australian home.

The intention is not to provide an exhaustive guide to passive design—there are plentiful other sources of detailed information on the topic—but to ensure that builders and developers appreciate the importance of thermal performance in creating low carbon housing.

The extent to which homes comply with the energy requirements of the National Construction Code (NCC) is tested through modelling using a 'star system' under NatHERS protocol. The definition of a 10-star NatHERS rated home (the highest rating available under the current protocol) is that it remains "thermally comfortable without the need for artificial heating and cooling".

According to the Department of Environment, the average home built before 1990 scores only one star under NatHERS, while less than 1% of homes built

Principles:

- Control of heat flows through the thermal envelope of the home can improve comfort levels and reduce the need for artificial heating and cooling.
- In most Australian climate zones, the ability to capture cooling breezes is a welcome feature.
- A building that is merely compliant with the energy efficiency requirements of the NCC is the 'least-best' performing building that you are permitted to construct.
- A NatHERS assessment is a compliance modelling tool for residential buildings. It gives an indication of the thermal performance of the design but, like any modelling tool, is imperfect. Starting with a great design based on the passive design principles in this section should lead to a high NatHERS rating. (However, starting with a high NatHERS rating will not necessarily result in a great design).

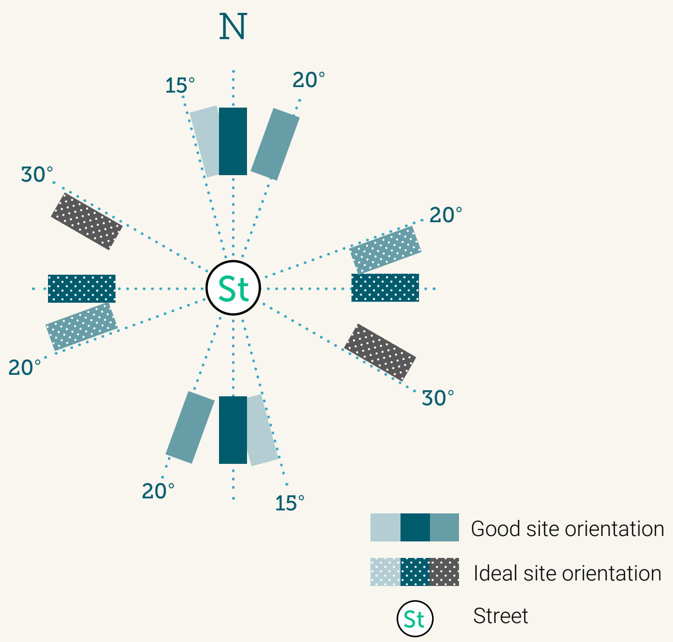


Figure 2.1 Lot Orientation Guide (all climate zones).
Source: Adapted from yourhome.gov.au

> It is a very old concept of designing your building to understand and work with the climate, the orientation and the location.
>
> Caroline Pidcock, Architect

between 1990 and 2003 (when minimum energy performance requirements were introduced) achieved the current minimum rating of six stars. Low carbon housing should target the highest NatHERS rating possible through good passive design.

STRATEGIES

There are numerous passive design strategies. Individually, some have been standard practice in good house design and construction for centuries. Combined, they provide a reliable road map to achieve good outcomes. They include:

Location and local climate

Understanding the climate zone and local weather factors helps determine building code requirements. Observing local housing responses and speaking to neighbours can help developers understand how the local climate has contributed to those responses.

Lot orientation

How the lot is oriented can significantly impact how the building is located and oriented, particularly in higher density locations where the building may take up the bulk of the lot. For this reason, planning, subdivision and road layout decisions can have a major impact on passive design outcomes. For climate zones 4–8 (refer to map on page 6), northern site orientation is preferred and in all climate zones a longer east-west axis will minimise the heat gain on summer mornings and evenings and help with the management of natural light. The diagram above shows the optimal site orientation to support passive design outcomes.

Home layout

Living areas ideally should be located on the northern side of the home to give them access to natural light and managed solar heat gain. Bedrooms, which are usually smaller and their comfort levels easier to manage, can be located in areas with less natural light and sunshine.

Building envelope

Section J of the NCC covers compliance requirements for thermal performance of the building envelope. For housing, these requirements are usually assessed through NatHERS. This modelling approach dictates a minimum compliance level; however, goals can be set higher. Aiming for a higher NatHERS thermal performance does not add significantly to the cost of a residential construction, therefore low carbon housing projects should aim to exceed minimum requirements by at least one star.

Window and shading design

In cold climates the home should present as much clear glazing to the north as possible to trap winter sunshine while still maintaining the thermal performance of the building envelope. When cooling is required, shading of northern glazing is generally more straightforward than western and eastern glazing which attracts considerably more direct sun. More elaborate—and costly—solutions such as active external shutters or blinds, or highly treated glazing, may be required if windows have direct east/west orientation.

For warmer climates, shading should deal with solar gain from all sides. In these climate zones it is important for windows to be able to open safely and securely to encourage entrance of cooling breezes. In zones where no solar heat gain is required, block-out shading is recommended.

The Australian Window Association manages the Window Energy Rating Scheme (WERS) and publishes excellent information on window ratings and terminology.

Cross ventilation

In hot weather, capturing a breeze is an effective way to cool the interior of a dwelling. General principles for good cross ventilation include:

- **Direction**: Understand where cooling breezes come from—the sea, over bodies of water, and off forests and mountains.
- **Mid-height entry openings**: Create openings in the middle of the wall to make it easier for breezes to enter and reach most parts of the interior.
- **Simple pathway**: A breeze should be able to enter and exit a building without having to negotiate a complex pathway. Narrower floorplans provide more effective ventilation than wider ones.
- **Oversize the exit**: The effectiveness of cross ventilation is generally determined by the size of the exit opening, which ideally should be at least three times larger than the entrance opening.

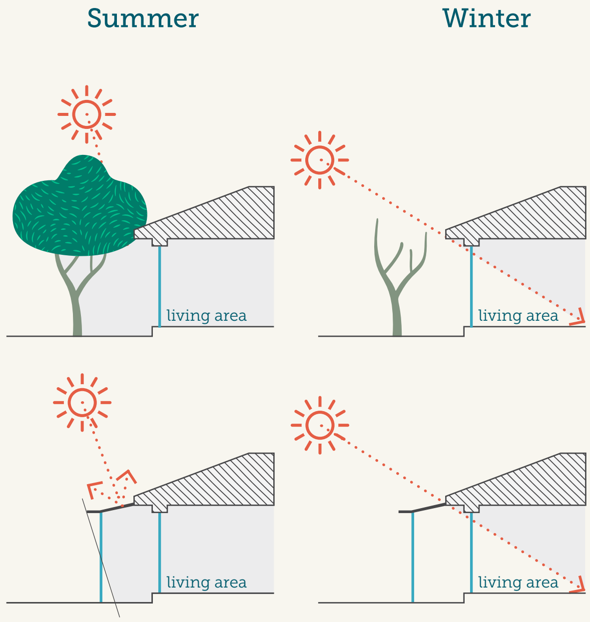


Figure 2.2 Optimal shading for most Australian climate zones. Source: Adapted from yourhome.gov.au

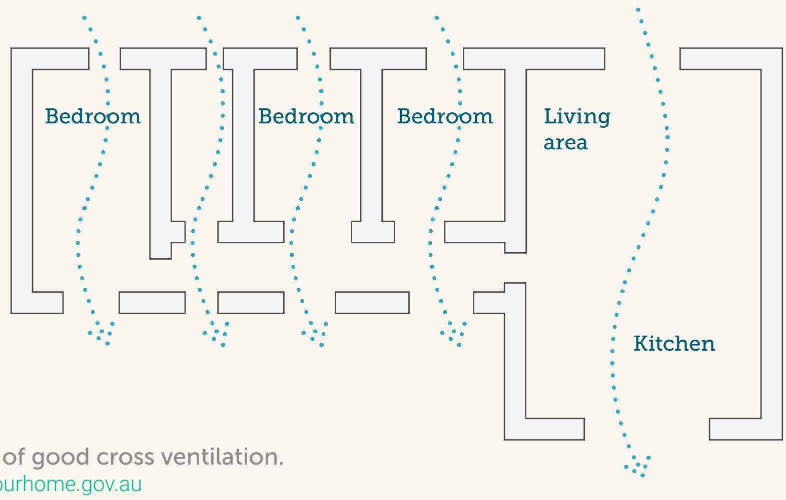


Figure 2.3 Principles of good cross ventilation.
Source: Adapted from yourhome.gov.au

Thermal mass

Thermal mass is a measure of a material's ability to absorb heat. Heavy materials such as concrete, clay bricks or tiles absorb and retain heat at higher rates because their thermal mass is greater. For this reason, heavy materials are sometimes referred to as 'thermal batteries'.

Thermal mass inside a home stores heat energy when the ambient temperature increases or when the material receives direct sunshine. The material then releases that energy when the air temperature drops. Understanding this effect is essential if thermal mass is to be used to improve, rather than diminish, a room's thermal comfort. Since thermal mass design depends on controlling the exposure of the interior of a home to the sun, it can be considered an extension of window and shading design.

The diagrams below apply mainly to southern climate zones which have warm summers and cold winters. In warmer northern climates, design should avoid storing heat inside the home via thermal mass and instead maximise opportunities to capture cooling breezes. In southern climates, especially in winter, thermal mass in the home should be exposed to direct heat from the sun during the day allowing it to release heat in the evening as temperatures drop.

In summer, the opposite effect should be encouraged. House design should direct sun off the high mass elements to limit daytime heat inside the home. This allows thermal mass to then absorb heat from the air, lowering internal temperatures. At night, cooling breezes should be encouraged onto the high mass elements so the process can be repeated the following day.

Passive House

Passivhaus, or Passive House as it is known in Australia, is a housing performance standard developed in Europe and characterised by five key elements:

- **High insulation levels** – typically far exceeding compliance requirements.
- **High thermal performance windows** – double or triple glazed, very well sealed and with thermally broken frames that contain a resin or plastic that physically separates the interior and exterior window spaces, thereby breaking the pathway for heat energy to be transferred.
- **Airtightness** – very low levels of air leakage throughout the building envelope.
- **Avoid thermal bridges** – connections linking the inside and outside of the home that conduct heat. Typically, these occur for construction convenience but can impact overall thermal performance.
- **Heat exchange ventilation systems** – in well sealed buildings, mechanical ventilation is required when windows are closed. Centralising this ventilation allows incoming and outgoing air to be passed through a heat exchanger to recapture some of the heating or cooling energy to temper incoming air.

The Passive House approach is sometimes said to be at odds with passive design principles. This is partly because Passive House tends to minimise windows due to the cost of installing high-performance glazing. However, this is less a fundamental difference than a design issue and the two approaches are not mutually exclusive. A Passive House that adopts passive

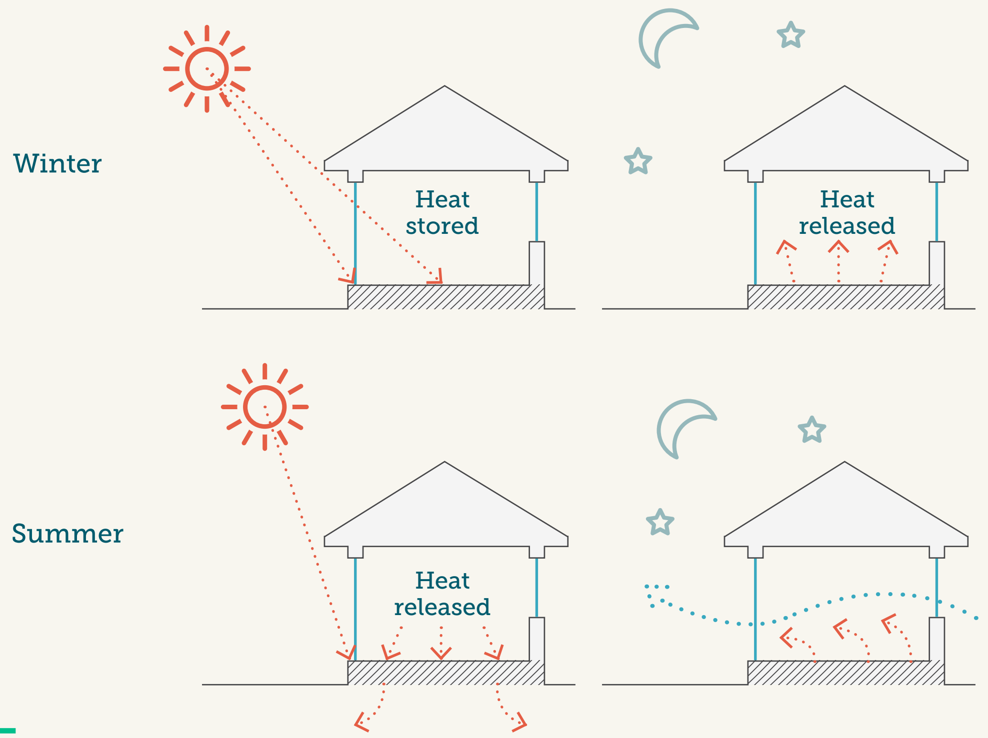


Figure 2.4 Thermal mass – winter and summer.
Source: Adapted from yourhome.gov.au

design principles around shading, cross ventilation and natural light will still use less energy, while also giving occupants a connection to the outdoors that is beneficial for health and wellbeing.

Passive House design also has less need for thermal mass because the heat exchange and ventilation system it promotes uses airmass inside the home as the heat storage medium. This means lighter construction methods can be employed to achieve very high performance with little energy input. The Passive House approach is highly effective when site orientation and solar access are sub-optimal, and therefore of interest in high-density developments where these elements are more constrained. Read more at passivehouseaustralia.org

Summary

There are many sources of detailed information on passive design and these should be reviewed as part of the design process. Yourhome.gov.au is a good first stop.

Boosting the thermal performance of a home will improve comfort and reduce energy consumption. Access to ample fresh air and natural light has health benefits for occupants.

Minimum compliance for thermal performance can be improved with little or no increase in the total build cost of a new housing project.

While renewable energy systems are providing increasingly cost-effective access to low carbon energy, this Guide promotes the prudent approach of not using this energy unnecessarily, and looking first to use the climate and other natural resources to create homes that are naturally comfortable and healthy for occupants.

Potential impact:
16%
of household emissions

Construction method and materials

The method and materials used to construct a home have a major impact on whether it can be considered 'low carbon'.

Both construction method and materials can dictate the performance of the final structure and some materials have much higher levels of embodied carbon emissions during their production and transportation. Despite this, design and build quality will always have a greater impact on low carbon outcomes than materials or construction technology.

Principles:

- The choice of construction materials can influence the final performance of a building but only proper assessments can provide certainty.
- The method of building is also a factor: prefabrication offsite and assembly onsite is usually a lower carbon option.
- Waste minimisation during construction is an often-overlooked aspect of low carbon building.
- While materials and methods are important, design and build quality, combined with renewable energy systems, will generally have a greater impact on carbon emissions over the building life-cycle.

STRATEGIES

Measuring embodied energy

A timber frame construction will generally have less embodied energy than a masonry one, but only a calculation will provide certainty and quantify the difference.

For a thorough comparison of construction methods and materials, a Life Cycle Assessment (LCA) by a professional provider is the gold standard. A more cost-effective option is to use an online calculator, which can provide a reasonable approximation if carefully applied (see page 12).

Inherently low carbon construction options

A number of construction materials use organic base materials that absorb CO2 as they grow. These include 'natural' materials like timber, straw bale, or hemp brick. However, the many variables in the farming and manufacture process mean it is impossible to make blanket statements about which has the lowest carbon footprint (for example, some modern materials, including masonry, have the ability to absorb CO2 and lock it into their molecular structure). As a general principle, however, using natural materials rather than masonry should result in lower embodied emissions. If the base materials include waste products—such as rammed earth construction that uses recycled rubble—there will be an even greater benefit.

Photo: VAM Media

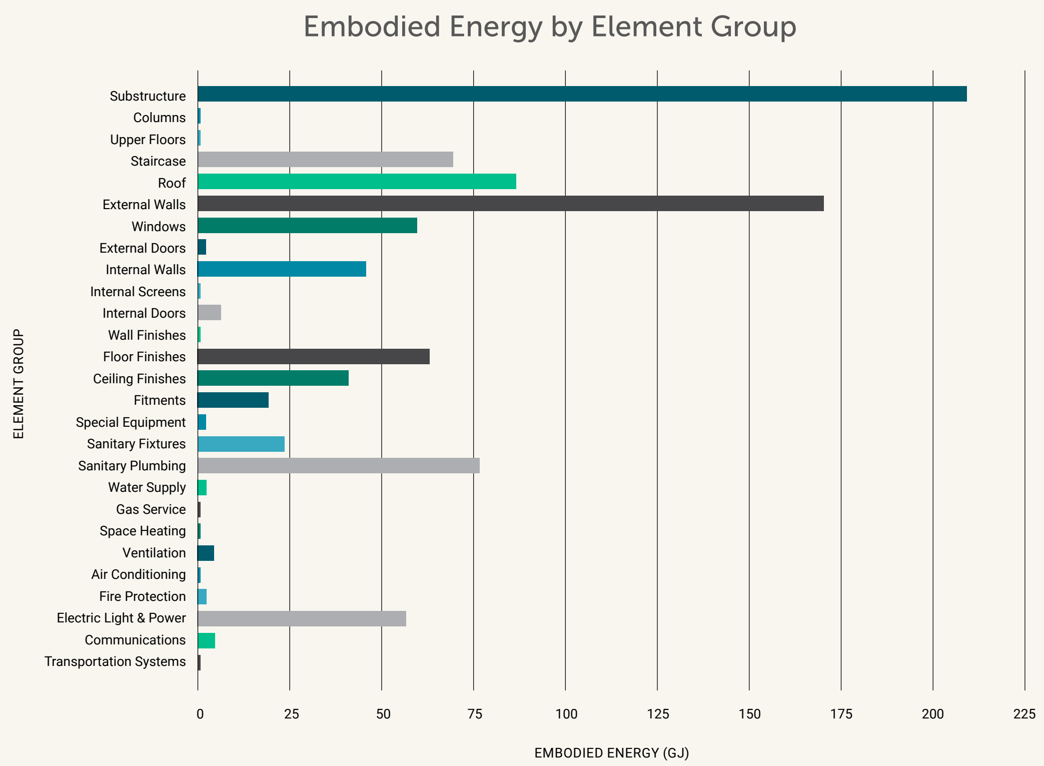
Waste minimisation

Construction and demolition waste is generally highly recyclable. According to the Australian National Waste Report, last published in 2016, the construction sector recycled 64% of the 20-megaton waste stream that year, leaving a huge amount of material going to landfill. To minimise this waste, and therefore reduce embodied energy, the well-established strategy of Reduce–Reuse–Recycle applies:

- **Reduce** waste generation by designing to standard sizes. Factory fabrication generally provides the best opportunity for efficient use of source materials, so consider offsite manufacture and modular techniques that can build entire dwellings, or major portions of them, offsite and then crane them into place. Modular building also substantially reduces onsite construction time and site impacts.
- **Reuse** materials from demolition and identify a location onsite where any excess materials can be set aside for use by other trades. Consider salvage materials in the house design—these can add character as well as reduce the overall materiality of the project.
- **Recycle** anything that can't be used onsite by identifying an accessible recycling centre and ensure everyone understands what kinds of materials it will accept and under what conditions.

Testing performance

The carbon account of a house tends to be dominated by its occupancy phase. Whatever construction method and material choices are made, the quality of construction will profoundly affect the eventual energy performance of the dwelling. Tests can be done at the end of construction to identify problems in the construction, including two that should be considered mandatory for all projects:



Source: Tucker S.N., Ambrose M.D., Embodied Energy of Dwellings, CSIRO 1997

- **Building sealing**: a pressure test, or 'blower door test', will establish the level of air leakage from the building. Airtightness is an important factor in achieving good levels of comfort and thermal performance.
- **Thermal imaging**: use of a thermal imaging camera to examine the building envelope will identify any weak points in insulation, glazing performance and air leakage.

Pinpointing embodied emissions

Embodied emissions are a core consideration in low carbon construction methods and material choices. The CSIRO published a study in 1997 on embodied greenhouse gas emissions in dwellings which provides a good starting point for understanding where the major sources of embodied emissions are likely to be in a new housing project. A table from the study (above) shows the typical contribution to embodied energy (analogous to emissions) of the various elements of a residential building. The structure of the building accounts for the most emissions followed by elements such as linings, floor finishes and plumbing pipework.

There are low carbon alternatives for most of these sources of embodied emissions. Builders can source recycled steel and aluminium, replace masonry walls with 'hempcrete' or rammed building rubble and, where possible, limit the use of plastic items. Beware of frequently invoked 'low carbon' construction methods such as laminated timber or timber frame—these can involve high levels of emissions if the source of timber is not carefully selected or if the resulting building is not resilient and has a short lifespan. If a project is to genuinely address embodied emissions, a comprehensive review of the proposed construction methods and materials, using an experienced assessor or a robust online tool, is essential.

Summary

Construction method and materials selection will impact the quantity of embodied emissions in a project. These are best assessed using LCA. Once the building is occupied, emissions are more impacted by the quality of construction than the type of construction.

Waste management of construction materials has become more advanced in recent years and a small amount of research can uncover local ways to recycle materials that can't be reused onsite.

Photo: Acorn Photography

Potential impact:
32%
of household emissions
(when combined with building design)

Outdoor landscape and garden design

The role of landscape design in reducing carbon emissions is underappreciated. By including plants and gardens in the design stage, developers can create better performing homes by reducing energy requirements and boosting comfort levels.

Shade is an important passive design principle and evapotranspiration by plants can change the microclimate in and around a house.

Principles:

- Ideally, outdoor greenspace design will support and enhance the local natural ecosystem and restore biodiversity.
- Greenspace areas can provide opportunities for local food production.
- The garden and greenspace are designed to use water sustainably, in the context of the location and site.
- Greenspace design is integral to a holistic passive design, contributing to shading and wind management strategies, as well as providing a cooling effect in the immediate vicinity of the project.

STRATEGIES

Strategies to create effective outdoor and landscape design include: choosing the right kind of trees and shrubs, understanding and mitigating the impact of human-made 'heat islands' and utilising passive heating and cooling.

Shade trees

Evergreen plants are recommended for hot humid climates and even for some hot dry climates. For all other climates, deciduous vines or trees are planted to the north, and deciduous or evergreen trees to the east and west. Shading and evapotranspiration from shade trees reduce summer temperatures and the energy demand for household cooling.

Alternative surface treatments

Paving that is permeable to water supports stormwater management and enhances evaporative cooling effects. Decking and gravel in non-garden areas and mulch pathways offer cooler options than concrete. 'Heat islands'—areas that are significantly warmer due to human activities—are avoided by creating shading and planting green borders around landscaping to promote cooling.

Green roofs

Green roofs can be either intensive (like a traditional garden set on a roof) or extensive (lightweight and relatively low maintenance). A lightweight growing medium provides insulation and shade, reduces summer cooling demands, limits heat transfer through the roof and improves the performance of heating, ventilation and air conditioning systems.

Green walls protect buildings from direct sun exposure, although they may require significant amounts of water and care to maintain. Green walls are a good response where space or access to open soil is limited.

Cooling gardens

Appropriate landscaping enhances passive heating and cooling. Native ground covers and trees/shrubs with shading and cooling potential are the best options. Trees planted in front gardens of north facing properties should be deciduous to maintain solar passive design principles. Shrubs can provide localised shading of windows. Select plants that allow filtered light into the building and plant characteristics (such as foliage density, canopy height and spread) that match shading requirements. Wall vines and ground cover insulate against summer heat and reduce reflected radiation.

Windbreaks and wind harvesting

Vegetative windbreaks reduce wind chill and other impacts of strong winds. Similarly, strategically planted trees and gardens facilitate the movement of air for cooling effects.

COMPLEMENTARY IDEAS

Water efficient practices

These assist in reducing mains water consumption. They include soil improvement practices, planting local indigenous species, mulching, and the adoption of hydrozoning—the grouping of plants together based on their water and management requirements.

Waterwise native or endemic species

Climate-appropriate plant species can be selected via a recommended plant list provided by local councils and water authorities. These should be included in design guidelines.

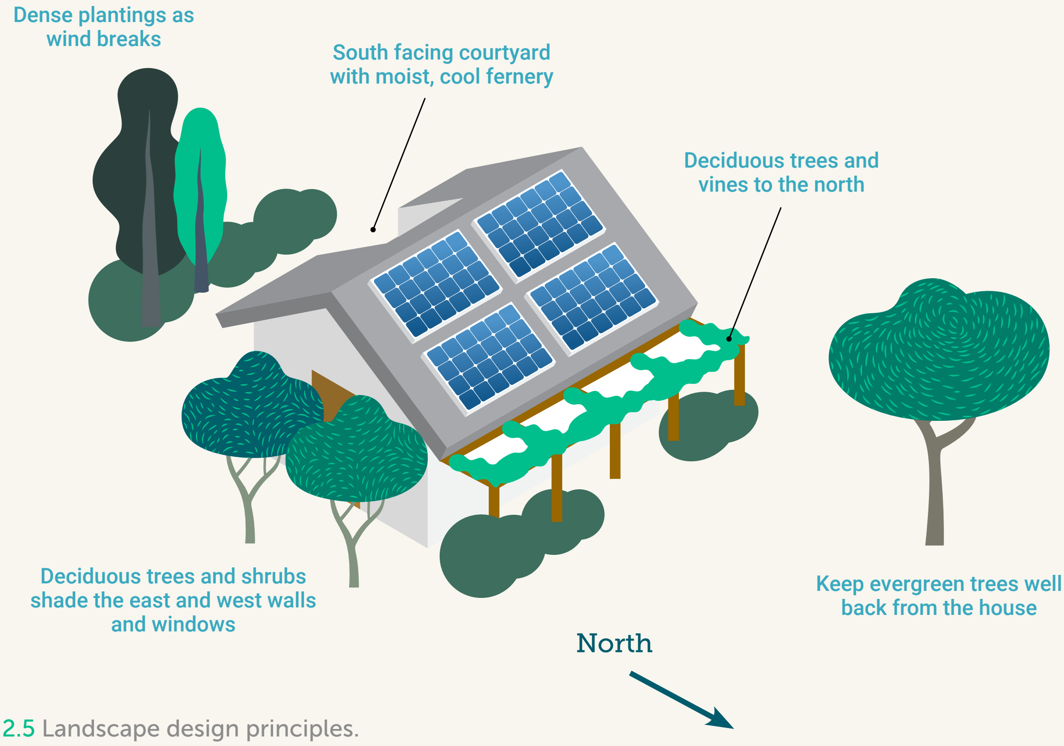


Figure 2.5 Landscape design principles.
Source: Adapted from yourhome.gov.au

Summary
The role that landscape design plays in the performance of the overall built environment is often underestimated. Considering the entire site and designing gardens to be integrated with the house design results in better performing homes.

Some of the general principles of landscape design to support comfortable, low carbon housing are illustrated above.

More information

- Passive design – YourHome.gov.au
- Embodied emissions – Embodied Emissions of Buildings (CSIRO 1997)
- Landscape and heat island reduction – YourHome.gov.au
- Gardens – Growing Green Guide
- Reflective pavements research – IOP Science
- Draft report on reducing urban heat islands (USA) Environment Protection Authority
- LCAs – The Australian Life Cycle Assessment Society (ALCAS)
  The Building Products Innovation Council (BPIC)

Top: Onsite renewable power generation and solar passive design contribute to environmental performance. Photo: Acorn Photography
Below left: The garden includes food production and habitat provision with local native plantings. Photo: Acorn Photography
Below right: The home does not compromise on high levels of comfort and finishes. Photo: Joel Barbitta

Josh's House (Fremantle, WA)

Josh's House, located in the Fremantle suburb of Hilton, has achieved a 10 Star NatHERS rating using conventional building materials, demonstrating that high energy performance is possible for family homes at little or no extra cost.

Solar passive design and good use of shading removes the need for air conditioning year-round. Photo: Acorn Photography

Built in 2013 on a budget typical for a family home at that time, the project boasts high levels of comfort throughout the year without the need for air conditioning even during Fremantle's hot summers and cool winters.

The design is based on well-established solar passive design principles to ensure maximum thermal comfort year-round, with no air conditioning or artificial heating requirement. Energy and water efficient fixtures and appliances, combined with onsite power generation, rainwater harvesting, and greywater recycling all contribute to the environmental performance of the home.

Features:

- East-west orientation with maximum glazing to the north for winter solar gain (shaded in summer) and minimal glazing to the east and west to minimise summer heat entry
- High insulation value to roof and walls to minimise uncontrolled heat loss/gain, and pelmeted curtains on the windows to reduce heat loss in winter
- Effective use of thermal mass inside the home
- Electric vehicle charging
- Solar tubes to 'daylight' internal areas
- Garden includes food production and habitat provision with local native plantings
- Integrated greywater system to irrigate selected garden areas.

Ongoing monitoring of performance and publishing of the gathered data are key principles of the project. The project website contains real time performance data as well as an extensive array of factsheets and other information.

To read more go to: joshshouse.com.au

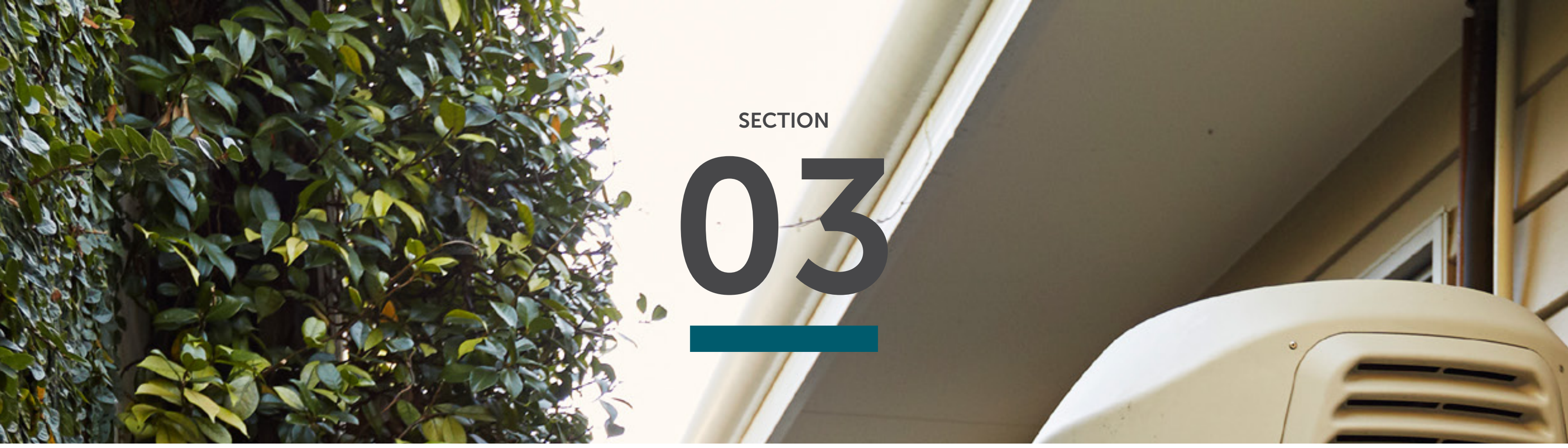
NatHERS Rating
10 stars

Onsite renewable energy
6.6 kW photovoltaic

Energy storage
10 kWh (lithium-based battery system)

Hot water
Heat Pump

Rain tanks
20 kL (with auto-switching to mains back-up, plumbed to whole-of-home)



SECTION

03

Services

Ensuring a house operates efficiently with minimum energy requirements is a key element of low carbon design.

Photo: Acorn Photography

Operational emissions over the lifetime of a new home will constitute the bulk of all associated emissions. Owner-builders and developers should consider low carbon options for hot water systems, space heating and cooling systems, and appliances and lighting—all of which have a dramatic impact on a home's overall energy performance.

Potential impact:
18%
of household emissions

Hot water service options

According to the Australian Bureau of Statistics, water heaters are the second largest users of household energy (after space heating), accounting for more than 20% of household energy.

Energy consumed for water heating is also the second largest source of household greenhouse emissions, emitting 24% of greenhouse gasses in the average Australian household. For this reason, developers and owner builders should choose the most energy efficient hot water heaters. Two broad types of water heating systems dominate the Australian market: **Instantaneous systems** – powered either by gas (natural or LPG) or electricity; and **storage systems** – powered by gas (natural or LPG), electricity, solar, or heat pump. Wood-fired hot water systems are not common in Australia but may be appropriate in some locations, particularly if fuelled with sustainably harvested, carbon neutral fuel.

Solar thermal hot water systems have been a mainstay of Australian domestic water heating for many years, often providing a low carbon service even when boosting is required. The cost of installing solar photovoltaic (PV) systems is decreasing dramatically.

Principles:

- Capturing energy directly from renewable sources to heat water is ideal for low carbon outcomes.
- Photovoltaic modules make more effective use of incoming solar energy on a roof than thermal collectors, particularly if combined with a heat pump hot water service. The efficiencies are comparable at typical temperatures; however, thermal systems stop collecting once the required water is heated, while PV systems continue to generate electricity for other purposes.
- Electric hot water systems linked to onsite renewable energy systems absorb excess generation not used by other services in the dwelling. This may be a higher order use of excess generation than battery storage, because of the efficiency losses of the charge/discharge cycle.
- Unlike gas systems, electric hot water systems allow for a zero-carbon service when supplied from Green Energy sources.

STRATEGIES

Selecting the most appropriate low carbon hot water system will depend on the size of the household and the availability of renewable energy sources, including grid-based Green Energy.

Solar thermal

Solar thermal hot water systems are very well established in Australia and can be electrically boosted. In climate zones 1–5, boosting should be required only in winter if the system is correctly installed. These units often include the storage tank on the roof, saving space on the ground.

Heat pump

Heat pump storage is becoming cost competitive with solar thermal hot water systems. Heat pumps use the same refrigeration cycle as reverse-cycle air conditioners to draw heat from the air and transfer it to water. They are comparatively large units as they have an insulated storage tank plus the compressor (the 'pump') that captures heat from the surrounding air. They have been, until recently, a costly option but like PV systems their price is coming down.

Note: The compressor will make some noise, similar to a typical air-conditioner compressor, so consider this in the design of the home.

Electrical storage

Australia has been on the verge of banning electric storage hot water systems for some years. Despite their popularity—they are generally low-cost to purchase, silent, and have no moving parts—their conversion of a very high-grade energy (electricity) to heat water is at a ratio worse than one-to-one (because of heat losses through the tank). However, in recent years, the advent of controllers that allow the units to be powered from excess renewable energy production (particularly rooftop PV) has resulted in a reprieve. Even so, because the hot water unit draws most energy in winter, when a PV system is likely to be generating at its lowest annual average in most climate zones, only dwellings with oversized PV systems should consider this approach.

Gas storage

In principle, unless a carbon free gas supply is available, water storage heaters that use gas will always have a higher carbon emissions profile compared to systems that run on electricity (which are capable of running on 100% renewables). In most states, gas is also more expensive to purchase.

Instantaneous electric

Of all the electrical systems, instantaneous systems are the most efficient because they heat only water

Photo: JBA

that is required at a given time and are located close to the outlet, thereby reducing heat loss. However, instantaneous electric hot water systems typically require a large amount of power for short periods of time, impacting peak demand and therefore cost.

COMPLEMENTARY IDEAS

Load shifting

Electric storage hot water systems (boosted solar thermal, heat pump, and electric) can all be powered with excess onsite renewable energy generation. A simple controller can detect when excess energy is available and direct it to heating water. The hot water system thus becomes a form of energy storage. This idea is known as 'load-shifting'—moving the hot water load to a time when it can be met with low carbon renewable energy. A less advanced, but reasonably effective, method of achieving the same outcome is to use a simple timer to enable the hot water unit or booster to kick in during the time of day that renewable energy production is peaking (e.g. early afternoon for most PV systems).

Connect a heat pump to the PV system

In most cases, this will be the most efficient hot water option, resulting in lowest GHG emissions, especially where roof area is limited (and thus ruling out extensive PV modules and thermal collector panels). This is for two reasons: First, a typical heat pump has a coefficient of performance of three or more, meaning that every unit of electricity consumed results in three units of heat being added to the water. So, while solar thermal systems are more efficient than PV in most situations, this tripling of the PV output results in comparable water heating efficiency. Second, once a solar thermal system heats a tank of water, it will stop collecting energy. The heat pump will also stop heating water, but the PV system will continue to generate electricity to meet other loads or for export.

Hydronic space heating

In which heated water is moved via sealed pipes to radiators or in-slab heating throughout the home – is based on the basic heat pump model. This way of meeting heating (and even cooling) needs generally achieves high levels of comfort. Several suppliers now offer packages that combine a hot water service with space heating and cooling.

Energy conservation

Residents can change their behaviour (that is, use less hot water) to reduce the amount of resources consumed. Installing a robust shower timer in the bathroom is a simple conservation idea that can reduce both water and energy consumption.

Summary

Any hot water system can be considered 'low carbon' if the source of energy is low in GHG emissions.

In most cases, the low carbon choice will be between electrically boosted solar thermal and heat pump systems linked to a renewable energy supply, such as rooftop PV.

It may be time to look closely at heat pump-linked PV for hot water services, given PV with control systems and energy storage makes best use of available rooftop area and the cost of both PV and heat pumps is reducing.

The installation, particularly pipework insulation, and commissioning including programing of timers, controllers and setpoints, needs to be done by a competent installer who understands the low carbon intentions of the project.

Potential impact:

32%

of household emissions

(when combined with building design)

Space heating and cooling options

Although passive design can improve home comfort, most Australian homes require some active heating and cooling to maintain desired levels of comfort year-round. There are ways to use active cooling and heating systems efficiently and to link them to renewable energy sources to minimise emissions.

When air conditioning is needed, options include: ceiling fans; heat pump driven systems (typical reverse-cycle air conditioning); heat pump driven hydronic systems (radiator and in-slab heating and cooling); gas heating; and wood-fired heating.

At all times, optimal design approaches and the efficiency of these systems should be examined, including options to power them with renewable energy.

Principles:

- Consider passive design in the first instance, making the most of site resources to achieve the highest levels of comfort without resorting to air conditioning. See the Orientation and Passive Design section of this Guide, page 14.
- After optimising passive design, identify the preferred mode of heating and/or cooling. Understand the context. Space heating and cooling is used to improve comfort and other health benefits, so there is little value in installing a system that meets energy and emissions targets but does not provide a satisfactory service.
- Electric space heating and cooling systems allow for a zero-carbon service when supplied by zero carbon electricity.

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> Space heating and cooling consumes, on average, 40% of household energy.

ABS

STRATEGIES

Ceiling fans

The fan is the active cooling system of first choice for a low carbon home. Fans support the body's natural cooling mechanisms and in hot weather can produce the sense of a three degree temperature drop. They can also assist in cold weather by moving warm air near the ceiling down the walls and into the inhabited areas of a room. In this case the fan is used in reverse—or 'winter mode'—to move air laterally around the room.

Zoning

Identifying target zones in a home for heating and cooling will inform decisions about system types. Central systems, such as ducted or hydronic, are usually capable of some level of zoning. The following are some examples of zones in a generic home:

- **Multiple levels**: Each level or storey within the home is zoned separately to meet different requirements.
- **Bedrooms**: These can be a single zone in a ducted or central system. Bedrooms may require some heating or cooling but generally less so than living areas. Broad set points should be used when air conditioning is required in bedrooms since comfort can most easily be achieved by adding or removing bedding.
- **Living areas**: In modern homes, these are generally open plan with living/dining/kitchen combined. Typically, they are the largest areas in a home that require conditioning.
- **Home office**: Often a smaller space that merits its own service since the space is usually used on a different timetable from the rest of the home.
- **Bathrooms**: These are typically not conditioned spaces but, in some climates, heating may be required for some of the year. Because of the requirement for these rooms to be well ventilated, the most efficient approach is to provide immediate 'on the skin' heating using heat lamps. Heated towel rails dry towels and can also provide a sense of warmth for modest energy demand. If a centralised hydronic (in-slab) system with controls is in use, then it may be possible to provide heat to bathrooms for high-use periods of the day, drying towels and improving comfort when needed.

Once the zones have been identified, the most effective way of achieving comfort in each zone can be determined. If a central system is chosen, its ability to control a range of zones should be reviewed.

Central systems

Typically, central systems offer reduced overall efficiency because of poor energy performance related to their size and because of the heat losses associated with extended piping and ductwork. However, there may be reasons for pursuing a central system, particularly if combined with a large renewable energy source, such as solar PV, wind or bio-mass. In these instances, and if the control system is sufficiently capable, it may be possible to divert excess daytime renewable energy generation to pre-heat or pre-cool the home in readiness for the evening thermal comfort demand. However, this approach relies heavily on excellent performance in the building envelope and thermal mass design.

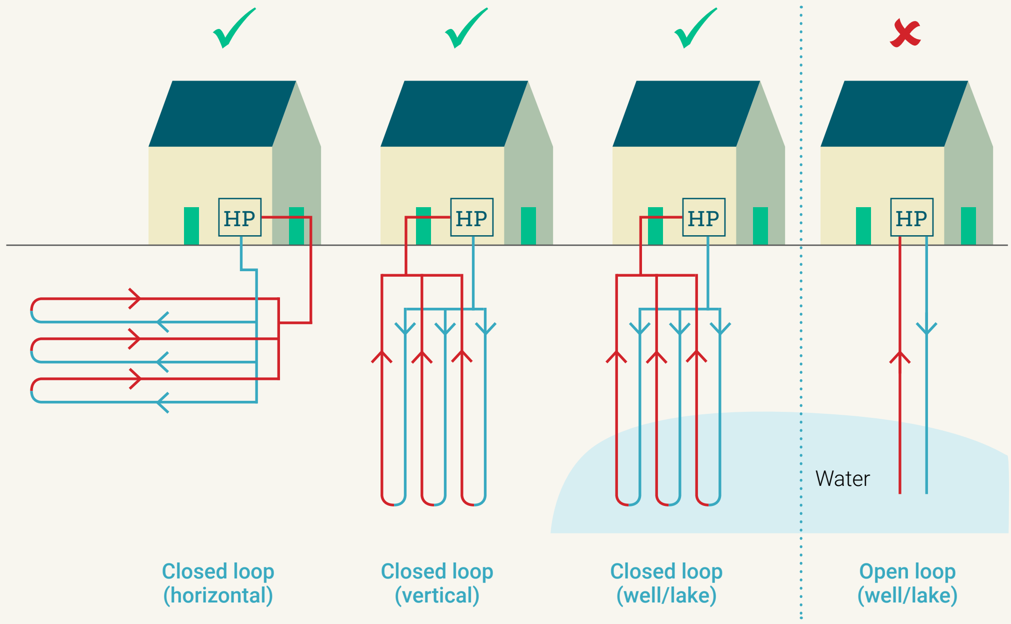


Figure 3.1 Ground source heat pump (HP) systems.
Source: basix.nsw.gov.au

Primary considerations for centralised systems include:

- Is there a plentiful, low carbon fuel source available that makes a central system viable?
- Is there a supplementary energy source available such as geothermal heat, to make a central system more efficient?
- Is insulation around pipes and ductwork regularly maintained?
- Does the system size reflect household demand?

Central systems have a perception of quality and may achieve higher comfort levels by providing heating and cooling with less air movement. They may also suit some low carbon fuel sources. However, generally speaking, there is no fundamental reason to choose a central system to achieve lower carbon emissions, especially if reverse cycle systems drawing energy from renewable sources are an option.

COMPLEMENTARY IDEAS

Supplementary energy sources

Ground mass and water bodies can be used as energy sources, sometimes referred to as 'shallow geothermal' energy. Typically, they have stable temperatures, often in a comfortable range, and this stored heat can be used to heat buildings in winter and cool them in summer. For example, the ground temperature in Perth, Adelaide, Melbourne, Sydney and Canberra is approximately 16–18°C while in Brisbane it is 22–23°C. In contrast, Darwin has a ground temperature of approximately 31°C and Hobart approximately 14°C.

Heat pumps can draw on this stored heat reserve if a heat exchanger is added to the compressor and a working fluid is circulated through the ground or water body. Open systems do the same thing but with ground water drawn across the heat exchanger and then re-injected. However, open systems' interference with natural water supplies means they are generally not encouraged.

Passive systems temper the air by passing it through a labyrinth or long pipe. This allows the heat exchange to happen, which is typically slow when the air and earth have only a relatively small difference in temperature. The problem for passive systems is that very large surface areas—typically long lengths of buried pipe—are required to achieve the heat exchange required to temper the incoming air. This means potentially large quantities of materials and earthworks are required to bury them and a fan is needed to drive them.

Use low carbon energy when available

As with the hot water service, there may be some latitude to divert excess renewable energy generation to heat and cool spaces. Although this energy may not be available in the evening when these services are most in demand, it can be stored earlier in the day to reduce the evening thermal load if combined with a high-performance building envelope and well-designed thermal mass. Central hydronic systems are particularly amenable to this approach as they come with built-in thermal mass and typically have the kind of control system that can be programmed for this purpose.

Heating costs

If standard (non GreenPower) grid electricity is the only option, gas systems may produce lower carbon emissions for the same heating service. Paying the additional tariff for certified 100% renewable electricity will reduce these carbon emissions to zero but may increase costs. It should be noted that, for medium to large systems, reverse cycle systems may be more cost effective to run than gas systems, even with the additional renewable energy tariff.

Solar thermal space heating

These systems capture solar thermal energy and move it into living spaces. A longstanding example is the 'trombe wall', a wall built on the 'winter sun' side of a building with a glass external layer and a high heat capacity internal layer, with rooftop versions emerging more recently. These passive systems tend to be bulky and produce heat only when the sun is shining but, combined with a high-performance building envelope, they can be effective. They are often a good solution where passive design cannot be optimal or as a retrofit.

Solar cooling

Active solar cooling units come in a variety of emerging technologies, including absorption and adsorption methods. The typical coefficient performance of absorption and adsorption refrigeration indicates these technologies will be hard pressed to compete with heat pumps driven by rooftop solar photovoltaic systems, but they may merit further investigation. More information can be found here.

Solar thermal/hydronic

Solar thermal hot water systems can supplement a hydronic heating system, although, as has been established, solar photovoltaic generally represents a more efficient use of available roof space and solar resource.

Summary

Passive design is the most desirable and cost-effective way to regulate internal temperatures without the need for active space heating.

Once passive design is considered, the next option for low carbon outcomes is ceiling fans.

If active heating and cooling are required, consider the zones where the service is required, the heat source such as the ground or solar thermal, and scheduling the service to use on-site renewable energy.

Potential impact:
26%
of household emissions

Appliances and lighting efficiency

Australia has an excellent energy 'star' rating scheme for appliances that gives a visual representation of emissions.

By understanding this system, as well as considering how to reduce standby loads and unnecessary energy use in lighting and appliances, households can dramatically reduce their energy usage. For a more detailed analysis, see the **Guide for Low Carbon Households**.

STRATEGIES

Lighting

There are four basic strategies based on technology and design for reducing the energy used for lighting a home.

- **Efficient bulbs** – LED lighting is fast becoming the norm for domestic lighting but it is still important to specify this with builders. The Bulb Buyer's Guide and smartphone app are excellent resources that can help when shopping.
- **Sensors, timers and dimmers** – Timers and sensors are the norm for security lighting but can also be used in other applications where

Principles:

- Behaviour has a large impact on the emissions from appliances, but design can impact behaviour. For example, a household with easy access to a clothesline will likely use a clothes dryer less often.
- Most appliances in Australia are covered by energy efficiency rating schemes, with many electrical appliances required to meet mandatory performance standards.
- Generally it is not advisable, with the possible exception of light bulbs, to change a fully functional appliance for a more efficient one solely on the basis of energy efficiency. However, by the end of a product's lifespan it should definitely be replaced with a more efficient version.
- Electrical lighting and appliances can provide a zero-carbon service when supplied from zero carbon (renewable) energy.

Photo: JBA

lights are often left on unnecessarily, such as in pantries, corridors, basements and sheds. Modern light dimmers use pulse-width modulation to reduce the power delivered to the light and so reduce energy consumption. The effectiveness of dimmers depends on the bulb technology, but they are generally well suited to LED lighting. Dimming an LED by 50% halves the light's power consumption. Lighting control systems are available as standalone systems or as part of a wider 'intelligent home' system providing remote and central control of lighting.

- **Daylighting** – brings daylight into the home through glazing design, preferably indirectly and without introducing unwanted heat. The website YourHome has more information on skylights, natural lighting and window design.

- **Appropriate lighting** – ensures that light levels are appropriate and that task lighting, such as desk lamps, is used. The NCC does not define lighting levels, other than setting maximum power allowances for artificial lighting.

Efficient appliances

In 2012, the Greenhouse and Energy Minimum Standards (GEMS) Act came into effect, enabling a framework for a variety of mechanisms to address energy efficiency in appliances. Two of the mechanisms that have been developed through this framework are:

- **Minimum Energy Performance Standards (MEPS)** – a benchmark approach that ensures appliances of a certain type demonstrate a minimum efficiency level before they can be sold in Australia and New Zealand. The MEPS system is regulatory and most consumers would be unaware that it is in place. It specifies the minimum level of energy performance that appliances, lighting and other electrical equipment must meet or exceed before they can be offered for sale or used for commercial purposes. As long as a piece of equipment has been bought in Australia, it should achieve at least the minimum efficiency required at the time of purchase for that product type.

- **Energy rating labels** – the energy efficiency star rating label is required to be attached to certain appliance types and may also be used voluntarily for other appliances. Energy Rating Labels must be shown on the following types of appliances (note that this list may change over time): air conditioners (single phase); washing machines; clothes dryers; dishwashers; televisions; refrigerators; freezers; computer monitors; and swimming pool pumps (currently by a voluntary rating scheme).

  The star benchmarks are periodically reviewed and updated, generally as an appliance type becomes more efficient on average. The general principle of 'the more stars the better' applies. Using the Energy Rating website, it is possible to research all available models of a given level of performance, making shopping for energy efficient appliances more straightforward.

Phantom or standby loads

The International Energy Agency introduced the 'One-Watt Plan' in 2005 to reduce the amount of energy used in appliances when in 'standby' mode, from the average of five watts to just one watt. Many countries, including Australia, agreed to adopt this target and a decade later the average standby load is closer to half a watt. However, this is an average figure, so appliances with high phantom loads may still be in circulation.

New appliances generally specify their standby power consumption and consumers should look for appliances with less than one-watt consumption. For existing appliances, use a power meter (low cost versions are available to purchase, or they can be borrowed from the local council library or environment centre) to assess whether there are any problem appliances in the home. If possible, these appliances should be turned off at the wall when not in use.

COMPLEMENTARY IDEAS

Central switching for non-essential loads

Systems similar to those used in hotel rooms can switch off all non-essential electrical devices from a central control point. This is typically implemented through a 'non-essential' power circuit that is part of the wiring installation. There are also wireless systems that communicate directly with individual power points or connected switches that are plugged in between the power point and the appliance. These central systems save the resident from having to check appliances individually and also reduce phantom load losses.

Control systems/intelligent homes

Technology is evolving that can provide a degree of automated control for homes. These systems rely on connectivity with appliances or, at minimum, power points. They provide an interface for controlling home systems from a central point and allow the resident to program timers or other triggers. Home systems can be automated to some degree, responding to changes in the electricity tariff or weather sensors. In some cases, algorithms can be implemented to minimise carbon emissions.

The Internet of Things (IoT) is an extension of this connected appliance concept, which may involve control of the appliance from a controller in a remote location. In all cases, the low carbon objective of the household must be clearly communicated to those implementing these systems at the design and installation phases of home construction so that programming can reflect that objective.

Summary

Lighting and appliances account for a large portion of the electricity consumption of a typical home. This can be reduced through energy efficiency—choosing devices that provide the same service with less energy consumed, and through energy conservation—finding different ways of using appliances so that fewer emissions are produced.

The advent of intelligent home management systems can support energy conservation.

More information

- Advice on buying a hot water system in Australia – CHOICE
- A university level review of hot water systems – Cornell University
- Guidance on heating and cooling systems – YourHome.gov.au
- Energy ratings schemes – EnergyRating.gov.au
- Choosing energy efficient appliances and lighting – Guide to Low Carbon Households

CSR House (Sydney, NSW)

Building product supplier CSR established CSR House in Schofields in Western Sydney in 2012 as an applied research and demonstration project aimed at improving the knowledge surrounding the choice and use of building materials in a typical family home.

The aim of CSR House is to design and build an attractive 8-Star energy efficient home as inexpensively as possible. Photo: CSR

Starting with a 6-star design, the project team focused on low carbon upgrades, thermal comfort and natural light to achieve an 8-star rating. Photo: CSR

The primary aim of CSR House was to design and build an attractive 8-Star energy efficient home as inexpensively as possible and, in doing so, identifying opportunities to optimise current building processes.

Features:

- Project team started with a 6-star NatHERS design and then carefully tracked and published upgrades to achieve 8 stars
- A focus on thermal comfort, acoustic performance and natural light as key design principles
- Common sense approaches – upgrades where additional cost and effort was of marginal value were avoided.
- Surface mounted lighting with a degree of smart control
- Use of lower carbon concrete – Holcim EcoMax™ which contains up to 65% less cement
- Minimum use of toxic Volatile Organic Compound (VOC) paints and finishes.

The house now acts as a research facility where monitoring is carried out to evaluate the building's performance. With around 140 sensors installed to measure everything from internal temperature and personal comfort, through to thermal bridging issues, the information is used to inform the building industry about ways to build more affordable high-performance homes.

NatHERS Rating
8 stars

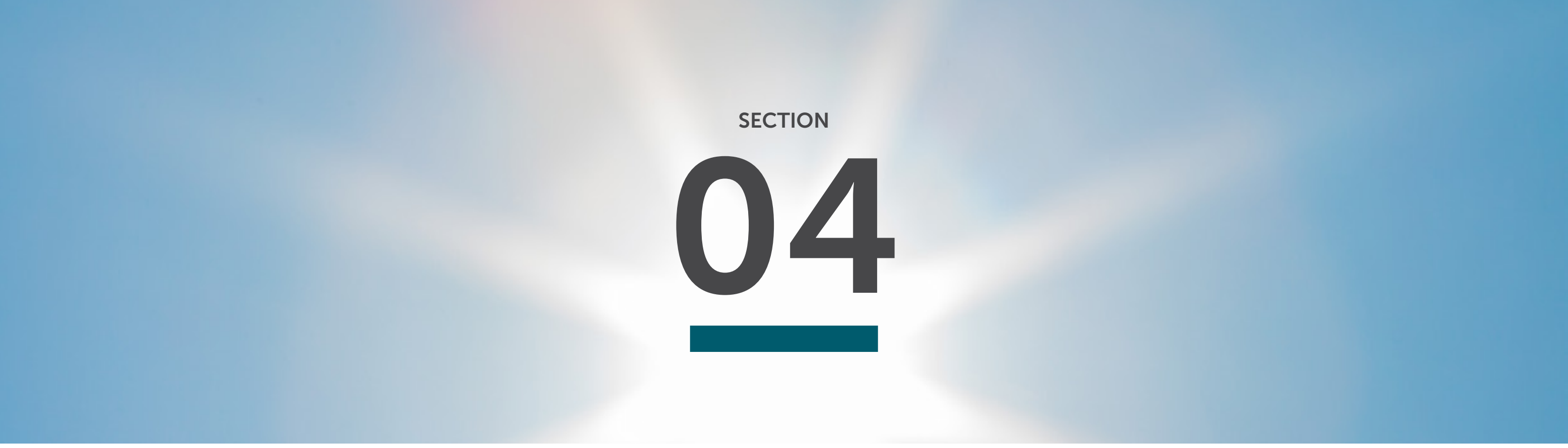
Onsite renewable energy
1.5 kW photovoltaic

Energy storage
None

Hot water
Solar hot water, gas boosted.

Rain tanks
10 kL (with auto-switching to mains back-up, connected to all garden taps, toilets and the washing machine.)

To read more go to: joshshouse.com.au/star-performers/csr-house-sydney/

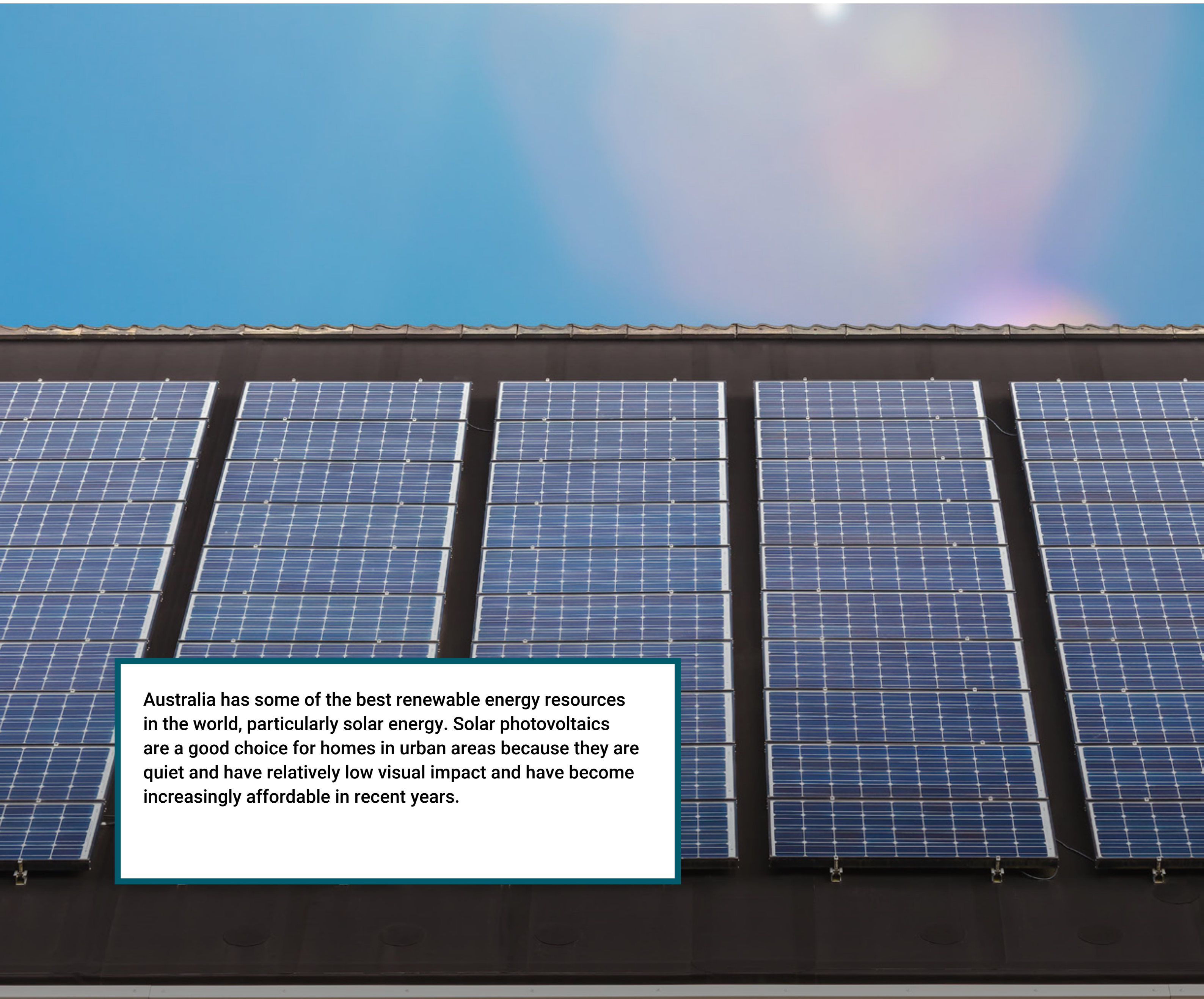


SECTION

04

Energy

Building homes with renewable energy systems in place allows them to source energy without producing carbon emissions and to play an active part in the decarbonisation of the energy system.



Australia has some of the best renewable energy resources in the world, particularly solar energy. Solar photovoltaics are a good choice for homes in urban areas because they are quiet and have relatively low visual impact and have become increasingly affordable in recent years.

Photo: JBA

Energy sources and onsite renewable energy systems

This section looks at renewable energy systems for the home and sourcing clean energy through the grid.

A range of renewable energy systems are available, some of which are more applicable to housing than others. The renewable energy systems that are recognised by the Australian Government's Clean Energy Regulator as suitable for households include:

- **Solar photovoltaic** panel systems that have a capacity of no more than 100kW and a total annual electricity output less than 250MWh.
- **Wind** systems that have a capacity of no more than 10kW and a total annual electricity output of less than 25MWh.
- **Hydro** systems that have a capacity of no more than 6.4kW and a total annual electricity output of less than 25MWh.

Solar hot water systems and air source heat pumps can also qualify as clean energy systems.

Principles:

- The best way to use renewable energy generated onsite is to meet all loads onsite.
- The choice of renewable energy systems will depend on availability and local conditions.
- Renewable energy can only be considered 'zero carbon' if all embodied emissions of the renewable energy system and equipment and any operational emissions associated with fuel, maintenance and self-consumption are offset.

Home electric vehicle charging point. Photo: Acorn Photography

STRATEGIES

In the home

There are a number of factors that drive the choice of a renewable energy system:

- **Resource availability** – Is there good solar access? Is it a good wind site? Is there a moving body of water onsite?
- **Site constraints** – Does the local government permit wind turbines? Are there heritage considerations limiting rooftop solar?
- **Network and regulatory constraints** – If the renewable system is connected to the grid, what approvals are required and what restrictions exist?
- **Budget** – What can I afford and what is a rational choice for my system? How do the financials of my system compare to other things I could do with my money?
- **Objectives** – Is the aim to create a 'zero energy home' (ZEH) that produces more energy than it uses, or to go 'off-grid'?

The grid

The electricity grid is an interconnected network for electricity supply. Conductors, generally copper wires, connect sources of energy like gas turbine generators, coal fired power stations, hydro power generators and on-grid battery systems with households, commercial buildings, street lights and anything else that depends on electricity. The grid is carefully managed by the network manager, or utility, and there will be strict requirements on any equipment that is connected to it, particularly generation equipment. This is why if your home energy system is connected to the grid it must meet various requirements and be approved for connection by the network manager. Grid electricity has become less carbon intensive over recent years because of the Renewable Energy Target (RET), which covers most electricity suppliers, and because of home renewable energy systems feeding in their excess generation.

The carbon intensity of each state electricity grid is published annually as the 'Grid Factors' in the National Greenhouse Accounts Factors by the Australian Government's Department of the Environment and Energy. (See table 41 in the 2017 edition.) Grid-supplied electricity can also be zero carbon, although this usually comes with an inflated tariff. Learn more about certified Greenpower.

Solar photovoltaic systems

The photovoltaic (PV) effect was first demonstrated in 1839 and describes the ability of certain materials to develop a voltage, which can drive an electric current, when exposed to photons of light. The technology was developed over the last century for use in powering long-life remote equipment, including in satellites and space exploration. Modern domestic PV systems have the same virtues of a long operational life and very low maintenance. The major innovations in the technology for domestic use have been in production systems, improved availability and reduced prices, and to a lesser extent in efficiency, with average efficiency improving over the last decade from around 12% to around 17%. Estimating how much electricity a given PV system will generate over a typical year will assist in understanding the financial value of the system and how it will help meet the objectives set for the project. This estimation can be done by the PV supplier and will be based on one of the following approaches:

- **Modelling**: there are many modelling platforms that provide various levels of detail. For simple systems without shading issues, PVWatts is a simple-to-use online tool from the American National Renewable Energy Laboratory (NREL). More complex scenarios can be modelled using software tools such as the Swiss-based PVsyst.
- **Deeming**: The Clean Energy Regulator uses a deemed rate determined by location to award renewable energy certificates. The deeming rate is conservative to account for systems that may be installed in sub-optimal conditions. The Clean Energy Regulator provides a postcode based list of deeming rates and a calculator. The Australian PV Institute has developed a tool that incorporates 3D information to assess PV potential of sites in Australia.

Wind systems

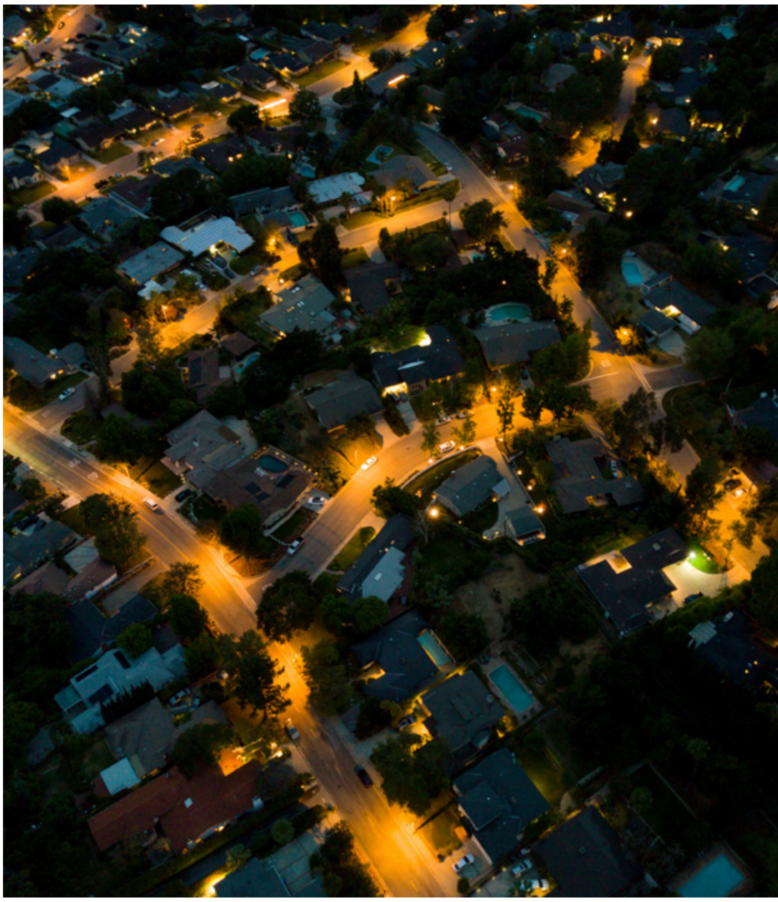
Small wind turbines can be installed in urban settings subject to local government approval. A wind turbine rated less than 10kW will typically have blades spinning at high speed to produce energy. This high-speed operation can lead to wearing and fatigue of mechanical parts. However, if a suitable maintenance regime is in place, small wind turbines may provide a good value solution for sites with regular access to wind at speeds in excess of five metres per second. The Australian Renewable Energy Agency maintains a national map that helps Australian sites pre-assess the viability of wind systems

Hydro systems

Systems that extract power from moving water, without requiring a dam, are generally referred to as 'micro-hydro'. To qualify for the Australian Government's Clean Energy Regulator scheme, micro-hydro systems need to be rated at less than 6.4kW. Because they are rare in Australia and almost non-existent in urban settings, they are not addressed in detail in this Guide. However, this does not mean they are irrelevant to low carbon housing and there may be increased use of these systems in the future. Owner builders and developers who think they may have an opportunity for a micro-hydro system should contact a supplier for an assessment.

Distributed energy storage systems (DESS)

In a home energy context, the DESS is generally a device that stores electricity from onsite generation



and makes it available to meet onsite loads. Technologies vary and include lead-acid and lithium ion batteries and, less commonly, salt water batteries, flow batteries, capacitors and flywheels.

A DESS will not increase the amount of renewable energy produced, but can increase the amount that is used onsite, rather than exported to the grid. The financial value of these systems is therefore based on the difference between the cost of imported grid electricity and the value of renewable energy exported from the site. If this difference is small, or negative, then it may be better to use the grid as a 'virtual storage system' by exporting all excess generation and importing electricity when required. Note that if you are pursuing a formal carbon neutral status, certified Greenpower imports are required, or an alternative offsetting method used.

COMPLEMENTARY IDEAS

Load shifting and dispatchable loads

Simple devices can be installed to direct excess onsite electricity production to meet onsite loads that are 'dispatchable', that is, not time-critical. An example is water heating; as long as the heating unit meets its set-point temperature each day and provides hot water when required, it doesn't matter when it heats the water in the tank. Electric vehicle charging and washing machines are other examples. The provision of energy to dispatchable loads is made possible through:

- **Diverters**: These are sometimes referred to as 'Hot Water Diverters', because that was their original use. Excess PV electricity can be diverted to the hot water system rather than being exported to the grid, reducing the need to import grid electricity.
- **Timers**: A simple timer can achieve a similar outcome to a diverter by enabling the dispatchable load circuit, such as the hot water system circuit, at a time of day when PV electricity production is highest and other loads are low—early to mid-afternoon for most family homes. This will generally reduce imports from the grid but needs to be monitored to make sure that the programmed time of day is right for the particular home.
- **Control systems**: These are 'intelligent' versions of diverters/timers that can communicate with the load controller—the EV charging point controller for example—to determine the best time to provide service and at the same time maximise the use of renewable energy onsite. Integrated versions of this control approach go further to coordinate multiple loads and multiple sources of energy, including batteries, to achieve an overarching outcome such as lowest cost, or lowest emissions.

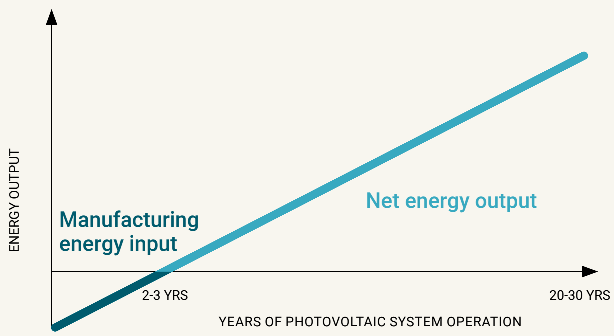
Embodied emissions

The renewable energy systems discussed here are made from high carbon intensity materials such as steel, aluminium, glass and plastic. Although offsetting the embodied emissions at purchase is the most thorough response, it is also possible to use exports from grid-connected renewable energy systems to offset the embodied emissions of the system.

Energy payback

In the case of PV systems, there has been much discussion about the 'energy payback time' – the time that it takes for systems to have produced as much

PV system energy payback chart



Source: reneweconomy.com.au

energy as was consumed in its manufacture and lifecycle emissions to point of installation. Studies suggest this is around 2–3 years for systems in Australia.

The chart (above), from UNSW researcher Dr Muriel Watt, shows the average energy payback time based on a number of studies of mainstream PV systems.

Materials in PV panels

PV modules and other components include some exotic metals, sometimes including heavy metals such as cadmium and lead, generally in trace amounts. There is a vast amount of waste PV material globally and Australia's PV waste stream is growing. The recommended response is aligned to the classical waste materials hierarchy:

- **Reduce** – Minimising the need to replace systems prematurely is crucial. The PV module generally has a long life, with modules producing useful amounts of power after 50 years or more, and so providing long-term value for the material consumed. Ensuring that the system is well designed and located and can meet all anticipated loads will mean that it remains useful and is retained over its design life.
- **Reuse**– Finding opportunities to re-deploy modules and systems can be difficult but the off-grid market can provide an opportunity. A second-hand market exists in this space.
- **Recycle** – Recycling PV modules is a growth industry. An example is Reclaim PV Recycling, which reclaims good condition individual cells from salvaged PV modules.

Summary

Renewable energy systems are highly viable at the domestic scale, with technical and financial factors improving dramatically over the last decade to the point that the majority, if not all, of a home's energy needs can be produced onsite from renewable sources.

The increased availability of certified green energy means that even homes that cannot install their own renewable energy systems can choose zero carbon energy sources.

Attention to a home's passive solar design, its thermal performance, internal thermal mass, landscaping, and its fittings and operation ensures the best use of available renewable energy supplies while providing better levels of comfort throughout the year.

Potential impact: up to **76%** of household emissions

Monitoring and management systems

Providing households with information on their resource consumption often leads to reductions, even without any other strategies in place. The move to 'intelligent homes' with control systems that help manage energy use takes this concept to the next level.

This section looks at the benefit of installing monitoring systems to help households reduce energy demand. The focus is on energy monitoring but similar monitoring of water can have an impact on carbon emissions. Devices include smart meters, dashboard displays, home automation, and network management schemes.

Control systems should provide a level of visibility to residents so they can interrogate how the system is operating without a high level of technical understanding.

Principles:

- The addition of monitoring and control systems to a home should result in improved amenity and reduced energy consumption, GHG emissions, and cost.
- Monitoring systems that require users to go to a specified location, usually online, to check performance are useful diagnostic tools if there is a problem, or to review performance when considering a change or upgrade.
- Monitoring systems that 'push' information to residents through alerts on smart devices or a visible presence in the home are most effective at driving behaviour change.
- Incorrectly installed control equipment can result in large energy costs.
- Privacy and ownership of household data are important principles. Where a system is connected to the internet or other external network, the supplier should provide assurances around how these principles are managed.

STRATEGIES

Clamp on metering

The simplest monitoring uses 'current transducers' (CTs) that can be clamped around the cables in the meter box to monitor energy flows and usage without major electrical works.

Smart meters

Utility meters that provide some level of communication about energy flows are known as 'smart meters'. They are often an additional meter hardwired into the home electrical system to collect and transmit data.

Individual loads

Individual circuits or meters can be installed for particular loads, such as the hot water system, allowing households to monitor specific energy use separately. Plug-in appliance loads can be monitored using a 'smart socket' system (either a plug-in unit that connects between the power point and the plug of the appliance, communicating data wirelessly), or a hard-wired system that includes a monitoring device built into power points around the home, communicating wirelessly or through the home network.

Interface

An online dashboard is a simple way of making monitoring information available and will usually enable a level of storage of data and analysis. An in-home unit could be a wall-mounted screen that tells residents how the home is performing and alerting them to any possible problems. Or it could be as simple as a light that changes colour as energy use intensifies, alerting residents to the need to limit the use of power-hungry appliances.

Control systems

Automation in the modern home enables systems to function correctly and to schedule actions through a calendar and timers. They include: building elements that improve passive performance such as motorised controllers for blinds (internal and external), awnings, windows, vents and fans; and controls for appliances such as heaters, air-conditioners, hot water systems, battery storage, washing machines, driers and lighting. Control systems receive information from sensors in the home such as thermometers, light level sensors, and motion detectors, and are able to adjust systems to match occupant activity.

Network operator control signals

In some locations, the network operator can send a signal to a house's utility meter, enabling the dwelling to take advantage of different tariffs by automatically activating dispatchable loads at lower cost. Although not inherently a low carbon option, these systems could be a useful part of optimising grids with high levels of renewable energy penetration, supporting the decarbonising of the economy.

COMPLEMENTARY IDEAS

Consider sharing household data with researchers. There are many research projects that rely on 'real world' data on how people use their homes. These projects lead to advances in understanding of how to achieve low carbon outcomes in housing, and can multiply the benefits achieved on individual projects.

Summary

The trend towards automation appears inevitable in housing as in other building types. Commercial offices now have standard integrated control systems capable of some level of optimisation.

To make these systems a success in the home, they need to be carefully commissioned and installed and regularly evaluated.

Monitoring systems provide valuable information and can empower residents to take more control of their energy use. Behavioural change has modest impacts but the improved level of engagement with home energy use may lead to informed investment in systems that do make a dramatic difference.

More information

- PVWatts is a simple yet powerful online calculator that will estimate PV system performance for a particular location
- The Australian PV Institute has developed a tool that incorporates 3D information to assess PV potential of sites in Australia
- The Australian Renewable Energy mapping Infrastructure service has an open access online wind atlas
- The Alternative Technology Association, now known as Renew, did a study comparing gas to electricity for water and space heating, finding that electricity is the better financial option in almost all scenarios
- The One-Watt Program for reducing phantom loads

Z–Range Display Home (Melbourne, Victoria)

The Z-Range Display Home by SJD Homes in the satellite suburb of Officer, south east of Melbourne, was developed as part of a national research project undertaken by the CRCLCL to better understand the cost implications of high-performance features in the volume housing market.

Above and below: The home was designed to meet or exceed its net operational energy requirements through onsite solar PV generation and power monitoring and assessment. Photos: SJD Homes

Completed in 2018, the four-bedroom, two-bathroom house was designed as a Net Zero Energy Home (ZEH), that is, designed to meet or exceed its net operational energy requirements through onsite solar PV generation over the year, assuming typical occupancy.

Costings provided by the builder for the upgrades that were needed to meet this performance benchmark had a seven-year payback period based on an estimated savings of $2,588 on energy bills per annum.

Features:

- North facing living areas with generous solar access for winter warming
- Optimised building envelope design specific for the Victorian climate
- High efficiency reverse cycle heating and cooling system
- High efficiency heat pump water system
- Energy efficient appliances and lighting
- Integrated energy management and monitoring system
- No gas.

As well as being an active display home for SJD Homes, visitor surveys are being conducted to gain insights into market interest in high performance housing. The house also serves as a demonstration site for the New Home Energy Advisory Service program run by the South East Councils Climate Change Alliance (SECCCA) in partnership with Sustainability Victoria.

To read more go to: joshshouse.com.au

The home was designed to be north facing with generous solar access for winter warming. Photo: SJD Homes

NatHERS Rating
7.3 stars

Onsite renewable energy
5 kW photovoltaic

Energy storage
10 kWh (lithium-based battery system)

Hot water
Heat Pump

Rain tanks
None. Lot serviced by district recycled water scheme.

SECTION

05

Water

Water is a valuable—and increasingly scarce—natural resource and its efficient use in residential developments is a key factor in urban sustainability. The adoption of water sensitive urban design reduces embodied emissions associated with water pumping and wastewater treatment and helps households conserve supplies.

Photo: Joel Barbitta

Potential impact:
4%
of household emissions

Water systems

Pumping water to the home and garden, and disposing and treating wastewater, results in energy consumption and therefore GHG emissions.

Wastewater treatment operations, in particular, are among the most energy intensive activities carried out in our cities. This section looks at the many strategies to reduce water consumption and improve the way water is distributed inside and outside the home through water-efficient appliances, stormwater management, good garden design, climate appropriate irrigation and alternative water sources.

Principles:

- Mains water (and precinct or district alternate water sources) come with embodied GHG emissions that should be reported on the operational carbon account.
- Reductions in mains water consumption decreases the energy required to treat and transfer water to the home and reduces the amount of wastewater requiring disposal and treatment.
- Water efficiency inside and outside the home is encouraged via water-efficient fixtures/appliances/irrigation/garden design.
- Identifying alternative water sources reduces mains water consumption.
- Onsite water systems may increase energy use, so this should be taken into account when sizing renewable energy systems.
- Smart meter monitoring and feedback of water use can assist in behaviour change and improved efficiency of irrigation systems.
- Higher levels of water use may be required for home grown fruits and vegetables, but this is offset by the low carbon footprint of locally produced and consumed food.

STRATEGIES

Outdoor water use

Water consumption in the garden can be reduced by mulching and soil improvement practices, planting dry climate species and applying the principles of hydrozoning–the planting of species with similar water and maintenance requirements in groups with their own controller stations that deliver appropriate amounts of water. Newly landscaped areas with hydrozoning require irrigation during plant establishment phases and then only in extended hot and dry periods.

Efficient irrigation

Automatic irrigation systems should include evapotranspiration sensors, soil moisture sensors and rain sensors to ensure climate responsiveness. Water efficiency measures such as the installation of in-line drip irrigation and the use of spray irrigation for turf areas will reduce water-related energy demand.

Swimming pool evaporation

Accredited covers over swimming pools and spas reduces water evaporation.

Alternative water sources

Subject to local regulations, rainwater and greywater used outside the home decreases the consumption of mains water and associated energy requirements. In most locations, rainwater can also be used inside dwellings for toilet flushing and washing machines.

On-site management of stormwater

Water sensitive urban design principles incorporated into landscape and garden design, permeable paving and the retention of existing vegetation helps to restore the local water balance, retain soil moisture and reduces mains water consumption.

Water efficient appliances

Efficient water heating systems and appliances such as toilets, taps, shower heads, washing machines and dishwashers substantially reduce greenhouse gas emissions by reducing the energy required to treat and transfer mains water to households. Better water efficiency in households also acts as an offset to the increasing use of desalination in mains supplies, which has a higher energy demand.

Waterless toilets

The composting toilet is an onsite alternative to centralised sewage systems that uses minimum energy and generally no water. Simple passive designs can make waterless toilets easier and cheap to build, monitor and maintain. Typically, composting toilets are only permissible in unsewered areas on large blocks and require local government approval.

Efficient plumbing

Planning your room configuration to ensure kitchen, bathroom, toilet and laundry are located close together and in close proximity to your hot water system reduces heat loss through pipes and water wastage from having to run cold water sitting in the pipe while waiting for hot water to arrive. Insulation of pipes (lagging) also assists to reduce heat loss from water on the way to the tap.

COMPLEMENTARY IDEAS

Performance monitoring

Smart metering can demonstrate water use and opportunities for savings for both mains water and alternative water sources (e.g. rainwater) in 'real time' and provide feedback on equipment performance or water supply issues. Collection and dissemination of data is useful for behaviour change and industry/research knowledge sharing, particularly if there is access to a user-friendly web interface.

Summary

Using less water reduces carbon emissions in the residential context by reducing the energy required to pump mains water and to treat and dispose of wastewater.

Alternative water sources, such as onsite rain and greywater collection systems, can help to save water used from the mains, but can increase energy use onsite, so consider this when sizing renewable energy systems.

Swimming pools and spas

One in every ten Australian homes has a pool, but residents are often unaware of how much energy their pool consumes.

Pool pumps are the second biggest user of electricity in Australian homes after hot water systems, and pools are responsible for around half a percent of Australia's total annual greenhouse gas emissions, or about three megatonnes of carbon, each year.

Swimming pools are a mainstay of Australian suburban culture. Keeping them full of clean, comfortable temperature water consumes both water and energy. Some simple considerations when installing a pool will make a dramatic difference to its ongoing energy and water use and resulting carbon emissions.

Principles:

- A swimming pool will consume energy and water but a relatively small investment in improved equipment can reduce impacts.
- Correct pump sizing is important for energy efficiency.
- Pool pump motors are often more powerful, run longer and much faster than required.
- Reduced carbon emissions related to operating a swimming pool can be achieved with no negative impact on water quality.
- Although pools emit gases, often with a chlorine odour, these need not be considered in the carbon account of the swimming pool.

This Guide addresses pools that typically serve one or a few residences, using water that is heated, filtered and treated with chlorine, salt or similar and that have a circulation pump and a cleaning system. There may be alternative ways of managing a home swimming pool not covered here, such as natural swimming pools–also known as swimming ponds or bio pools–for which some of the advice here may not apply.

The strategies here can reduce GHG emissions from pool hot water systems as well as utility GHG emissions that result from supplying water.

STRATEGIES

Pump sizing

Avoid the tendency to oversize pool pumps to ensure capacity to achieve good water quality. This oversizing is frequently out of proportion and results in much higher than necessary electricity consumption. A correctly sized pool pump allows the filter and treatment system to achieve good water quality, without wasting energy. A professional who has been advised that you don't want to waste energy should be engaged to size the pump.

Pool heating pump speed

Installing a variable speed pump capable of operating at lower speeds and correctly tuning throttle valves can dramatically reduce energy use and still lead to a 250% increase in water heat. The chart (below left) illustrates the results of a CRCLCL research project on this topic:

Pool blanket

An insulated pool blanket reduces heat loss as well as evaporation. Electrically driven, hidden pool blankets are more cost effective to install when the pool is being constructed and will lead to more effective use of the blanket.

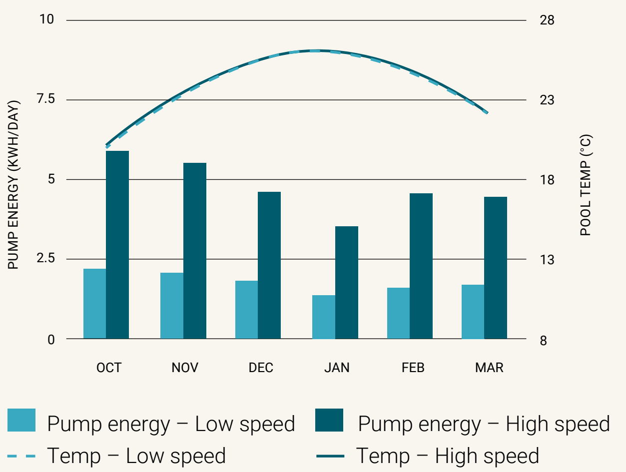
Pool heat sources

The energy source options for heating pool water parallel those for domestic hot water, including heat pump, gas, and solar thermal. Pool systems can be simpler, and potentially more efficient, because the temperature change required is typically less than that required by domestic hot water.

Filtration and cleaning

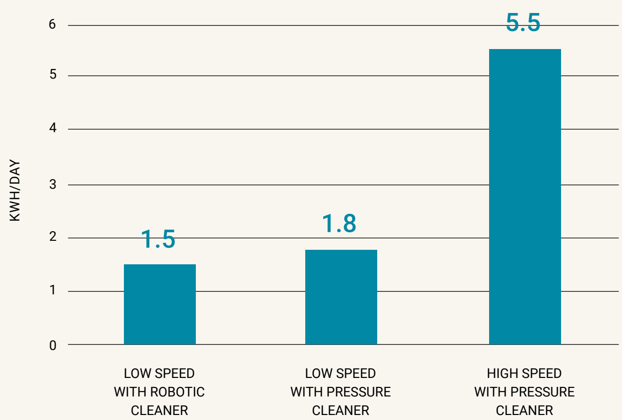
A robotic cleaner is the most efficient way to clean a pool, in terms of electricity consumption, because it reduces the energy required to run the circulation pump. The following chart from a CRC LCL research project illustrates the reduction:

Pool heating pump speed



Source: Sproul A, Zhao J (2017) CRCLCL Project RP1014: Fact sheet.

Filtration and cleaning



COMPLEMENTARY IDEAS

Swimming pool heating and cleaning may be considered a dispatchable load and so part of a strategy to optimise renewable energy use on site. Investigate the control system requirements to link swimming pool equipment to the house's renewable energy system prior to pool system selection.

Summary

Reductions in energy consumption of over 50% are possible with relatively affordable upgrades to the basic pool equipment.

No compromise on water quality is necessary to achieve these reductions.

Reducing evaporation from a pool further reduces the overall carbon emissions from the pool's operation.

More information

- YourHome has more information on water efficiency measures
- Josh's House Greywater factsheet
- Josh's House Integrated Water Systems factsheet
- Energy rating for pool pumps – Currently the rating scheme is voluntary only

Above: The home includes climate-sensible design features suited to the local tropical climate. Photo: Darren Finlay
Below: Excellent air movement is achieved through natural breeze-ways, ceiling fans, and roof and eave vents. Photos: Darren Finlay, VAM Media

Innovation House (Northern Queensland)

Innovation House by Finlay Homes is the first 10 Star NatHERS rated home in northern Queensland. The project was driven by second generation builder Darren Finlay in response to a growing market interest in high performance housing and his frustrations with the lack of information and built examples available.

Timber framed construction and lightweight materials reduce embodied emissions. Photo: VAM Media

Located in the Townsville suburb of Mount Low, the three-bedroom, two-bathroom, single-storey dwelling initially served as a display house to showcase the project to the public.

In addition to the climate-sensible design features suited to the local tropical climate, the home includes a number of energy and water efficiency features, as well as grid-integrated solar generation and battery storage to minimise demand on the grid and improve energy resilience.

Features:

- Orientation of indoor and outdoor living areas to optimise natural light and ventilation
- 900mm eave shading to all walls, high R-value insulation throughout, excellent air movement and ventilation via natural breeze-ways and openings, ceiling fans, roof and eave vents for heat purging
- Ceiling fans installed throughout the home, including all living areas and bedrooms
- LED lighting throughout, and ultra-sonic motion sensors outdoors and in walk-in-robes
- Greywater reuse system (laundry only)
- Timber framed construction and lightweight materials to reduce embodied emissions (concrete block is the industry standard in Townsville).
- Reused/recycled materials for landscaping.

Data is collected across a range of parameters including thermal performance, energy and water use to enable a comparison to be made with local averages.

To read more go to: joshshouse.com.au

NatHERS Rating
10 stars

Onsite renewable energy
5 kW photovoltaic

Energy storage
10 kWh (lead acid battery system designed as an emergency back-up uninterrupted power supply (UPS) due to cyclone prone location)

Hot water
Heat Pump

Rain tanks
25 kL (with auto-switching to mains back-up, connected to garden taps and toilets)

SECTION

06

Occupancy and the operational phase

The way we use our homes and the behaviours we encourage within them can contribute significantly to our carbon footprint. Good housing design can support low carbon lifestyles by helping occupants to make low carbon choices daily.

This section covers the emissions related to the occupancy phase of a home and the ways in which housing design can support lower carbon lifestyles. Key strategies lead to changes in behaviour regarding energy use, operational waste management and transport considerations. For more detailed information on how to run a low carbon household, see the Guide to Low Carbon Households.

Behaviour and lifestyle

Good house design can help occupants make the right decisions every day that reduce energy use and carbon emissions.

STRATEGIES

Information – see 'Monitoring and Management' in Section 4 of this Guide for information on gathering and communicating data on a house's performance for the purpose of identifying opportunities to reduce energy use and GHG emissions. More detailed information on how to reduce energy use can be found in the **Guide to Low Carbon Households**.

Education – Consider providing all residents with access to a local sustainable living course. These are provided through local councils and environment centres.

Principles:

- Providing information to residents on their energy consumption and carbon emissions can empower them to make behavioural and other changes as they see fit.
- Consider the design of the home so that barriers to low carbon choices are minimised.

Operational waste management

Waste can be managed in kitchens, bin storage areas, and in gardens that encourage local food production.

STRATEGIES

Reduce waste production by providing kitchen and pantry spaces that encourage cooking with raw food and enable occupants to buy food in bulk rather than depending on small packets bought frequently. Productive gardens reduce the amount of shop-bought food.

Reuse can be encouraged, again by ample pantry space to store containers and other used items.

Recycling rates can be improved by 'separation at source'. In most cases, some level of separation of waste streams is encouraged prior to municipal collection. Provide well-designed bin storage that encourages conscious use of the recycling system.

Principles:

- The reduce–reuse–recycle waste strategy applies and should be supported by the home design
- Understand local options for separation of waste and reprocessing/recycling

Transport emissions

While not formally part of a new house's carbon footprint, occupants' transport-associated GHG emissions can be influenced by new home design.

For example, around 80 per cent of electric vehicle recharges can be done at home, and how easily a house caters for active transport like cycling will have an impact on occupant behaviours.

STRATEGIES

Active transport – Consider bicycle use as a fundamental aspect of housing design. Where will they be stored, maintained, and how are they wheeled to the street and back? Allow for at least one bike per occupant. Anticipate the growth in use of 'eBikes' by ensuring there is a dedicated power point available at the bike storage location.

Electric vehicles (EVs) – If there is a car bay or garage, ensure that a dedicated charging circuit is run to that location. The charging point itself can be installed to match the particular electric vehicle chosen but installing a circuit to the highest practical amp rating at the construction stage will make the process more cost effective. Consider circuits of at least 16 amps for this purpose, and up to 40 amps if practical, based on advice from an electrician or engineer.

Car share – Investigate car share services in the area as a viable option. A share system makes better use of the embodied emissions of an individual vehicle than single ownership vehicle, is increasingly likely to be electric powered with fast charging onsite, and frees up space at the home for other purposes such as more greenspace or a secondary dwelling.

Principles:

- Encourage active transport options – walking and cycling
- Support low carbon vehicle options, such as electric vehicles charged from low carbon electricity
- Not all homes can have excellent public transport access, but the daily commute should be factored into site selection.

Appendix – CRCLCL supporting research

Following is a list of relevant CRCLCL research projects that are the source for the much of the information contained in each section of this Guide.

Section 01 Getting started

BASIX Outcomes and Possible Modifications – This review of the BASIX tool, used in NSW as part of the approvals process, includes projects covering post-occupancy investigations of new residential buildings in NSW that compare BASIX modelled results to real-life data. The study identifies areas for improvement of the model; establishes the links between government regulations, design options and post-occupancy behaviour; and informs future sustainability strategies and policy.

http://builtbetter.org/node/2696

Frameworks for High Performance Housing – This report provides an overview of NatHERS and BASIX, and introduces two emerging sustainability tools (eTool LCA and ARCActive). A high-performance housing Case Study is provided to demonstrate how these tools and frameworks can be applied.

http://builtbetter.org/node/3906

Section 02 Building and landscape

Fact Sheet: Integrated Carbon Metrics - A Multi-Scale Lifecycle Approach for the Built Environment
The Integrated Carbon Metrics (ICM) project is building knowledge about both the direct and indirect carbon emissions in the building process, to better inform those making decisions about our future built environment.

http://www.lowcarbonlivingcrc.com.au/research/program-2-low-carbon-precincts/rp2007-integrated-carbon-metrics-%E2%80%93-multi-scale-life-cycle

Cool Roof Technology – This project looked at how to make a roof cooler than the air temperature around it, even under the most intense summer conditions.

Urban Micro-climates – http://builtbetter.org/node/2550

Admittance and Thermal Mass – To get a deeper understanding of thermal mass design, and how it needs to combine with insulation and other considerations, this deep dive into the science of periodic heat flows may be of interest.

Monitoring and verification of performance of new and retrofitted low carbon buildings – https://www.sciencedirect.com/science/article/pii/S1877705817316958

Landscape and Urban Cooling – Landscape design features as a key strategy in reducing the urban heat island effect

http://builtbetter.org/node/3583

Measuring the Thermal Performance of Landscape and Gardens – The CRCLCL has been looking at ways of assessing the impact of landscape on heat, energy, and greenhouse gas emissions. There is strong interest in an evidence base for including these impacts in energy modelling for future compliance requirements in the construction sector.

Rating the thermal performance of a residential landscape – http://builtbetter.org/node/3911

Low Carbon Concrete is Possible – Concrete is the second most-used material after water and the production of cement is responsible for between 5 and 8 per cent of global carbon dioxide emissions. The development of low-carbon concrete is pursued worldwide to help the construction industry make its contribution to decarbonising the built environment.

Pathways for overcoming barriers to implementation of low CO2 concrete – http://builtbetter.org/node/2677

Integrated carbon metrics – http://builtbetter.org/node/3194

Other Research into Embodied Emissions – The CRCLCL devoted an entire research pathway to this topic. There are a number of papers available on a range of subjects related to materials and embodied emissions.

http://www.lowcarbonlivingcrc.com.au/research/program-1-integrated-building-systems/impact-pathway-2-lowering-embedded-carbon-buildings

Real World Verification of a Housing LCA – This research monitored ten energy efficient Australian houses and recorded data about energy use and photovoltaic generation over one year. The houses were assessed with a relatively new LCA tool in addition to the Australian mandatory house energy assessment Nationwide House Energy Rating Scheme (NatHERS).

https://www.rees-journal.org/articles/rees/abs/2017/01/rees170017s/rees170017s.html

Section 03 Services

How a Hot Water System is Used Can Affect its Performance – Actual performance of solar thermal systems depends on quality of installation and on usage. Solar thermal systems may be performing below optimum from a carbon and energy point of view in many cases because they are being boosted to too high a temperature, too often. The times of day that people use hot water may not be well matched to the best times of day to harvest solar thermal energy.

Lochiel Park - The actual performance of solar water heaters – http://www.lowcarbonlivingcrc.com.au/research/program-3-engaged-communities/rp3017-adelaide-living-laboratory-hub

Ways of Using the Sun for Cooling – Although the technology examined in this investigation is not ready for domestic application, it may be of interest to see what is happening at the cutting edge of heating and cooling systems.

Concentrated Solar Thermal Systems and Absorption HVAC Systems – http://www.lowcarbonlivingcrc.com.au/research/program-1-integrated-building-systems/rp1002-concentrated-solar-thermal-systems-and

Low Energy Lighting – Comparing technologies and benefit of low energy lights: they work! RP3017 Lochiel Park - Does energy efficient lighting result in lower energy use? The evidence from a near zero energy housing development.

https://www.unisa.edu.au/lochiel-park

Section 04 Energy

Analysis for PV and Battery Sizing – This paper uses CRCLCL work at Lochiel Park, SA, as a basis for an algorithm to size PV/battery combinations.

Lochiel Park - analysis of PV and potential for batteries – http://search.ror.unisa.edu.au/record/UNISA_ALMA51147057490001831/media/digital/open/9916138185201831/12147057430001831/13147057420001831/pdf

Distributed Energy Storage Systems – A scoping study to better understand the key issues, challenges and opportunities for distributed energy storage within Australia.

Distributed Energy Storage – http://www.lowcarbonlivingcrc.com.au/sites/all/files/publications_file_attachments/rp1013_scoping_study_issues_paper_2016.pdf

An in-depth study of a storage system installed at the CRCLCL Living Laboratory project 'Josh's House' in Fremantle in WA revealed some surprising outcomes and indicated some important considerations for the rollout of home energy storage systems.

'Josh's Battery – a more even relationship with the grid' – https://www.rees-journal.org/articles/rees/full_html/2017/01/rees170016s/rees170016s.html

Understanding and Predicting Home Energy Consumption and Production – Algorithms for a customer-focused software solution that interprets energy supply and demand at the system level (focusing on residential, but applicable also to small commercial). Interpreting the complex relationship between cost, supply and load along with accurate data and analytics enables end users to proactively manage demand. The algorithms will take local load, weather and energy generation inputs and automate the analysis of the electricity production and consumption.

Forecasting and home energy analysis in residential energy management solutions – http://www.lowcarbonlivingcrc.com.au/research/program-1-integrated-building-systems/rp1023-forecasting-and-home-energy-analysis

Monitoring Systems Overview – This report provides an introduction to the automated monitoring of residential buildings for the purpose of data collection for research purposes and end user feedback, but it is also a great introduction to the topic in general.

http://builtbetter.org/node/3905

Section 05 Water

The Energy in Wastewater Treatment: Wastewater treatment operations have high levels of associated greenhouse gas (GHG) emissions. This renders current wastewater practices unsustainable and optimisation is needed to reduce the impact of operations and to enable the industry to achieve strategic energy and carbon neutrality goals.

Fact Sheet: Reducing the energy intensity and carbon emissions of waste water treatment – http://www.lowcarbonlivingcrc.com.au/research/program-2-low-carbon-precincts/rp2017-energy-benchmarking-efficient-low-carbon-water

Lower Bills and Less Energy: For heating and filtration, relatively minor upgrades translate to real dollar savings, and pool owners can still enjoy acceptable pool thermal conditions and excellent water quality.

Impact of Energy Efficient Pool Pumps – http://www.lowcarbonlivingcrc.com.au/research/program-1-integrated-building-systems/rp1014-impact-energy-efficient-pool-pumps-peak-demand

Minimising Your Pool's Energy Consumption: Pool pump motors are often more powerful and run longer and much faster than required.

Fact Sheet: Minimising Your Pool's Energy Consumption – http://www.lowcarbonlivingcrc.com.au/research/program-1-integrated-building-systems/rp1014-impact-energy-efficient-pool-pumps-peak-demand

Adopting a suite of integrated water saving initiatives will maximise household mains water efficiency, as well as reducing impacts on water cycle infrastructure and ecosystems:

Byrne, J. Green, M. & Dallas, S. (2018). *WSUD Implementation in a Precinct Residential Development: Perth Case Study*. Book chapter edited by Sharma, A. Begbie, D. & Gardner, T. Approaches to Water Sensitive Urban Design. Elsevier, UK.

Coombes, P.J., Smit, M., Byrne, J. & Walsh, C.J. (2016). *Water resources, stormwater and waterway benefits of water conservation measures for Australian capital cities*. In Proceedings of Conference: Stormwater2016, Stormwater Australia

Smart metering and behavioural changes:

Fielding, K.S., Spinks, A., Russell, S., McCrea, R., Stewart, R., & Gardner, J. (2013). *An 895 experimental test of voluntary strategies to promote urban water demand 896 management*. Journal of Environmental Management, 114(1), 343-351.

A review of the effectiveness of technologies for water usage feedback:

Sonderlund, A.L., Smith, J.R., Hutton, C.J., Kapelan, Z., Savic, D. (2016) *Effectiveness of smart meter-based consumption feedback in curbing household water use: Knowns and unknowns*. Journal of Water Resources Planing and Management 142, 04016060.

Section 06 Occupancy: the operational phase

Opportunities for Education and Capacity Building: The CRCLCL conducted research, interviews, and a survey to identify opportunities to bring a wider understanding of low carbon living.

Education for Low Carbon Living Final Report – http://builtbetter.org/node/2724

Behaviour Change Tools Tested: This research used an explanatory design mixed method approach to investigate the energy and water use in eight homes over a two-year period, before and after an intervention based on persuasive behaviour change.

Ten House Living Lab Study – https://www.sciencedirect.com/science/article/pii/S0378778817329882?via%3Dihub

Reduce Emissions and Make Food a Circular Economy: Currently, we divert much of our inedible food waste to landfill which releases around 9 million tonnes of CO2-e p.a. Through composting this organic matter and using that compost to help grow food, there is an opportunity to improve crop production and to reduce landfill and GHG emissions.

CO2 Reduction and Food Production from Household and Commercial Food Waste: Composting for Different Urban Forms – http://www.lowcarbonlivingcrc.com.au/research/program-2-low-carbon-precincts/rp2019-co2-reduction-and-food-production-household-and

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