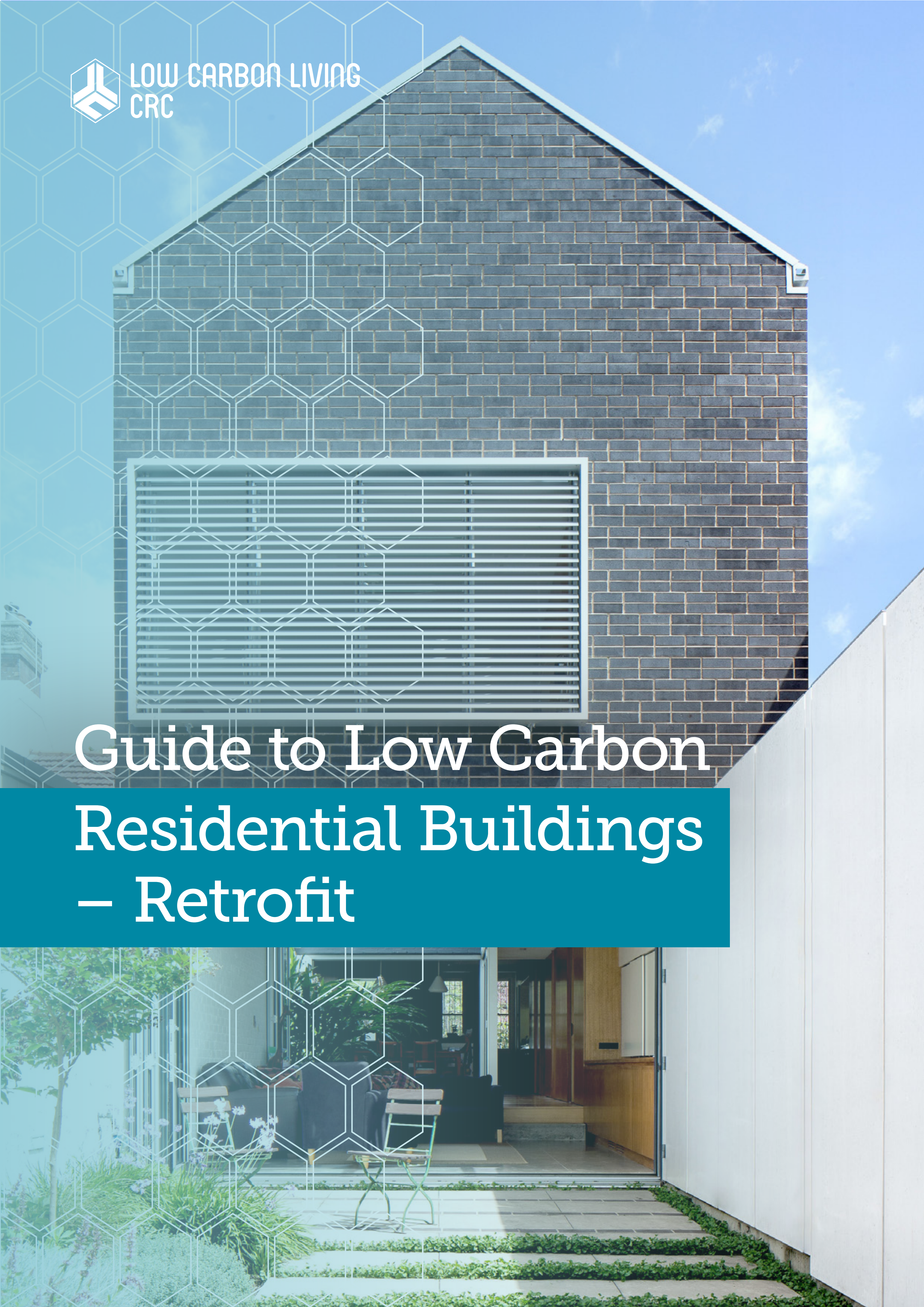
LOW CARBON LIVING CRC



Guide to Low Carbon Residential Buildings – Retrofit

Acknowledgements

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Guide to Low Carbon Residential Buildings – Retrofit

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Contents

Glossary

Building envelope
The physical partition between the inside of a building and the external environment, consisting of the building's exterior walls, floor and roof, and exterior doors and windows.

Climate region
A distinctive climate zone within Australia, adapted from the National Construction Code climate zones.

Dwelling typology
The architectural style and era in which the home was built.

Embodied energy
The energy consumed by all of the processes associated with the production of a building, from the mining and processing of natural resources to manufacturing, transport and product delivery.

Evacuated tube hot water system
A system to heat water by gathering and retaining solar energy through heat collector tubes that are more efficient than flat plate collectors.

Evaporative cooling
An air conditioning system that utilises the capacity of water to absorb a significant amount of heat in order to evaporate (change phase). They work most efficiently in dry climates.

Greywater
Wastewater sourced from sinks, showers, washing machines and similar sources that is reused for toilet flushing and garden irrigation without requiring major treatment.

Heat pump
A system that absorbs heat from the surrounding air to heat water without the need for electric element, gas or solar heating.

Hydronic heating
A system that distributes heated water (typically from a gas heater) to radiator panels or underfloor heating pipes.

Instantaneous hot water
A system that provides continuous flow hot water without the need for a storage tank. Usually gas powered.

LED lighting/ 'light emitting diode'
A small electroluminescent light that is more energy efficient and emits much less heat compared to traditional light sources.

Low-e glazing/Low emissivity glazing
A coating that reduces the amount of heat conducted through glass by around 30%.

National Construction Code
A performance-based code that sets out the minimum requirements for safety, health, amenity and sustainability in the design and construction of new buildings (and new building work in existing buildings) throughout Australia.

Natural ventilation
The process of supplying air to and removing air from an indoor space without using mechanical systems.

Operational energy
The energy consumed by a building to satisfy the demand for heating, cooling, ventilation, lighting, equipment and appliances.

Passive solar design
The design of windows, walls, and floors to distribute solar energy to heat living spaces in winter and cool them in summer.

Phase change materials (PCM)
Materials that absorb heat from the environment when they melt and release heat to the environment when they freeze, while themselves retaining a near constant temperature.

Purge ventilation/night purging
A strategy for removing heat (and stale air) from a building by bringing in cool night air without the use of active cooling and ventilation.

Retrofit
Relatively minor modifications that increase the efficiency or performance of a building with minimal alterations to its bulk, scale and form.

R-value
A measure of how well a material performs as thermal insulation, or more accurately, the thermal resistance of a material. Under the National Construction Code, the required total R-values for the building fabric vary depending on climate zone.

Solar photovoltaics

The conversion of light into electricity using semiconducting materials, typically panels, each comprising a number of solar cells which produce voltage and electric current.

Stack effect

Natural ventilation based on the principle that hot air rises. Stack effect ventilation draws in cooler air at the base of buildings to replace hot air vented at the top.

Standby energy

Energy used by an idle device while in standby mode; that is, when still switched on at the power point.

Thermal bridging

Occurs when a conductive material allows an easy pathway for heat flow across a thermal barrier. Common examples include aluminium window frames and wall studs.

Thermal mass

The capacity of a material to absorb and store heat energy, providing a thermal 'buffer' against temperature changes.

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.

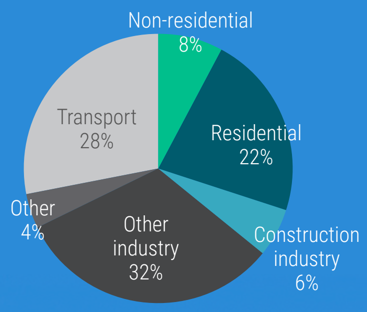
This presents a **significant challenge** as well as a **valuable opportunity** for the built environment sector to contribute to emissions abatement and mitigation.

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.

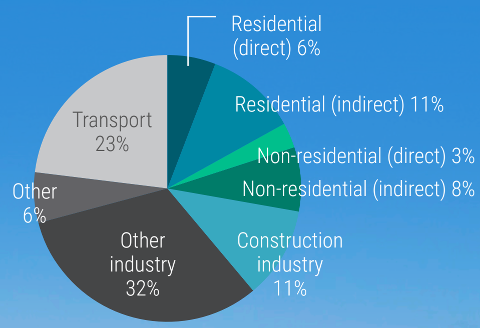
It is clear that if Australia is to achieve these targets, curbing emissions from **the built environment will play a central role**. And with more than 75% of the world's population predicted to be living in cities by 2050, the decisions and actions taken now will have effects decades into the future.

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

This guide offers practical advice to homeowners, builders and designers embarking on a retrofit of an existing home. It focuses on relatively simple adaptations to improve a home's comfort, while reducing energy bills and carbon emissions.

It is a response to an increasing need to address carbon emissions from *existing* residential buildings. Historically, policy on reducing carbon emissions has focused on regulating new-build projects; however, with less than 2% of the building stock in Australia replaced each year, there is a clear need to reduce carbon emissions in homes that have already been built and occupied.

The document builds on key research conducted nationally by individuals and organisations, including the Australian Government's Department of Environment and Energy and local universities, working in the areas of low carbon retrofit options, housing typology and climate.

The practical nature of the information aims to appeal to a diverse readership, from people with little or no formal training or experience in construction and design to those who are qualified builders and architects.

Importantly, the advice here covers only residential buildings, which include the National Construction Code building classes 1, 2 and 3. For commercial retrofits, please refer to the **Guide to Low Carbon Commercial Buildings – Retrofit**.

Similarly, homeowners embarking on extensive refurbishments that significantly change the form or layout of their dwelling, or who are planning home extensions or a new construction, should refer to the **Guide to Low Carbon Residential Buildings – New Build**.

Homeowners or those in rental properties who are seeking to avoid major retrofits while at the same time reduce their household energy use should refer to this guide's companion document, the **Guide to Low Carbon Residential Buildings – Households**.

What is retrofit?

Less than **2%** of existing houses in Australia are replaced each year

Retrofit can be defined as changes or upgrades that improve a building's efficiency or performance without significantly altering its bulk, scale and form. It also includes changes to external features such as shading and landscaping.

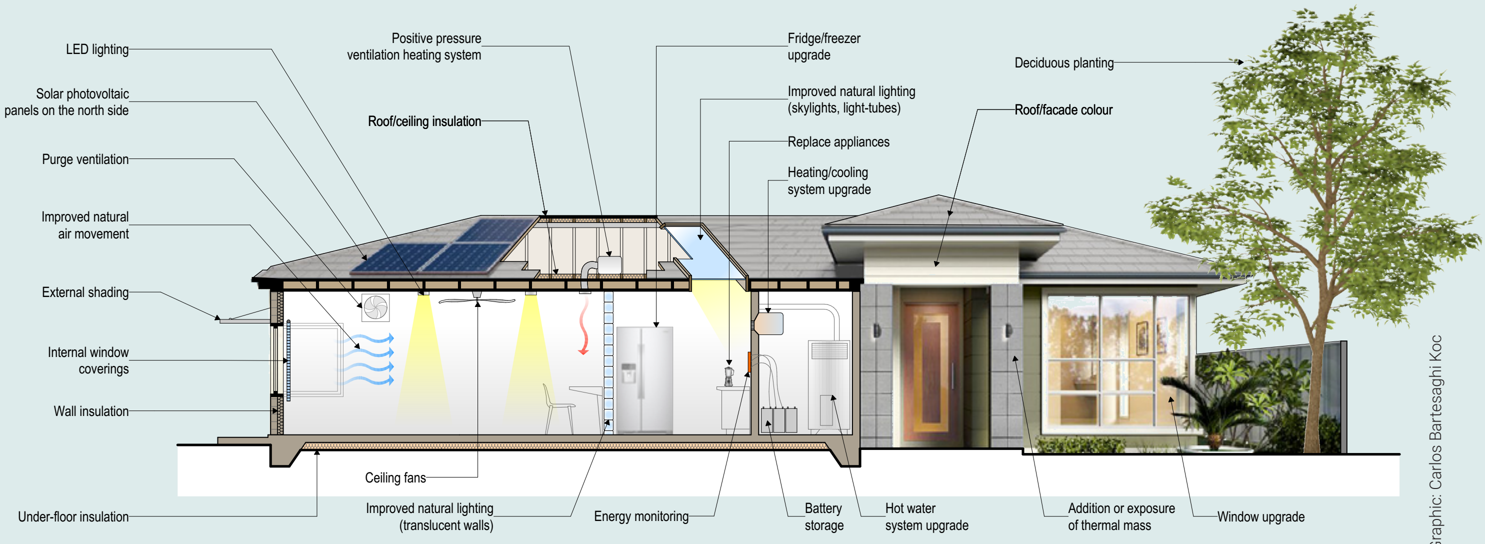
Housing stock in Australia changes slowly, so modifying established homes with updated technology and materials to reduce energy use and greenhouse gas emissions is crucial if the nation is to meet its international obligations.

Typically, retrofits can be completed by the homeowner or a tradesperson without the need for building approvals from local or state government agencies. Retrofit options are diverse: they have different installation difficulty and cost, as well as varying impacts on comfort levels and energy use. Examples range from simple fixes (changes to light fixtures, window coverings and door seals), to major modifications (solar photovoltaic panels, thermal mass and roof and wall insulation).

Substantial work that requires building approval or work that significantly changes the layout or use of the home, or any new home construction, falls outside the retrofit remit. Similarly, changes related to occupant behaviour or the sustainable use of appliances and furniture are covered in other Guides in the series.

> "Retrofitting increases the efficiency or performance of a building with minimal alterations to its bulk, scale and form."

Australian homes use approximately **30%** of the electricity used nationally



Graphic: Carlos Bartesaghi Koc

How to use this guide

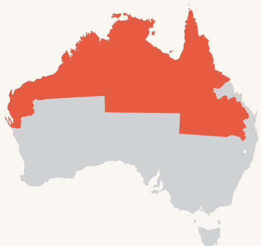
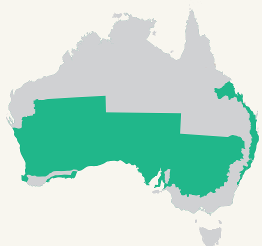
An interactive structure allows users to navigate information uniquely relevant to their needs before presenting a comprehensive rundown of retrofit options, including indications of each option's upfront cost, ease of installation, benefits to home comfort and energy savings.

Information and advice on retrofit options are grouped according to two main classifiers: **Climate Region** (the distinctive climate zone where the home is located); and **House Typology** (the architectural style and era in which the home was built). These are mapped in an interactive tool, **or matrix**, that allows readers to move easily between relevant information.

Once users determine their home's typology and climate region, they can follow links in the matrix (below) to arrive at information that most relates to their situation. They can return to this matrix to make a different selection or click through to specific retrofit options. A comprehensive list of options is located at the end of this Guide.

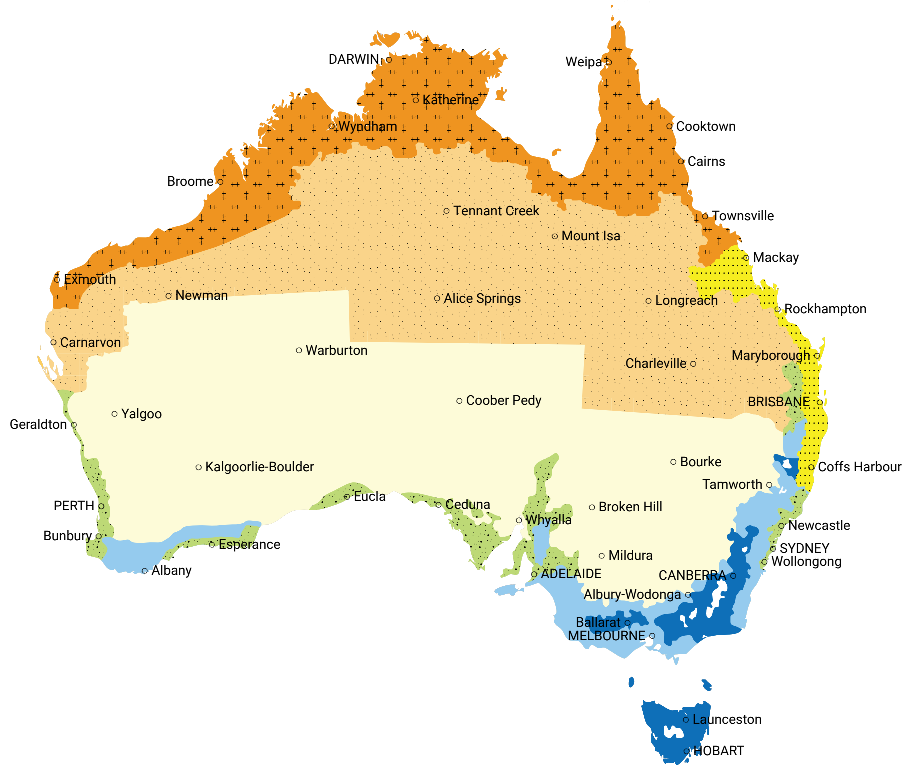
More information
Further advice on retrofitting can be found in the Australian Government's YourHome guide at: yourhome.gov.au

The Retrofit Matrix

Climate Region / Housing Typology			
PRE–1920	PRE–1920 Hot Summer/Warm Winter	PRE–1920 Warm Summer/Mild Winter	PRE–1920 Mild Summer/Cold Winter
1920–1970	1920–1970 Hot Summer/Warm Winter	1920–1970 Warm Summer/Mild Winter	1920–1970 Mild Summer/Cold Winter
1970–2000	1970–2000 Hot Summer/Warm Winter	1970–2000 Warm Summer/Mild Winter	1970–2000 Mild Summer/Cold Winter
POST–2000	POST–2000 Hot Summer/Warm Winter	POST–2000 Warm Summer/Mild Winter	POST–2000 Mild Summer/Cold Winter
APARTMENTS	Retrofit options for apartments in any climate region		

Climate regions

Heating and cooling are estimated to account for **40%** of a building's total energy use



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

The first step in using the Retrofix Matrix is to determine where your home is located according to climate region.

Climate has a significant influence on a dwelling's energy needs and related carbon emissions and a home's geographical location will determine which retrofit options are most beneficial.

The National Construction Code defines eight distinct Australian climate regions that influence a building's energy requirements for heating and cooling. Although climate regions vary, many of the most beneficial retrofit solutions can be implemented across regions, with only minor variations. Therefore, for the purposes of this guide, the eight climate regions can be simplified into three zones that share the same target retrofit outcomes.

Zones 1 and 3
HOT SUMMER / WARM WINTER

Zones 2, 4 and 5
WARM SUMMER / MILD WINTER

Zones 6, 7 and 8
MILD SUMMER / COLD WINTER

Housing type

Once the climate zone is established, the next step is to determine what housing type best describes your dwelling. Construction methods and the era in which a home was built will influence what retrofit options are most suitable.

Australia's architectural styles are closely linked to the history of the country, reflecting fashion, culture, economic circumstances and available construction materials, and are the result of both local and global influences.

This guide allocates dwelling types to eras that are loosely broken up by historical events and construction trends. After construction, homes may have undergone multiple renovations and retrofits, each reflecting the era in which they were carried out. For this reason, the following breakdown is a guide only and requires self-assessment and a combination of housing typologies to arrive at the most suitable retrofit strategy.

Australia's architectural styles are closely linked to the history of the country.

Queen Anne

Mid Victorian

Terrace

Federation

Typical heritage pre–1920 housing examples in Australia

Pre–1920 homes

Homes in this era are typically built on-ground with single brick walls and timber stud internal walls. Weatherboards are introduced later in the period. Windows are timber framed and double-hung or hinged without draft or weather seals. Steep pitched roofs with corrugated iron are common and terracotta tiles appear with higher frequency in the latter part of the era. Gable front ends and wrap around verandas and eaves feature in some designs. These homes generally have no insulation, poor airtightness and minimal solar passive design. Fixed shading on north and west windows is common in the latter part of the era.

Considerations:

- No insulation
- Poor airtightness; leaky envelope and windows often exacerbated by the age of dwellings, especially if maintenance has been neglected
- Minimal solar passive design.

Typical 1920–1970 housing examples in Australia

1920–1970 homes

Homes of this era typically have walls that are single or double brick with timber studs. Weatherboards and fibro cladding are also prominent. Timber double-hung windows are common, moving toward aluminium frames without seals in the latter part of the period. Designs and layouts vary with the increased number of architectural styles. Terracotta or corrugated iron pitched roofs with eaves are the norm as is fixed shading on north and west windows. These homes generally have suspended timber floors, no insulation and poor airtightness.

Considerations:

- Low levels of ceiling insulation, but generally no wall or floor insulation
- Airtightness is poor to average, depending on build quality and air vents
- Front and rear verandas are common, eaves provide summer shading.

Brick Veneer

Modern

Brick Veneer

Outer Suburban

Typical 1970–2000 housing examples in Australia

1970–2000 homes

Following campaigns to phase out asbestos in the 1980s, homes of this era typically feature less cladding and more brick veneer construction. Most homes are slab on ground constructions with tiled or carpeted floors. Aluminium-framed sliding windows with basic seals are common, as are cement roof tiles, metal sheeted roofs, fixed or adjustable external shading and ceiling insulation. Many homes, particularly those from early in the era, lack wall insulation and airtightness is poor-to-average depending on construction.

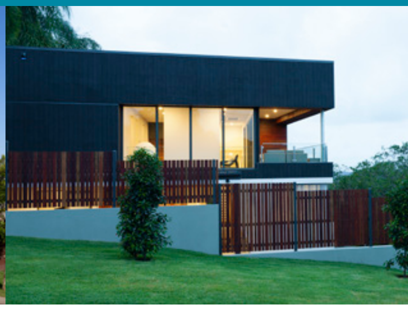
Considerations:

- Most houses lack insulation
- Airtightness is poor-to-average, but improves towards 2000
- Solar passive design is uncommon; however, fixed or adjustable external shading may be present.

New Wave

Contemporary

New Wave



Contemporary

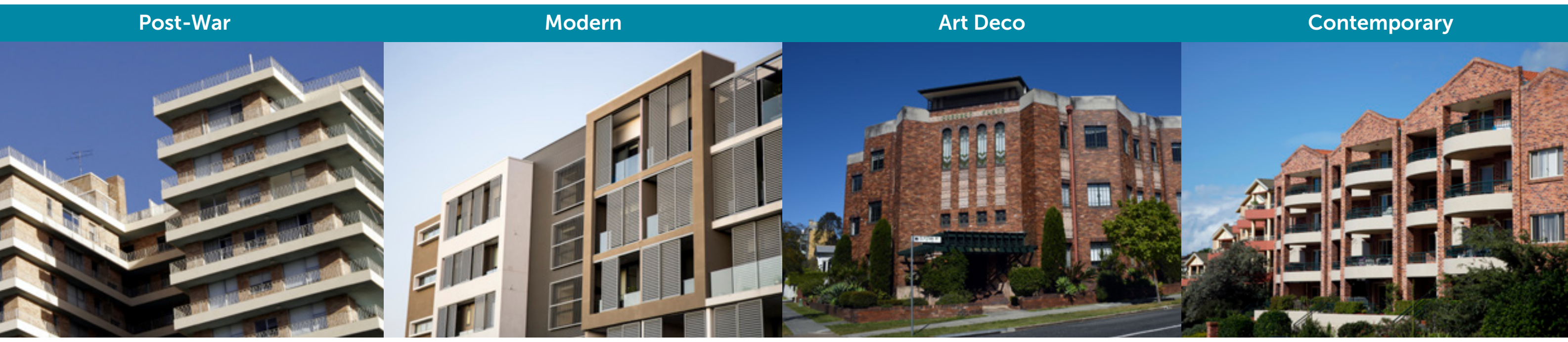
Typical post–2000 housing examples in Australia

Post–2000 homes

Homes with brick veneer construction or light cladding predominate in this era with a wide variety of designs and increased floor area. Minimum standards for building performance were introduced in the ACT in 1995 (4 star) and nationally in the Building Code of Australia in 2003. As a consequence, insulation in walls and ceilings is common, although the extent varies according to standards in place at the time of construction. Airtightness also improves but depends on build quality. External shading is a feature and solar passive design becomes more common.

Considerations:

- Ceiling insulation present and wall insulation likely, but efficiency depends on standards at the time of build
- Airtightness improves throughout the period, but is variable depending on build quality
- External shading is present in wide variety; solar passive design is considered, though rarely prioritised.



Typical apartments and higher density living

Apartments and Higher Density Living

High-density living is ubiquitous in all major Australian cities. Most constructions are located adjacent to coastal areas in temperate climates; however, the majority of retrofit options can be applied across all climate regions.

Australia boasts many styles of apartments, generally with quality of construction improving over time. The extent of insulation in individual complexes is dependent on the building regulations in place at the time of construction. Typically, apartments are built from masonry or concrete, with concrete flooring between levels, and tiled or carpeted floors. Timber-framed windows are common in older apartments, while most modern apartments feature aluminium-framed, single-glazed windows. Passive design considerations are absent in older apartments but are featured in most modern constructions in the form of window shading and improved airtightness. Shared internal walls, floors and ceilings limit external exposure as a ratio to floor area and with higher thermal mass apartments maintain a more stable internal temperature compared to detached houses.

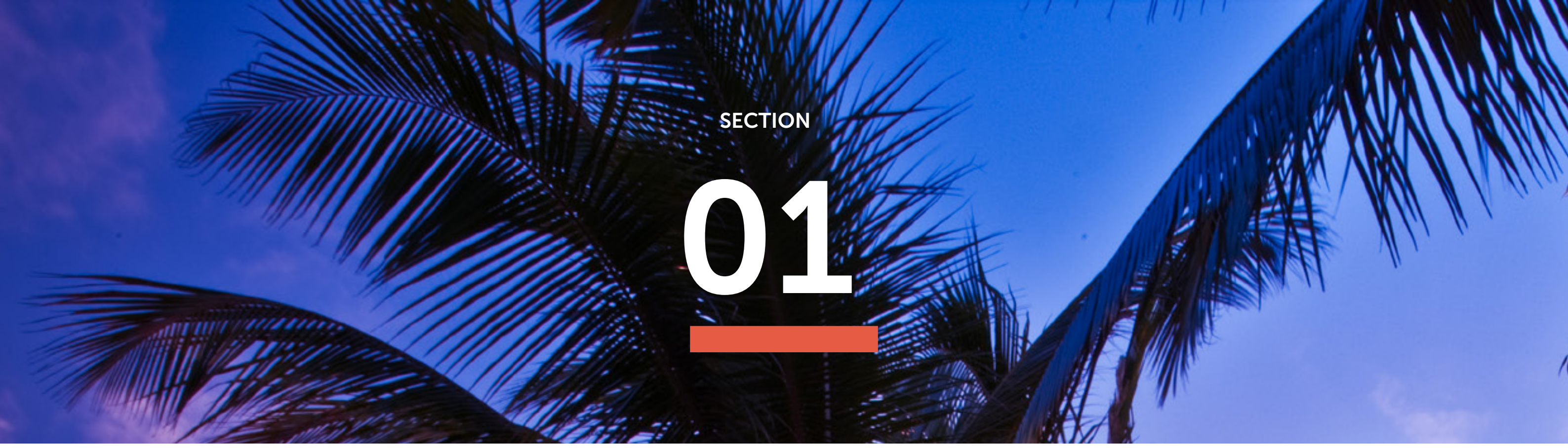
Considerations:

- Little to no insulation in older apartments
- Airtightness improves throughout the period, but is variable depending on build quality
- External shading present only in modern apartments, with the majority lacking solar passive design.

Assessing the options

When choosing retrofit options, it is important to assess their overall impact and value for money. In this Guide, each option is ranked according to its impact on home comfort, installation difficulty, up-front cost and energy saved. The assessment is based on household type and climate zone and results may vary according to unique situations.

Category	Symbol	Meaning
Home comfort Improvements in home temperature, lighting, ventilation and noise reduction.		Minimal or no direct impact on home comfort
		Moderately improves home comfort
		Greatly improves home comfort in most cases
Installation difficulty How easy it is to install the option.		Little difficulty, most people are able to do the work
		Can be done by someone with experience in the field
		Commonly needs a licenced tradsperson for installation
Up-front cost Refers to initial capital outlay. The cost may be reduced if homeowners undertake their own installation.		Minimal or no cost when done by homeowners
		Can cost more depending on material or labour cost
		Typically higher cost
Energy savings Money saved due to lower energy needs after option is installed.		Has minimal to no impact on home energy cost
		Reduces home energy cost in most situations
		Can potentially save a high proportion of energy bill

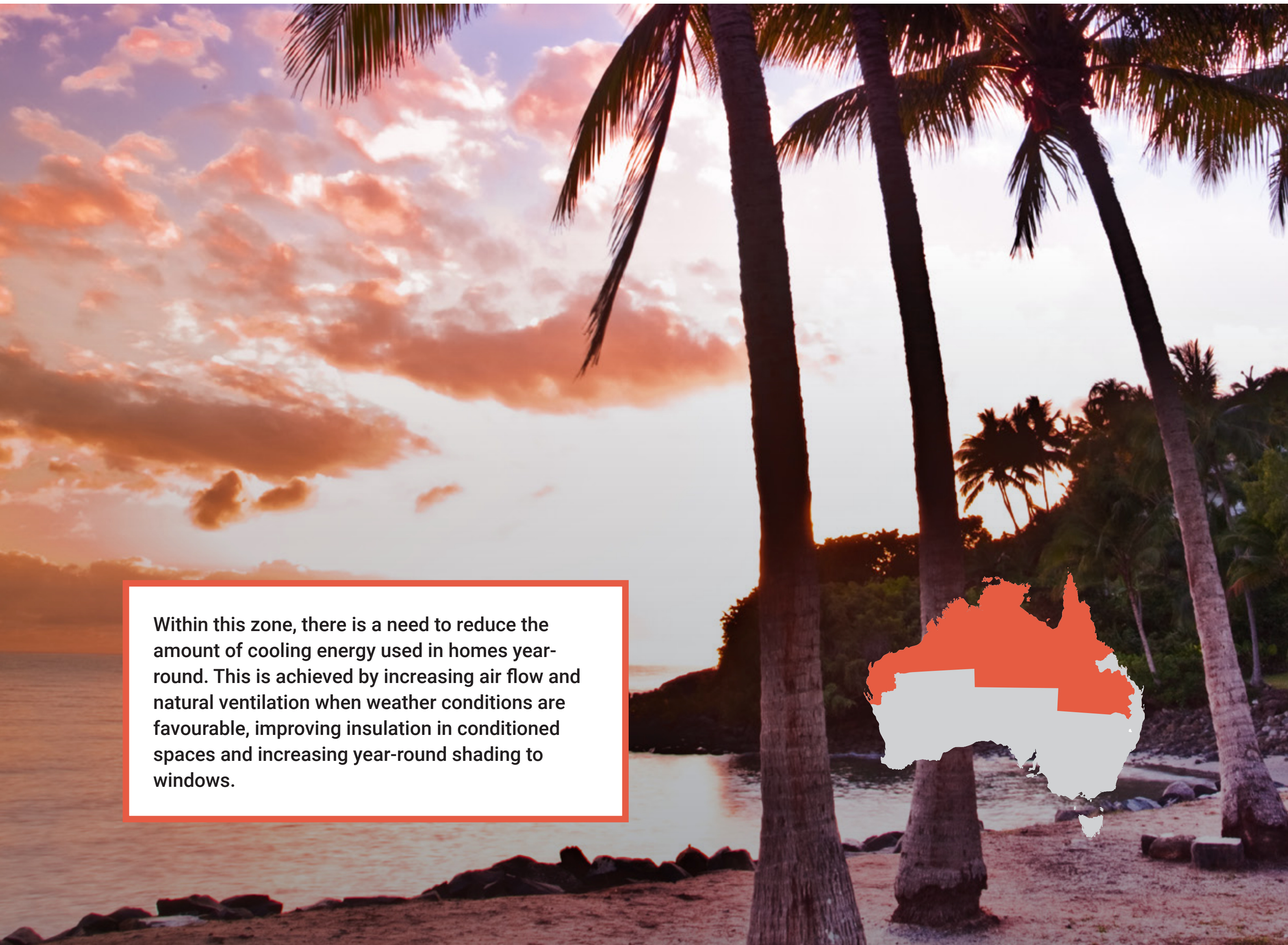


SECTION

01

Hot Summer and Warm Winter

This climate zone encompasses the National Construction Code climate regions 1 and 3, and includes the majority of Queensland, the Northern Territory and the northern half of Western Australia.



Within this zone, there is a need to reduce the amount of cooling energy used in homes year-round. This is achieved by increasing air flow and natural ventilation when weather conditions are favourable, improving insulation in conditioned spaces and increasing year-round shading to windows.

Pre–1920 homes: Retrofit options

Homes of this era in this climate zone benefit from improved air flow, rooftop solar panels and insulation; however, retrofit options are limited due to heritage restrictions. Air movement from natural ventilation and fans can increase heat dissipation and reduce the requirement for cooling energy. Limiting direct sunlight through windows via shading and tinted glass can further decrease cooling energy requirements. If air conditioning is used, an efficient system and improved insulation and airtightness can further reduce energy use while improving home comfort.

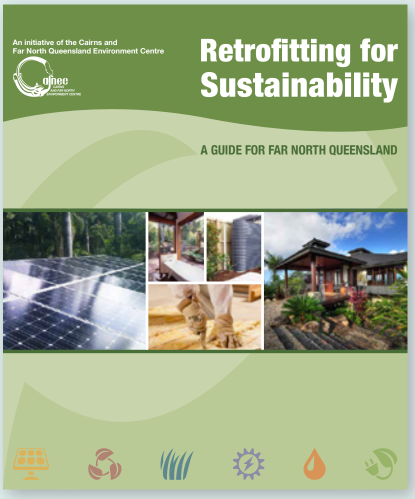
Retrofit Option	Home Comfort	Installation Difficulty	Up-front Cost	Energy Savings
Natural ventilation	2	2	2	2
External window shading	2	2	2	2
Air movement	3	2	1	2
LED lighting	1	1	1	2
Hot water system upgrade	1	3	3	2
Air conditioning upgrade	2	3	3	3
Roof/ceiling insulation	1	1	1	2
Improved airtightness	2	1	1	2
Solar photovoltaic panels	1	3	3	3
Window upgrade	2	2	2	2

Retrofitting in the Australian tropics

Renovating for comfort, sustainability and lower energy bills in the tropics requires an appreciation of the challenges of heat and humidity and the threats posed by storms.

The Cairns and Far North Queensland Environment Centre has developed a 10-step plan for those embarking on a retrofit to encourage energy and water efficiency. It covers:

- Designing for the local environment and with passive solar principles
- Planning and finances
- Building materials, windows, shading and insulation
- Lighting, appliances, hot water and alternative energy sources
- Water saving devices and rainwater tanks
- Landscape design and planning



Read more at: cafnec.org.au

1920–1970 homes: Retrofit options

Homes built in this era in this climate zone benefit from improved air flow, insulation and shading. Air movement from natural cross flow ventilation can be improved by modifying window openings and screens. High ceilings are common and ceiling fans are an effective additional source of cooling. Shading to windows and uninsulated walls can reduce cooling load. If air conditioning is used, improvements to airtightness and the use of external shading to prevent solar radiation entering the home can significantly improve comfort levels and lower electricity bills. Ceiling and wall insulation are also recommended.

Retrofit Option	Home Comfort	Installation Difficulty	Up-front Cost	Energy Savings
Solar photovoltaic panels	🌡	⚒ ⚒ ⚒	$ $ $	⚡ ⚡ ⚡
Natural ventilation	🌡 🌡	⚒	$ $	⚡ ⚡
Ceiling fans	🌡 🌡 🌡	⚒ ⚒	$	⚡ ⚡
External window shading	🌡 🌡	⚒ ⚒	$ $	⚡ ⚡
LED lighting	🌡	⚒	$	⚡ ⚡
Hot water system upgrade	🌡	⚒ ⚒ ⚒	$ $ $	⚡ ⚡
Air conditioning upgrade	🌡 🌡	⚒ ⚒ ⚒	$ $ $	⚡ ⚡ ⚡
Roof/ceiling insulation	🌡	⚒	$	⚡ ⚡ ⚡
Improved airtightness	🌡 🌡	⚒	$	⚡ ⚡
Window upgrade	🌡 🌡	⚒ ⚒	$ $	⚡ ⚡

Moroccan cool

Rising out of an uncomfortable and outdated 1950s inner-city Darwin bungalow, this airy home — inspired by a Moroccan *riad* — features living quarters that frame a central courtyard and pool, providing passive cooling without the need for air conditioning.

Above and below: Cross ventilation and solar passive design provide natural temperature control. Photos: Fiona Morrison

Sustainability features:

- **Embodied energy** saved by reusing existing lightweight elevated home instead of demolishing and building new.
- Passive **evaporative cooling** achieved by placing the house around central pool.
- **Cross ventilation** maximised by the placement of windows.
- High **window louvres** installed to vent hot air and shade the sun.
- Solar passive design provides **natural temperature control** year-round removing the need for air conditioning.

Read more at: renew.org.au

1970–2000 homes: Retrofit options

Home building quality improves during this period as the building industry becomes increasingly regulated through the implementation of various Australian Standards and the introduction of the Building Code of Australia in the 1980s. Air conditioning becomes more common, but homes built in hot climates can continue to benefit from air movement through natural and mechanical ventilation. Upgraded insulation in the walls and ceiling and improvements to airtightness can further reduce the demand for cooling energy, as can the addition of external shading and rooftop solar power generation.

Retrofit Option	Home Comfort	Installation Difficulty	Up-front Cost	Energy Savings
Solar photovoltaic panels	●	●●●	●●●	●●●
Air movement	●●●	●●	●●	●●
External window shading	●●	●●	●●	●●
Natural ventilation	●●	●	●●	●●
LED lighting	●	●	●	●●
Hot water system upgrade	●	●●●	●●●	●●
Improved airtightness	●●	●	●	●●
Roof/ceiling insulation	●	●	●	●●
Wall insulation	●●	●●	●●	●●
Fridge/freezer upgrade	●	●	●●	●●

Keep it simple

Even modest homes can be retrofitted to improve comfort, sustainability and energy efficiency. The owners of this north Queensland log cabin used simple additions such as roof insulation, shading and an off-grid solar power system and battery to make the most of the dwelling's open design and elevated aspect.

Above and below: Expansive verandas in the east and west create cool, shaded spaces.
Photos: JCU

Sustainability features:

- A **new roof** installed and fully insulated.
- Outdoor timber ceilings added above the wide **verandas** on the east and west to provide morning and afternoon shade.
- **Log walls sealed** and screens added to windows.
- An **off-grid photovoltaic solar and battery** system to supply renewable electricity.
- An external wood-fired hot water system and **grey water recycling** filter system installed.
- Addition of a 27,000L rainwater tank.
- **LED** or compact fluorescent lighting installed throughout.

Read more at: jcu.edu.au

Post–2000 homes: Retrofit options

Homes of this era in this climate zone typically feature ducted air conditioning systems which make airtightness and insulation upgrades a priority. Rooftop solar photovoltaic panels are common and operate effectively in hot climates but regular maintenance is a must. Strict building standards that mandate minimum performance ensure low carbon features are already present in many homes. Even so, upgrades to windows, lights and appliances, combined with energy monitoring, can deliver additional gains.

Retrofit Option	Home Comfort	Installation Difficulty	Up-front Cost	Energy Savings
Natural ventilation	2	1	2	2
Solar photovoltaic panels	1	3	3	3
Air movement	3	2	2	2
Improved airtightness	2	1	1	2
External window shading	2	1	1	2
Window upgrade	2	1	2	2
LED lighting	1	1	1	2
Fridge/freezer upgrade	1	1	2	2
Energy monitoring	1	1	1	2
Air conditioning upgrade	2	2	2	2

Tropical upgrade

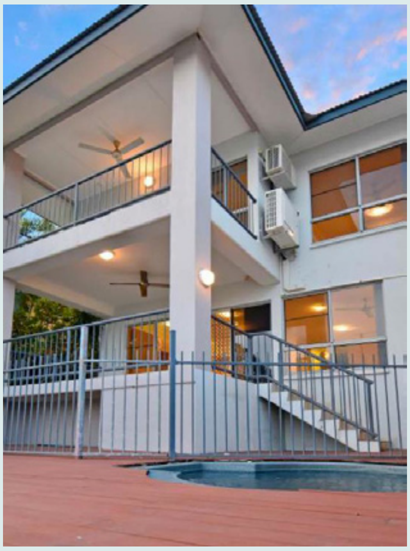
Multiple factors converge to make this double-brick townhouse a comfortable, well-located and sustainable place to call home. Additional shading, large operable windows and light external colours allow the occupants to keep comfortable year-round while leaving their air conditioner off.

Located near the city and many amenities, there is an opportunity to commute by foot. The homeowner has also installed an energy monitor and has plans to further increase the energy efficiency of the home after collecting and analysing energy usage data.

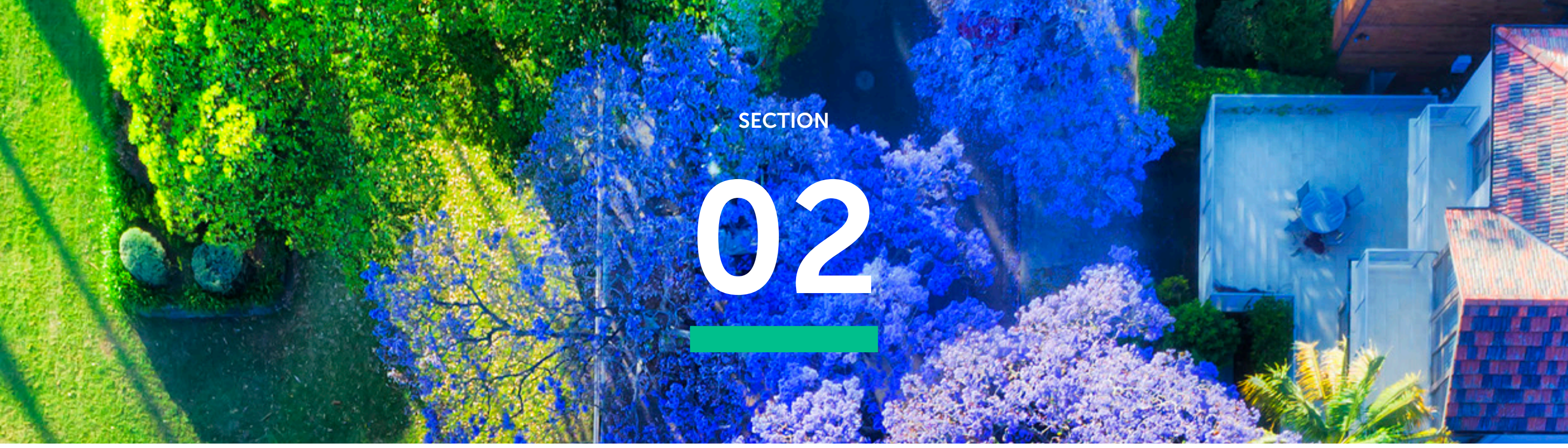
Sustainability features:

- **New plantings** shade the western side of the home.
- **Light external colours** reflect 70% of the sun's radiation.
- Large shaded north facing windows and large south facing windows provide **increased air circulation**.
- **Floor tiles** allow the concrete slab (thermal mass) to cool the home.

Read more at: coolmob.org



Above: Light and breezy allows occupants to do without air conditioning.
Left: Large shaded windows and terraces reduce sun exposure.



SECTION

02

Warm Summer and Mild Winter

This zone encompasses the National Construction Code climate regions 2, 4 and 5, and includes south-east Queensland, the south of Western Australia, and most of South Australia and New South Wales, including the Sydney region.

This climate zone is ideally suited to homes that take advantage of seasonal passive shading which lets in winter sunlight while blocking hot summer sun. Despite only moderate temperature swings across seasons, homes often need additional heating and cooling over the course of the year.

Pre–1920 homes: Retrofit options

Homes from this era in this climate zone can benefit from the introduction of rooftop solar panels and solar passive design; however, retrofit options may be limited due to heritage restrictions. Insulation and airtightness are important, and the introduction of thermal mass and seasonable shading can help regulate temperatures. Temperature swings between day and night can be harnessed to pre-heat internal spaces in winter and pre-cool them in summer, thereby reducing the need for heating and cooling energy.

Retrofit Option	Home Comfort	Installation Difficulty	Up-front Cost	Energy Savings
Solar photovoltaic panels	🌡	⚒⚒⚒	$$$	⚡⚡⚡
Improved airtightness	🌡🌡	⚒	$	⚡⚡
Roof/ceiling insulation	🌡🌡	⚒	$	⚡⚡
Air movement	🌡🌡🌡	⚒⚒	$$	⚡⚡
Wall insulation	🌡🌡	⚒⚒	$$	⚡⚡
LED lighting	🌡	⚒	$	⚡⚡
Hot water system upgrade	🌡	⚒⚒⚒	$$$	⚡⚡
Natural ventilation	🌡🌡	⚒	$	⚡
Addition of thermal mass	🌡🌡	⚒	$	⚡⚡
Deciduous trees and moveable external shading	🌡🌡	⚒	$	⚡⚡

Right: Louvre windows, bi-folding doors and natural light open up living spaces. Below: The home's street profile retains its heritage features. Photos: Douglas Frost and Ed Debenham

Inner city chic

Incorporating simple low carbon retrofit options in this Sydney renovation has helped to transform a rundown inner-city terrace into a naturally lit and sustainable contemporary home.

Sustainability features:

- **Improved solar access** through the addition of windows and creation of a courtyard to allow natural daylight into the home.
- **Improved natural-ventilation** by keeping room widths narrow and installing louvres to allow hot air to circulate.
- **Insulation and curtains** with high R-value used throughout to maintain favourable indoor temperatures in all seasons.
- **Thermal mass** in rooms that receive winter sun to store heat.
- **No air conditioning system** needed because of passive heating and cooling.

Read more at: architectureanddesign.com.au

1920–1970 homes: Retrofit options

Homes in this era and climate zone are often a result of mass construction and display poor design and building standards. Houses are typically lightweight, display no solar passive design and boast few energy reduction initiatives. Homes can benefit from the addition of wall and ceiling insulation and improved airtightness to regulate internal temperatures. Modifying solar access can take advantage of the winter sun and provide shading in summer, while controlled ventilation encourages the pre-cooling and pre-heating of internal spaces as required.

Retrofit Option	Home Comfort	Installation Difficulty	Up-front Cost	Energy Savings
Solar photovoltaic panels	1	3	3	3
Improved airtightness	2	1	1	2
Roof/ceiling insulation	2	1	1	2
Hot water system upgrade	1	3	3	2
LED lighting	1	1	1	2
Under-floor insulation	2	2	1	2
Natural ventilation	2	1	1	1
External window shading	2	2	2	2
Solar access	2	1	1	2
Wall insulation	2	2	2	2

Left: This 'whole-of-house' retrofit of a 1960s fibro shack is changing thinking on sustainability. Below: Original flooring and timber framing preserved to reduce embodied emissions. Photos: UoW

Fibro majestic

Researchers at the University of Wollongong used simple modifications and upgrades to transform this iconic 1960s fibro house, a ubiquitous and energy-inefficient dwelling, into an ultra-sustainable home for the future. This stylish and affordable approach is one of the best strategies to achieve significant economic and environmental gains across the Australian built environment.

Sustainability features:

- **Improved insulation** with high R-value materials added under floor, in walls and ceilings.
- Exterior asbestos cladding removed and replaced with sustainable, low-maintenance **pine sheet cladding**.
- **Improved solar access** and natural ventilation by combining the living, dining, kitchen and third bedroom and adding a raked ceiling with clerestory windows.
- **New timber-framed windows** with double-glazed Argon-filled units installed to improve the indoor and outdoor connection and reduce heat losses.
- Terracotta tiles, timber framing and flooring left in place to **minimise embodied energy**.
- **Thermal mass** added through concrete panel feature wall.

Read more at: illawarraflame.com.au

1970–2000 homes: Retrofit options

Typically found in larger suburban housing estates, homes from this era in this climate zone are the product of stricter building regulations and improved construction methods, particularly toward the end of the period. However, the efficiency of wall and ceiling insulation and airtightness vary according to build quality and homes can benefit from upgrades in these areas. The addition of solar panels on rooftops, hot water upgrades and improved solar access can deliver substantial energy savings.

Retrofit Option	Home Comfort	Installation Difficulty	Up-front Cost	Energy Savings
Solar photovoltaic panels	🌡	⚒ ⚒ ⚒	$ $ $	⚡ ⚡ ⚡
Improved airtightness	🌡 🌡	⚒	$	⚡
Hot water system upgrade	🌡	⚒ ⚒ ⚒	$ $ $	⚡ ⚡
LED lighting	🌡	⚒	$	⚡ ⚡
Roof/ceiling insulation	🌡 🌡	⚒	$	⚡ ⚡
Air movement	🌡 🌡	⚒ ⚒	$ $	⚡ ⚡
Solar access	🌡 🌡	⚒	$	⚡ ⚡
Wall insulation	🌡 🌡	⚒ ⚒	$ $	⚡ ⚡
Natural ventilation	🌡 🌡	⚒	$	⚡
External window shading	🌡 🌡	⚒ ⚒	$ $	⚡ ⚡

A life cycle assessment on this townhouse helped decide which retrofit options offered value for money. Photo: Alex Bruce, eTool

The 1980s townhouse

This Perth townhouse was modernised with sustainable retrofits, saving the owners 102% carbon emissions against the average Australian three-bedroom dwelling — all on a budget of $8,000.

Sustainability features:

- **Ceiling insulation** replaced.
- **Retractable shade cloth** installed on the western wall to keep home cool in summer.
- 2.6kW **solar PV system** installed to provide onsite solar energy.
- **Wood-pellet heater** installed for winter.
- **Ceiling fans**, combined with **insulation, shade cloth and plant screens**, maintain cool temperature throughout summer.
- Electric storage hot water system replaced with a **heat-pump hot water** system.
- $8,000 budget.

Read more at: liveability.com.au

Post–2000 homes: Retrofit options

Homes in this era benefit from minimum building performance standards which were introduced nationally throughout this period. The standards led to improvements in insulation efficiency, improved appliances and fittings, and increased airtightness. However, because homes are typically large there is no corresponding reduction in overall energy use. In this climate region, reverse cycle air conditioning, particularly ducted systems, are common, creating opportunities for energy-saving retrofits such as system upgrades, the addition of zone control and purge ventilation. With a predominance of slab on ground constructions, brick veneer walls and tiled or steel roofing, opportunities exist for additional insulation, the introduction of thermal mass and installation of solar photovoltaic systems for power generation and water heating.

Retrofit Option	Home Comfort	Installation Difficulty	Up-front Cost	Energy Savings
Solar photovoltaic panels	1	3	3	3
Improved airtightness	2	1	1	2
Purge ventilation	2	2	2	2
Hot water system upgrade	1	1	1	1
External window shading	2	2	2	2
Energy monitoring	1	1	1	2
Internal window coverings	2	2	2	1
Deciduous planting	2	1	1	2
Addition or exposure of thermal mass	2	1	1	2
Fridge/freezer upgrade	1	1	2	2

The stock standard Aussie

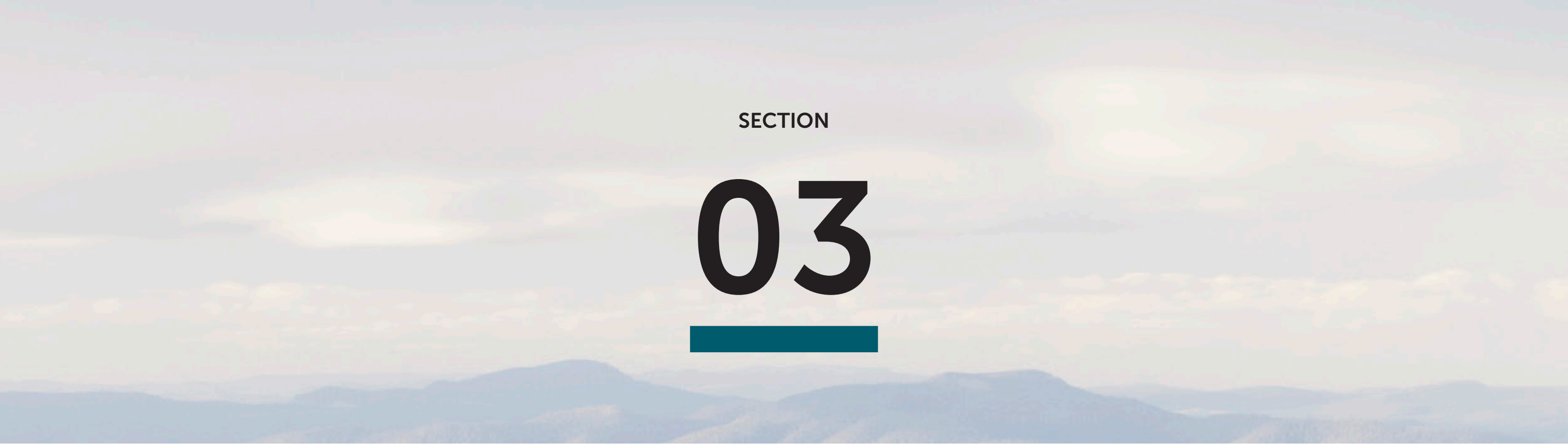
There is not a lot in the typical Australian brick veneer house that is thermally efficient. But simple retrofits to this country NSW brick veneer home show it is possible to own the epitome of Aussie housing and still reduce the burden on the wider environment.

Above: Magnetite windows. Below: 'Blow-in' insulation allows brick veneer walls to be fully insulated without removing external cladding.

Sustainability features:

- An **additional layer of insulation** added to the existing ceiling insulation.
- 'Blow-in' insulation retrofitted into the external walls without the need to remove cladding.
- **Secondary-glazing** magnetically fitted onto single-pane windows.
- 2 kW **solar photovoltaic system** installed.
- Movable **external shading** added to the east and north.
- **Evacuated tube solar hot water** system installed.
- 27,000L **rainwater tank** installed.
- **LED** and compact fluorescent lighting retrofitted throughout.

Read more at: architectureanddesign.com.au



SECTION

03

Mild Summer and Cold Winter

This zone encompasses the National Construction Code climate regions 6, 7 and 8 and includes the highlands of New South Wales and Victoria, the most southerly regions of Western Australia and Victoria, and all of Tasmania.

Though these climate regions can enjoy warm to hot summer days, they rely on heating in winter and during the majority of nights in autumn and spring. Exposure to cold winds exacerbates the need for heating during colder months.

Pre–1920 homes: Retrofit options

Homes of this era in this climate zone typically suffer from poor insulation and airtightness, resulting in a heavy reliance on heating, often from solid fuel wood heaters or inefficient element heaters. Retrofit options are often limited due to heritage restrictions, but a number of allowable retrofits can help improve building performance. Improving airtightness and adding insulation, as well as improving solar access in autumn, winter and spring, reduces heating needs and improves occupant comfort.

Retrofit Option	Home Comfort	Installation Difficulty	Up-front Cost	Energy Savings
Solar photovoltaic panels	🌡	⚒ ⚒ ⚒	$ $ $	⚡ ⚡ ⚡
Improved airtightness	🌡 🌡	⚒	$	⚡ ⚡
Roof/ceiling insulation	🌡 🌡	⚒	$	⚡ ⚡
Wall insulation	🌡 🌡	⚒ ⚒	$ $	⚡ ⚡
LED lighting	🌡	⚒	$	⚡ ⚡
Hot water system upgrade	🌡	⚒ ⚒ ⚒	$ $ $	⚡ ⚡
Internal window coverings	🌡 🌡	⚒ ⚒	$ $	⚡ ⚡
Addition or exposure of thermal mass	🌡 🌡	⚒	$	⚡ ⚡
Deciduous planting	🌡 🌡	⚒	$	⚡ ⚡
Window upgrade	🌡 🌡	⚒ ⚒	$ $ $	⚡ ⚡

Left and below: Good retrofits can help to highlight a property's history. Bottom: Retractable glass doors allow natural light and cross ventilation. Photos: Nic Granleese

Heritage, comfort and style

Heritage restrictions can sometimes rule out major retrofits. However, a subtle melding of heritage features with sustainable design has breathed new life and comfort into this 1870s brick terrace in Melbourne.

Sustainability features:

- Additional layer added to the existing **ceiling insulation**.
- **Insulation retrofitted** into the **external walls**, leaving cladding in place.
- **Secondary-glazing** retrofitted onto single-pane windows.
- 2kW **solar PV system** installed.
- **Removable external shading** added to the east and north windows.
- Solar **evacuated tube hot water system** installed.
- 27,000L **rainwater tank** installed.
- **LED or compact fluorescent lighting** retrofitted throughout.

Read more at: yourhome.gov.au

1920–1970 homes: Retrofit options

A focus on lower cost housing during this era led to homes with little consideration for the climate in which they were located. In this cold winter climate zone, homeowners face steep energy costs because of poor airtightness and insulation, and a heavy reliance on solid fuel wood fires and gas heating. A number of retrofit options can lower heating demand and improve occupant comfort, including rooftop solar panels, comprehensive insulation, improved airtightness and efficient window coverings.

Retrofit Option	Home Comfort	Installation Difficulty	Up-front Cost	Energy Savings
Solar photovoltaic panels	1	3	3	3
Improved airtightness	2	1	1	2
Roof/ceiling insulation	2	1	1	2
Wall insulation	2	2	2	2
Internal window coverings	2	2	2	2
LED lighting	1	1	1	2
Hot water system upgrade	1	3	3	2
Deciduous planting	2	1	1	2
Under-floor insulation	2	1	1	2
Positive pressure ventilation heating system	3	3	3	2

The light fantastic

An extensive retrofit transformed this cold and dark 1960s Canberra house into a light-filled and liveable family home that is more energy efficient and responsive to the environment.

Above and below: Retrofit changes resulted in a home that is brighter and more open to the environment.
Photos: Jeremy Rozdarz, Jigsaw Housing

Sustainability features:

- Floor plan re-arranged to move **living areas to the north** of the house.
- Solar hot water system installed.
- All windows and glazed doors replaced with **double glazed** uPVC units.
- Gas-fired hydronic heating system installed for heating in winter, **ceiling fans used for cooling** in summer.
- Ceiling penetration minimised and **good quality seals** installed around doors and windows to reduce drafts.
- **LED lighting** installed throughout.

Read more at: yourhome.gov.au

1970–2000 homes: Retrofit options

Housing from this era in this climate zone typically features improved insulation and window performance, which reduces heating demand. Airtightness measures also improve during the period and home designs often include mud rooms or other airlock-type features on external doors. Ducted gas or reverse cycle heating systems are common, although many are now ageing and inefficient and can be upgraded. Alongside the addition of solar panels on rooftops, retrofit options include upgrades to insulation and airtightness, and improvements to the efficiency of air conditioning and appliances.

Retrofit Option	Home Comfort	Installation Difficulty	Up-front Cost	Energy Savings
Solar photovoltaic panels	🌡️	🔨🔨🔨	💲💲💲	⚡⚡⚡
Improved airtightness	🌡️🌡️	🔨	💲	⚡⚡
Roof/ceiling insulation	🌡️	🔨	💲	⚡
Wall insulation	🌡️🌡️	🔨🔨	💲💲	⚡⚡
Internal window coverings	🌡️🌡️	🔨🔨	💲💲	⚡⚡
LED lighting	🌡️	🔨	💲	⚡⚡
Positive pressure ventilation heating system	🌡️🌡️🌡️	🔨🔨🔨	💲💲💲	⚡⚡
Heating/cooling system upgrade	🌡️🌡️	🔨🔨	💲💲	⚡⚡
Deciduous planting	🌡️🌡️	🔨	💲	⚡⚡
Hot water system upgrade	🌡️	🔨🔨🔨	💲💲💲	⚡⚡

Using reclaimed and recycled materials, and avoiding plastics, minimises embodied carbon. Photos: Dex Wong

Open plan and sustainable

Renovators of this 1970s brick veneer home in Bendigo struck gold with an open-plan and cost-effective makeover that uses basic and sustainable retrofit options.

Below: Secondary glazing allows original windows to be re-used.

Sustainability features:

- **Double glazing** installed throughout, with the homeowner re-using some single glazing by adding secondary-glazing.
- **Solar hot water** system and 1.5kW **solar PV** system installed.
- **Insulation** added to the floor, walls and ceiling.
- **Ceiling fans** installed for cooling in summer.
- High quality lead-free paints used and plastics avoided in their kitchen design.
- **Reclaimed and recycled materials** used in kitchen renovation.

Read more at: sustainability.vic.gov.au

Post-2000 homes: Retrofit options

Most homes from this era in cold climates are constructed to minimum building performance regulations, which include insulation and window efficiency requirements. Many homes feature roof, ceiling and wall insulation and improved or double-glazed windows. Gas or reverse cycle ducted heating is found in many homes and offers opportunities for upgrades. Other retrofit options include improvements to airtightness, more efficient building operation and increased awareness around occupant behaviours. Upgrades to high-efficiency appliances can also have a significant impact in otherwise high-performing homes.

Retrofit Option	Home Comfort	Installation Difficulty	Up-front Cost	Energy Savings
Solar photovoltaic panels	🌡	⚒⚒⚒	$$$	⚡⚡⚡
Improved airtightness	🌡🌡	⚒	$	⚡⚡
Positive pressure ventilation heating system	🌡🌡🌡	⚒⚒⚒	$$$	⚡⚡
Internal window coverings	🌡🌡	⚒⚒	$$	⚡⚡
Heating/cooling system upgrade	🌡🌡	⚒⚒	$$	⚡⚡
Hot water system upgrade	🌡	⚒⚒⚒	$$$	⚡⚡
Deciduous planting	🌡🌡	⚒	$	⚡⚡
Energy monitoring	🌡	⚒	$	⚡⚡
Fridge/freezer upgrade	🌡	⚒	$$	⚡⚡
Reduce standby energy	🌡	⚒	$	⚡⚡

Above: Wide eaves and verandas allow seasonal heating and cooling.
Below: An open floorplan encourages ventilation and zoning.
Photo: Michael Whitehouse

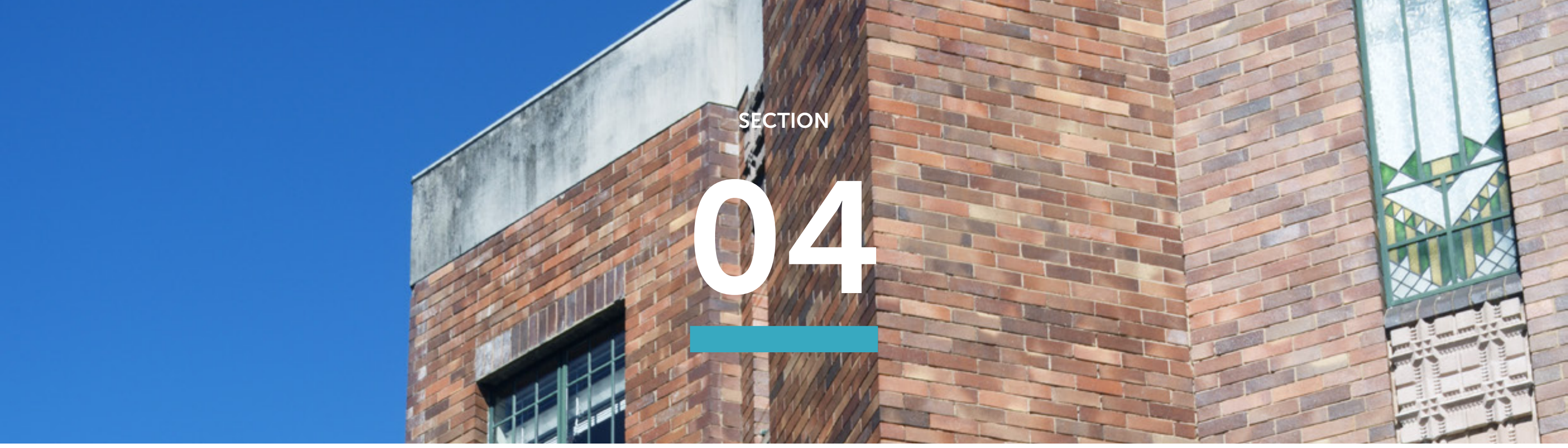
The next level: net zero energy

Not satisfied with their already modern and energy efficient home in Wilton in the NSW Southern Highlands, these owners wanted to create a net zero energy house.

The four-bedroom home came with a solar hot water system on its north-facing roof. As a complement, the owners installed a 5kW solar photovoltaic array to provide electricity to run the house and to export any surplus to the grid. The system ended up generating more than five times the energy used within the home, eliminating all electricity bills, including service charges.

Other sustainability features:

- A fan-driven and ducted **'purge' ventilation system**.
- Wall and ceiling **insulation**.
- High **thermally rated windows**.
- **Thermal mass** to stabilise internal temperature.
- Appropriately sized **eaves** to prevent overheating in summer and allow the sun to warm the house in winter.



SECTION

04

Apartments and Higher Density Living

High-density living can be found in all major Australian cities. Most constructions are located close to coastal areas which have a temperate climate; however, the majority of retrofit options for apartments apply to all climate regions.

Retrofit options

Retrofit options for apartments are usually limited to internal modifications as strata regulations can prevent external work without prior approval. Retrofits provide similar benefits to apartments across all climate regions and eras of construction, with minor differences. Improved airtightness, lighting upgrades and improved window coverings are among the most beneficial options. Some limited external work may also be viable with strata approval.

Retrofit Option	Home Comfort	Installation Difficulty	Up-front Cost	Energy Savings
Improved airtightness	🌡🌡	⚒	$	⚡⚡
LED lighting	🌡	⚒	$	⚡⚡
Ceiling/pedestal fans	🌡🌡🌡	⚒	$	⚡⚡
Internal window coverings	🌡🌡	⚒⚒	$$	⚡⚡
External clothes line	🌡	⚒	$	⚡⚡
Window upgrade	🌡🌡	⚒⚒⚒	$$$	⚡⚡
Energy monitoring	🌡	⚒	$	⚡⚡
Fridge/freezer upgrade	🌡	⚒	$$	⚡⚡
Reduce standby energy	🌡	⚒	$	⚡⚡
Replace appliances	🌡	⚒	$$	⚡⚡

Apartments in the coastal city of Wollongong. Below right: A balcony was enclosed with bi-fold windows. Photos: Michael Whitehouse

Apartment retrofits – a little goes a long way

Meeting the challenges that come with improving comfort and reducing energy use in apartments is no easy task. This young designer has demonstrated how to retrofit three very different Wollongong apartments to improve air quality, reduce road noise, and drastically reduce energy bills.

Sustainability features across the three apartments:

- **Energy monitoring** to better understand energy use from appliances.
- Standby energy reduced to almost zero by turning off key appliances at the wall.
- Inefficient ceiling **lighting replaced** with high efficiency table and floor lamps.
- Road noise and dust eliminated by **enclosing a balcony** with bi-fold windows.
- A 100mm-thick **foam applied** to a medium-sized window at night and on very hot days to add thermal and acoustic insulation at low cost.
- High-efficiency **reverse cycle air conditioning** installed where appropriate to replace portable, inefficient systems.
- Foldable **clothes lines** installed on balconies to reduce need for clothes drier.
- An adjacent unused rooftop area converted into a balcony after council and strata approval, offering **increased solar access** and a location for clothes drying and future solar panels.

SECTION

05

Retrofit options

A range of low carbon retrofit options are available to homeowners each with a level of impact dictated by housing typology and climate region. Below is a comprehensive list and explanation of the most beneficial low carbon retrofit options available.

The impact of each retrofit option is dictated by housing typology and climate region (see sections above). In order of general benefit, they include:

- Solar photovoltaic panels
- Roof/ceiling insulation
- LED lighting
- Hot water system upgrade
- Improved airtightness
- Ceiling/pedestal fans
- External shading
- Internal window coverings
- Improved natural air movement
- Wall insulation
- Under-floor insulation
- Heating/cooling system upgrade
- Battery storage
- Addition or exposure of thermal mass
- Deciduous planting
- Window upgrade
- Improved natural lighting
- Positive pressure ventilation heating system
- Purge ventilation
- External clothes line
- Fridge/freezer upgrade
- Upgraded appliances
- Energy monitoring
- Reduce standby energy
- Alterations to the home layout
- Roof/facade colour.

Improved natural lighting is an important retrofit option that can reduce energy bills and lift moods. Photo: Velux

Solar photovoltaic panels

Solar panels are easy to install on most existing homes. They generate electricity from the sun to offset household energy use, particularly cooling energy in summer, saving money for homeowners and reducing carbon emissions.

Some circumstances restrict their use, such as heritage provisions, aesthetic considerations, or whether the building is overshadowed or has a predominantly south-facing roof. Generally, however, solar photovoltaic panels offer good value for money.

Solar panels must be installed by a qualified electrician and represent a higher capital outlay than some other retrofit options. Even so, the direct offset of electricity cost and reduced carbon emissions make them an attractive option.

Residential solar panels in Australia come in two forms; **polycrystalline and monocrystalline**. Blue-coloured polycrystalline panels are cheaper than their counterparts and dominate the market. The more expensive, monocrystalline panels offer greater efficiency (they require less roof area), improved performance in cloudy or hot conditions and a longer lifespan.

When situations preclude the use of traditional panels, alternatives such as **solar photovoltaic films, flexible panels and roof tiles** can be used. These are more expensive and have a longer payback period.

Solar photovoltaic panels offer some limited shading on the roofing but are unlikely to affect home comfort.

Solar photovoltaic systems need to be installed by a licensed tradesperson.

The capital cost of solar photovoltaic systems is more expensive than most retrofit options.

Solar photovoltaic panels significantly reduce energy bills, making the initial cost worthwhile in most cases.

Roof/ceiling insulation

Historically, Australian homes have lacked adequate insulation. Its inclusion in new homes is now mandated to improve thermal comfort, reduce cooling and heating costs, and block noise.

Adding **insulation to ceilings** is easy and cost-effective in houses with accessible roof cavities. It is particularly important in hot climates to protect roof cavities from overheating and in colder climates where the roof can attract ice or frost build-up. Installation can be done by tradespeople or any able-bodied person capable of working in a tight space. Before doing any work, however, check the manufacturer's recommendations and safety requirements, in particular mitigation against exposure to asbestos or lead in older homes, and fire sparked by recessed lighting.

An alternative to bulk ceiling insulation is reflective **under-roof insulation**, which is installed below roof sheeting or tiles during roof replacement or as part of a larger renovation project. Under-roof insulation also minimises the risk of 'ghost leaks' forming from condensation on the underside of roofing material.

How well insulation performs is indicated by its R-value. The R-value represents the insulation's thermal resistance (resistance to conductive heat flow between indoors and outdoors). For example, insulation with an R4.5 will resist heat flow more effectively than insulation with R2.0. However, the improvement associated with higher R-values is not endless. Each climate has a maximum R-value above which the benefits from the reduced heat flow become minimal.

	Roof/ceiling insulation helps to maintain internal temperatures to more comfortable levels.		**Ceiling insulation can be installed by any able-bodied person capable of accessing a roof cavity.**
	Insulation batts have a minimal up-front cost when the work is done by the homeowner.		**Ceiling insulation reduces heating energy and to a lesser extent cooling energy, resulting in bill savings.**

LED lighting

Home lighting has evolved considerably in recent years, with each technological change resulting in reduced energy use for the same light output and increased bulb life. **LED lighting** has become the leader in home lighting efficiency and is now the first choice for a majority of new homes due to their efficiency, low cost and long life.

LED lights use only 15% of the electricity of standard incandescent bulbs for the same light output, while lasting 12.5 times longer. Initially more expensive than other lighting types, with increased popularity and mass production the cost of LED lights is now comparable to their fluorescent and halogen alternatives.

It is most cost effective to install LED fittings once their predecessors burn out; however, LED has reached a lifecycle cost point where it is becoming worthwhile and financially beneficial to retrofit all incandescent and halogen lights even if they are still functioning, particularly in areas where lights are used often. An electrician can easily replace downlight fittings with LED alternatives for minimal capital cost. LED fittings also bring other benefits: they burn cooler than halogen bulbs, reducing the risk of recessed lighting causing fire in ceiling insulation; and they do not need ventilation, making ceilings more airtight.

Another bonus of LED lights is they do not emit in the UV spectrum, so generally attract fewer bugs than incandescent lights. This makes them ideal for use outdoors during warmer months or in warm climate regions.

With the choice of warm/cool lighting and higher efficiency, lighting dark space improves comfort.	**Bulbs are easily replaced by homeowners, while recessed fittings are easily replaced by an electrician.**
Replacing lights with LED alternatives has a minimal upfront cost.	**LED lights use less energy than other lighting options and save money on energy bills depending on use.**

Hot water system upgrade

In most Australian homes, the hot water system is responsible for approximately 23% of household energy costs and is the second largest contributor of energy use and carbon emissions. An efficient hot water system with upgraded piping and fittings can help to reduce operational energy, energy bills and carbon emissions. Most older homes have element-type storage tanks, which are nearing the end of their lifespan and can be cost-effectively replaced.

Though **gas hot water systems** offer cheaper up-front costs, heat pump and solar hot water systems have the lowest energy demand and offer the best lifecycle cost benefit.

Air-sourced **heat pump hot water systems** use a compressor cycle to heat hot water in much the same way a reverse cycle air conditioner heats and cools a home, and results in far less energy use than traditional systems. Though still more expensive then electric element hot water systems, increased demand has seen prices come down and the operational savings will repay the additional up-front cost over a short repayment timeframe. Their main disadvantages: they need to be located outside and have reduced performance in cold climates.

Solar hot water systems are the most expensive to install. However, because they utilise free energy from the sun, they offer the best lifecycle energy cost and payback period. A majority of solar systems are flat plate, which operate most effectively in coastal and warmer climates. For colder climates, **evacuated tube solar hot water systems** offer good summer and winter performance for a slightly higher up-front cost. Another advantage of solar systems: they can be connected to an electrically boosted storage tank inside the home, reducing tank heat loss.

Instantaneous hot water systems do not store hot water in a tank and are located close to where hot water is used, so have zero energy loss. Gas systems are the most viable.

Other retrofit options can boost the performance of new and existing hot water systems. **Relocating tanks** inside the home, or housing them outside in insulated enclosures, results in less tank heat loss. **Upgrading hot water pipes** or adding insulation (lagging), minimises energy loss by keeping water hotter for longer on the journey from tank to tap.

Unless hot water is otherwise unavailable, retrofitting does not impact home comfort directly.

Lagging and tank housing can be done by home occupant, but a system replacement needs a plumber.

Replacing a hot water system involves a higher up-front cost, which pays for itself over the system life.

Efficient and solar hot water systems result in energy savings, making initial outlays worthwhile.

Improved airtightness

Improving the airtightness of dwellings, particularly in cooler climates, is cost effective and will reduce the amount of heating and cooling energy needed and improve home comfort. Older homes, in particular, tend to be draughty, causing heating and cooling energy to be lost to the outside environment. Improving airtightness is one of the few viable high-impact retrofit options for apartment owners.

A home's airtightness can be determined through a 'blower door test' organised by a contractor who temporarily pressurises the house by fitting a fan to an external door. The contractor observes air pressure at different fan speeds and records an airtightness rating. A mist generator shows air movement to pinpoint the exact source of any leaks. Most leaks originate from around windows and doors, fireplaces and chimneys, plumbing in walls, ventilation bricks, downlights, architraves, floorboards and ventilation fans.

Older windows and doors often fit loosely within their frames and are usually unsealed. Replacing older frames and applying seals can significantly boost airtightness and thermal performance.

Fireplaces are common in older homes and unused chimneys are a significant source of air leaks and should be sealed. **Ventilation bricks**, usually located high on walls, were once mandated to improve ventilation when unflued gas heaters were common but are now largely redundant and should be covered and sealed.

Spaces around **plumbing pipes and architraves** should be sealed using gap filler.

Older **floorboards**, even when covered by carpet, can be the source of air leakage, especially in homes that are suspended off the ground or have open air cavities below. Sanding and sealing floors will minimise leaks, while underfloor insulation can improve airtightness and thermal performance.

Replacing hot, ventilated halogen downlights with cooler, sealed LED alternatives will increase airtightness and give the added benefit of reducing fire risk in ceiling insulation.

Ducted exhaust fans in ceilings can be sealed by introducing a short length of ductwork off the fan with a non-return damper.

An airtight home improves temperature stability and reduces noise from outside and from wind.	**Most airtightness retrofit options are easily completed by homeowners.**
Depending on the work being undertaken, most airtight retrofit options have minimal up-front cost.	**An airtight home will save owners substantial heating and cooling costs.**

Ceiling/pedestal fans

Once passive cooling measures have been explored, ceiling and pedestal fans are the next priority. While fans do not lower the temperature of a room as such, they **circulate air** to remove body warmth and can improve a room's thermal comfort by up to 3°C on warm days.

Moving air directly over the body maximises the cooling effect and can be particularly beneficial in bedrooms at night.

Fans are energy efficient (typically 50–100W), making them cheaper to run than even the best-performing air conditioners and with lower associated carbon emissions.

On very hot days, fans and air conditioning can be used in tandem; the increased circulation of air makes the temperature feel cooler and the air conditioner's thermostat can be kept at a higher level. The energy used to run the fan is more than offset by the reduced output required from the air conditioner.

Both ceiling and pedestal fans come in a variety of designs; the most appropriate will depend on individual needs and circumstance. **Ceiling fans** are quiet and able to move large volumes of air, so are ideal for large rooms, while **pedestal fans** can be moved where needed, are suitable for apartments and rental properties and stored when not in use.

Air movement reduces temperature and improves comfort, while also reducing mould.

Pedestal fans are easily retrofit, while ceiling fans must be installed by an electrician.

The creation of air movement is relatively cost effective when compared to air conditioning.

Using air movement for cooling will use less energy and save on energy bills when compared to air conditioning.

External shading

External shading comes in a variety of forms and in hot and warm climates is a cost-effective way to reduce cooling energy in homes. In very hot climates, window shading should be total, blocking direct sun year-round while allowing for views and natural light.

In regions with warm summers and cool winters, external shading should shade windows from the summer sun, but allow direct sunlight in winter. Shading options include; fixed shading that takes into account seasonal angles of the sun, movable shading devices, and the planting of deciduous trees.

Fixed shading is easy to retrofit to existing homes and includes eaves, pergolas, verandas, or window shading. Eaves provide shading to northern windows in summer, while letting in winter sun as the angle of the sun reduces. Pergolas and verandas provide year-round shading for larger openings, while maintaining views and diffused light.

Shade cloth, adjustable louvres and shutters can be manually operated or automated. These shading devices can be adjusted to suit the shading needs at different times of the day and year as required. They can also provide privacy to outdoor spaces and protect from wind.

Shading and the control of light and glare within a home improves visual comfort.	**Fixed shading can be installed by building occupants. Most moveable shades are installed by contractors.**
Shading options vary in price but are typically at the low end of up-front cost of the retrofit options.	**Reducing direct sunlight entering through windows saves cooling energy.**

Internal window coverings

Window coverings inside the home are an effective way to reduce the need for heating and cooling energy. Options include blinds, curtains and shutters.

In hot climates, direct sunlight on windows greatly increases internal temperature. Any window that receives direct sunlight can benefit from a tightly fitted window covering that traps heat before it can penetrate further inside. It is important to remember that window coverings only mitigate heat that has already entered through the glass and so should be used in conjunction with external window shading to stop the bulk of the heat before it reaches the home.

In cool climates, the opposite process is at work. Heat energy can be easily lost through exposed glass; tightly fitted window coverings can keep heat inside the home.

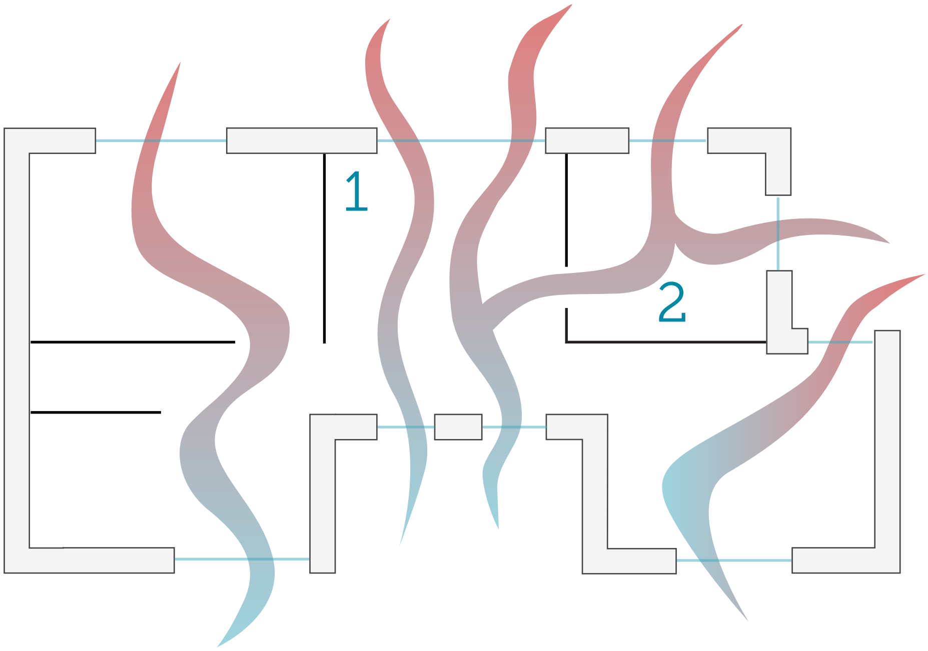
Whether to stop heat entering in summer or leaving in winter, **heavy curtains** or well-designed **blinds** are the most effective window coverings. When additional heating is necessary, insulating curtains can reduce moisture condensing on the glass and help prevent mould build-up on window frames.

Window coverings can be **automated** or **operated manually**. On extremely hot days, window coverings should be routinely closed during daylight hours but then opened at night. In colder climates the opposite is true: window coverings should be closed at night and opened during the day to allow warm sunshine to enter the home. For windows that are not exposed to direct sunlight, leave coverings closed.

In very extreme climates, windows can be a major weakness in home insulation, and curtains and blinds on their own will not greatly improve insulation performance. In these circumstances, an option is to temporarily fit insulating foam to window openings. Inexpensive and easy to cut, foam significantly limits the loss of cooling or heating energy through glass. It also reduces condensation and has the added benefit of blocking external noise.

Temperature mitigation and controllable light and privacy improve home comfort.	**Window coverings can be fitted by home occupants with some experience in building renovation.**
Depending on quality and size, window coverings usually have low to medium upfront costs.	**Window coverings can reduce some cooling and heating energy, but not to a significant extent unless used in tandem with insulating foam.**

Improved natural air movement



In warmer climates, allowing a **natural breeze** to pass through a home can increase evaporation, cool occupants and reduce the amount of cooling energy required.

Natural airflow both cools and ventilates homes and can be improved through retrofitting or modifying openings with options that can be as simple as adding insect screens to allow windows to be kept open at night or by strategically planting trees and bushes to direct cooling breezes through existing openings. In temperate climates, natural ventilation at the right time of the day can both heat in winter and cool in summer.

When retrofitting, consider **cross-flow ventilation** when deciding to update or relocate windows. Airflow is vastly improved if similar sized openings are located on opposite sides of the home, with no obstructions in between, as shown (above). Cross-flow ventilation can be achieved by leaving doors open or installing wall or ceiling vents to link rooms. Flows between openings on perpendicular walls are also beneficial.

The **type of window** is also important. Sliding windows typically open to only 50% of their total area, while most louvred windows can be opened completely.

Don't overlook **roof cavities**. During summer days, they can become very hot, with heat radiating down into the home. **Eave vents** provide natural air movement to the roof cavity, reducing overall air temperature. Because hot air rises, heat can also build up in internal stairwells and vaulted ceilings. In a process known as the 'stack effect', installing vents at the top of these spaces allows trapped hot air to escape.

Natural airflow connects indoor and outdoor spaces, providing fresh air to the home.	**Replacing or modifying window openings and installing vents are best done by qualified tradespeople.**
Replacing and modifying openings is a higher up-front cost option.	**When natural ventilation is used correctly, cooling energy savings can be achieved.**

Wall insulation

Bulk wall insulation is difficult to introduce to an existing home unless the external cladding or internal wall lining is removed as part of wider renovations.

If there are no plans to expose wall cavities, or if there are no stud wall cavities (such as in a double brick constructions), there are alternative options. One is **'blown-in' insulation**, where a foam product is pumped into wall cavities through a small opening in the brickwork or through the top of studs within the eaves. This method of insulation is non-invasive and cost effective. Blown-in insulation can also be used for ceilings which are difficult or unsafe to access.

If walls inside the home are being added or exposed during renovations, **internal bulk wall insulation** (pictured above) is recommended to help with zone control, where internal spaces are heated or cooled separately. This has the added benefit of blocking noise transmission between rooms, as well as reducing external noise.

Wall insulation stabilises internal temperature and greatly reduces noise from external sources.	**Bulk insulation can be easily retrofitted by homeowners and blown in insulation by contractors.**
Insulation has a low cost when done by homeowners, but contractors can be costly.	**Wall insulation greatly reduces heating and cooling energy bills due to the large surface area affected.**

Under-floor insulation

Older homes, particularly in the era from 1920 to 1970, typically have suspended floors with exposed cavities underneath. In these homes, significant cooling and heating energy can be lost through an uninsulated floor. This is less of an issue with slab on ground construction methods, where the thermal mass of the slab and ground maintain a stable internal temperature. Even so, in colder climates, or where underfloor heating is used, foam panels dug in around the slab can protect it from fluctuating ground surface temperature.

For suspended flooring, **underfloor insulation** is beneficial, provided there is adequate access. This insulation is fixed to the underside of the floor joists and not only improves thermal insulation but also airtightness. If there is not adequate crawl space, **'blown-in' insulation** can be used (see wall insulation above). An alternative to insulation is to install panels to the underfloor cavity's external openings to reduce airflow. The result is a floor cavity that is thermally connected to the internal space and ground, rather than the outside air, which has greater fluctuations in temperature. When replacing carpet or floor coverings, another simple retrofit is the inclusion of **insulating underlay**, which can significantly improve thermal comfort and airtightness.

Underfloor insulation not only stabilises temperature but provides a warmer floor and reduces noise.	**Can be easily retrofit by able-bodied home owners who are able to access an underfloor area.**
Insulation has a low cost when done by homeowners.	**Underfloor insulation in older homes greatly reduces heating and cooling energy.**

Battery storage

More homeowners are installing **batteries** to fully utilise solar photovoltaic generation, save money and be grid independent. Batteries store excess solar power generated during the day to make it available around the clock, removing the frustrating situation where excess power is sold to the grid at discounted rates during the day only to be bought back at inflated rates at night.

While batteries will be an essential component of future low carbon living, the technology is still in its infancy and is cost prohibitive for all but the keenest early adopters. Prices, however, are coming down in a similar trend to solar photovoltaic systems.

Even so, battery technology may already be viable in certain scenarios, including in:

- Areas with grid instability and regular blackouts. Battery technology provides reliable electricity supply and backup;
- Homes where connecting or upgrading electricity supply is cost prohibitive. Batteries can be a cheaper option;
- Homes that have critical energy requirements, including life support systems, which require a constant power source; and,
- Homes with regular low daytime energy use and high night time demand.

Battery storage would not directly impact home comfort.	**Battery storage needs to be installed by a qualified and certified electrician.**
Battery storage has a high upfront cost that is (currently) only partly repaid by energy savings.	**Battery storage saves a portion of energy cost depending on how it is used.**

Addition or exposure of thermal mass

Thermal mass allows a building to store and release heat to provide thermal equilibrium during temperature fluctuations. This equilibrium is created from high-density materials, such as concrete, bricks, pavers and tiles, as well as specially designed 'phase change' materials.

In older, lightweight homes with low airtightness, internal temperatures can closely reflect external temperature, resulting in cold and hot peaks outside an ideal comfort range. Retrofitting thermal mass can help stabilise these swings. To do this, thermal mass must be added inside the home's insulating and airtightness layer. Examples of retrofit thermal mass include introducing **tiled or heavier flooring, internal brick or stone feature walls, thermal mass furniture, internal water storage**, and **exposing favourable thermal mass flooring** such as insulated concrete.

Thermal mass works particularly well in areas adjacent to a heating source or exposed to direct sunlight in winter and shaded in summer. Introducing or exposing concrete or tiled floors adjacent to north facing windows or glass doors allows them to absorb the sun's energy and radiate warmth back into the home at night.

Phase change materials are manufactured materials that change from a solid to a liquid at a desired comfort temperature. Materials absorb and release a larger amount of thermal energy when undergoing a change of phase; therefore, these materials are the most effective method of introducing thermal mass benefits to a home. The materials are generally lightweight and can be concealed in the fabric of a home during most retrofits. Their drawback is they are highly designed and can come at a cost premium.

Stable temperature inside an ideal comfort band improves home comfort.	**Depending on the system used, thermal mass can usually be installed by the homeowner.**
Thermal mass can vary in cost from cheaper stone or concrete, through to expensive phase change material.	**In moderate climates, thermal mass can reduce cooling and heating energy cost.**

Deciduous planting

In cool and cold climates, the energy from direct sunlight reduces the need for home heating; however, poorly located or excessive vegetation can negate this benefit.

Pruning or removing vegetation that shades northern windows and outdoor areas during cooler months improves solar access.

In warm climates, planting deciduous trees (trees that shed leaves in autumn/winter) on east and west facing aspects provides shade in summer and sunlight access in winter. Green walls (pictured right) are an easy way to take advantage of solar access, particularly in homes with limited areas for planting. Green walls are gardens planted vertically that have the advantage of a reduced footprint, while providing thermal mass and shading. They are most effective on east and west-facing walls.

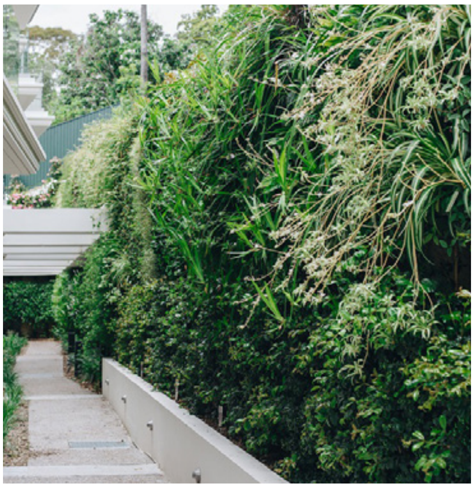


Photo: Junglefy

Allowing natural sunlight access to homes in winter provides a brighter, warmer space.	**Planting and garden maintenance are easily completed by homeowners.**
Pruning and planting represents minimal cost.	**Small energy bill saving can result from improved solar access through reduced heating needs.**

Window upgrade

Many older homes have poor performance window glazing and frames. Upgrading or replacing them is an effective retrofit that can lead to substantial benefits in a critical area of a home's thermal energy loss.

When considering moving windows or introducing new ones, north-facing windows are the most effective in moderating temperatures and natural light, especially in cold climates. In warm climates, avoid east and west-facing windows.

When choosing **window frames**, modern aluminium frames have the disadvantage of thermal bridging (temperature transmitted through the frame), but this is outweighed by improved airtightness. Modern timber or uPVC frames have the highest thermal performance but come at a cost premium.

The choice of glazing is also important. **Double-glazed** or **low-e windows** offer good thermal performance. Homes in warmer climates can also benefit from the addition of polycarbonate films to window glass. Like car window tinting, the films reduce the amount of the sun's thermal energy that passes through a window in summer, with the benefit of improved daytime privacy. Specially designed films protect against particular light wavelengths, such as UV. These allow visible light and reduce solar energy without affecting the aesthetic appearance of the glass. These films can also be retrofitted to windows in apartments.

Improved thermal performance results in a modest increase in home comfort.

Films can be applied by homeowners, but most window replacement is best done by a contractor.

Window and frame replacement is one of the higher cost retrofit options available.

A small heating and cooling energy bill saving results from high performance glass.

Heating/cooling system upgrade

Heating/cooling systems, like appliances, have become increasingly efficient over time. Older systems could be costing more to operate than they would be to replace, especially in extreme climates where their regular use represents a significant portion of a home's energy outlay. Over time, flexible ductwork can degrade and even detach from outlets or ductwork joins. The result is conditioned air blown into roof cavities, as opposed to the space where it is needed. A consultant engaged to assess the system can recommend when a new system is warranted and can suggest different air conditioning service and maintenance options.

Upgrading systems with system control technology, such as **zone control** can also lead to greater heating and cooling efficiency.

The performance of existing air conditioning systems can also be improved by ensuring adequate airflow to and around outdoor condensers.

A better performing heating/cooling system will better distribute air, resulting in improved comfort.	**A consultant or contractor is best employed to service equipment because of specialist knowledge required.**
The upfront cost of an upgrade or service is less than a new system, but is still one of the more costly retrofit options.	**Particularly in the case of disconnected ductwork, significant energy cost could be saved.**

Natural lighting

Introducing natural light to a home's internal areas reduces the need for artificial lighting during the day and can improve wellbeing as well as reduce energy costs. Introducing natural light can be as simple as using window furniture (curtains, blinds and shutters) more effectively. Beyond this, a number of retrofit options are available.

Skylights provide natural lighting to internal spaces without compromising privacy. When choosing a skylight, however, consider the heating and cooling energy that can be lost through the structure — it could lead to more money spent than saved. The best option is thermally disconnected (**tube-type**) solar lighting. Large glass roof windows should be avoided, particularly in hot climates.

Allowing light to move within the home is also important. Removing walls or modifying them to be translucent or transparent can help share light between rooms, while still maintaining privacy.

A naturally lit home improves home comfort.	**Skylight and opening modifications should be completed by contractors.**
Adding openings involves a moderate capital cost but results in lower lighting costs.	**Energy savings are limited to high-use areas.**

Positive pressure ventilation heating system

During winter, roofing and roof cavities can heat up sufficiently to provide active heating to homes. While rooftop solar heating systems capture energy to heat the home during the day, they rely on sunshine and don't provide heating on demand during the night or on cloudy days, unless they are connected to a thermal storage tank.

Liquid-based systems collect hot liquid from rooftop solar heating panels and passes it through a heat exchanger, similar to a ducted air conditioning system, to distribute heated air around the home.

Other systems collect heated air from within the roof cavity. These systems work best with dark coloured roofs, minimal under roof insulation on the roof's northern side, good ceiling insulation, an airtight roof cavity and air drawn at high pressure. These **air-based systems** not only heat the home, but also create air movement to reduce mould and improve comfort. In summer, they can be used to dispel hot air from the roof cavity and, if coupled to an outside air system, can draw in fresh air to cool homes at night.

Solar air heaters improve home comfort, particularly when no other heating is used.	**Solar air heaters are installed by qualified contractors.**
These systems have a medium upfront cost, typically less than traditional air conditioner installation.	**Substantial heating energy can be saved when the system is installed in a suitable location.**

Purge ventilation

Whole-house fans used for purge ventilation are an effective method of creating air movement in the home. These are either ducted systems specifically designed for the purpose, or units that make use of a ducted air conditioning system operating in the fan-only mode. Whole-house air movement is most effective when an occupant is close to an outlet and exposed to the draft created.

Controlled ventilation is an extension of a whole-house fan, where the ducted system actively monitors external, internal and roof cavity temperatures. The fan then draws air from outside or from the roof cavity to heat or cool the home as required. These systems are effective at pre-tempering a home in mild climates for night time cooling in summer, and daytime heating in winter. They also bring fresh air into airtight homes, improving air quality and reducing mould. They result in a slightly positive pressure within the home, which further reduces unwanted air infiltration.

Air movement and ventilation improves comfort temperature, while reducing mould.	**Purge ventilation is able to be retrofit to a home with an accessible roof cavity.**
These systems are generally cheaper to install than air conditioning but require similar expertise.	**Using air movement for cooling will save money on energy bills compared to air conditioning.**

Clothes lines

The energy used by clothes dryers can be eliminated by creating **suitable drying locations** inside and outside the home to be used during inclement weather. These simple and cost-effective clothes drying solutions can be easily retrofitted to homes.

No impact on home comfort directly, though can reduce mould from dryer use.	Easily installed by the home occupant.
Clothes lines are a low cost retrofit solution.	Can save energy in clothes drying depending on the extent of dryer use.

Fridge/freezer upgrade

Fridges and freezers are continually improving in efficiency with newer models using less energy than older ones. **Maintaining and repairing** broken door seals as well as switching off or removing multiple **unused fridges and freezers** will save significant energy, particularly in hot climates.

The choice of fridge/freezer has minimal impact on home comfort.	Fridge maintenance or replacement is easily done by home occupants.
A new fridge can have a medium up front cost, but quickly pay for itself in energy bill savings.	A lot of energy can be saved using an efficient fridge/freezer or turning off a seldom used fridge.

Upgraded appliances

Appliance manufacturers are similarly upgrading their offerings to be more energy efficient. Replacing inefficient older appliances with correctly sized modern alternatives will reduce household energy use.

Modern appliances, with improved functionality and safety, can improve home comfort.	Can be purchased and installed by homeowners without contractors in most situations.
Higher up-front cost depending on the appliances being replaced.	Most modern appliances operate more efficiently, particular with regard to standby energy, saving money.

Energy monitoring

Monitoring energy use is an important step in energy savings. Understanding exactly where energy is used in the home can help home occupants modify behaviours and lead to substantial monetary savings.

Energy monitoring doesn't affect home comfort.	**Though simple to install, energy monitoring should be installed by a qualified electrician.**
Energy monitoring has a low capital cost, but some building control systems have a high cost.	**Significant energy can be saved through behaviour modification but this varies depending on individuals.**

Reducing standby energy

Most electrical devices will use energy while in **standby mode**; that is when the device is switched on at the power point but is not being used. These small amounts, when added up over multiple devices and over long time periods, can represent significant energy use, as discussed in the *Guide to Low Carbon Residential Buildings – Households*.

No impact on home comfort. A minor inconvenience in having to switch appliances on and off at the power point.	**Switching off appliances at the outlet takes minimal effort by home occupants.**
There is no outlay cost, though automated switching devices can be purchased.	**Substantial energy bill savings depending on the number of appliances and their age.**

Alterations to home layout

The layout of a home, or a **change in use of spaces** within a home, can improve comfort and reduce energy use. In older homes what is otherwise allocated as a bedroom could be used as a living area and vice versa. Living areas located to the north, and bedrooms to the south, improve comfort and reduce artificial heating or cooling.

Home comfort is improved by having rooms in the right location.	**Screens and minor modifications can be completed by homeowners, or contractors if impacting on internal walls.**
The cost can vary depending on the extent of work required to reconfigure an internal space.	**Some energy cost is saved through reduced heating and cooling of spaces.**

Roof/facade colour

When considering **wall paint and roof colours**, remember darker colours collect more heat in winter in cold climates, while lighter colours reflect the sun's energy in summer. Specifically engineered 'cool' paints can reflect heat in hot climates, while the choice of roof colour can have significant influence on solar heating systems in cold climates.

A slightly more favourable internal temperature can result from colour choices.	**Painting of walls can be completed by homeowners, while modifying roof colour is done by contractors.**
Paint cost is minimal when the work is completed by homeowners.	**Small energy bill savings depending on climate region.**

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