Sustainable building design

Fact Sheet
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Passive design strategies

Macedon Ranges Shire Council

Sustainable building design

Know your local climate and microclimate

A building that responds well to its climate and its mircroclimate is considered to have good ‘passive design’.

Passive design is the building’s capacity to maintain a comfortable temperature using natural sources of heating and cooling such as the sun and cooling breezes, rather than artificial energy.

Before any new building project begins, a thorough analysis of the site’s climate and conditions should be undertaken. This is called a site analysis.

Local climate data such as seasonal temperature and rainfall averages, sun angles and prevailing wind patterns should be collected. Other site specific variables such as local geographic features, vegetation, contours, noise levels and overshadowing will need be observed on site.

Collecting this information at the beginning of a project will ensure that a site’s environmental conditions are understood and in turn utilized in the design resulting in a sustainable, energy efficient building.

Climate zone

Macedon Ranges Shire is in a cool temperate climate zone where heating is the main energy consumer. Roofs, walls and floors should be highly insulated. Glazing should be weighted towards preventing heat loss in winter and allowing heat gain from the sun in summer.

Key characteristics of the shire’s climate are:

- low humidity
- a high range between daily maximum and minimum temperatures
- four distinct seasons
- summer and winter temperatures exceed human comfort range
- cold to very cold winters with majority of rainfall
- hot dry summers.

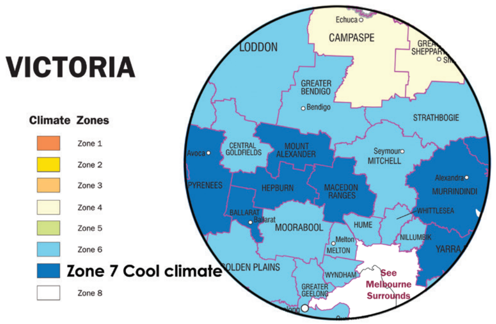

Figure1.1 Climate Zone Map – Victoria - Australian Building Codes Board

Temperature and rainfall

Average day/night temperatures for summer and winter as well as extreme temperatures should inform the design and construction of your building.

Rainfall data is useful when sizing rainwater tanks to reduce demand on potable water and to help design drainage systems in peak rainfall events.

Location	Eleva-tion (m)	Annual mean rainfall (mm)	Average summer (°C)		Average winter(°C)	
			day–night	range	day–night	range
Melbourne Airport	113	535	26.5–13.7	12.8	13.7–6.2	7.5
Macedon Forestry	505	853	23–11.8	11.2	8.6–3.5	5.1
Redesdale	290	579	29–13.2	16.4	12.8–3.8	9
Bendigo Airport	208	515	27.4–11.9	15.5	13.4–3.6	9.8

Table 1.1: Climate Statistics for various location in or adjacent to Macedon Ranges Shire–Bureau of Meteorology

Adapting to climate change

Our buildings have long lives so will be subjected to the stresses imposed by the predicted increases in temperature and the frequency of extreme weather events associated with climate change.

For example we need to respond to higher than expected temperatures through external shading, natural ventilation, thermal mass and insulation.

For more information on understanding climate change go to **www.climatechange.vic.au**

Included in this fact sheet:

Climate Zone

Temperature and rainfall

Adapting to climate change

Mandatory requirements:

You must meet: The National Construction Code (NCC) requirements, and the objectives and standards of the local planning scheme.

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Sun angles

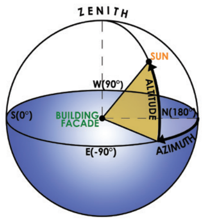

Figure 1.2 Altitude and Azimuth

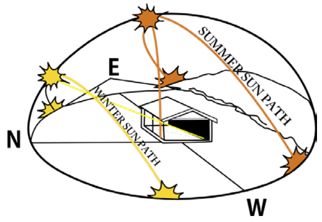

Figure 1.3 Winter summer sun paths

The sun's path changes throughout the year depending on date, time and location. Understanding the changing sun angle (altitude) and sun direction (azimuth) is an important aspect of passive design.

It allows us to calculate overshadowing and will influence the design of a building's envelope to reduce reliance on artificial heating and cooling.

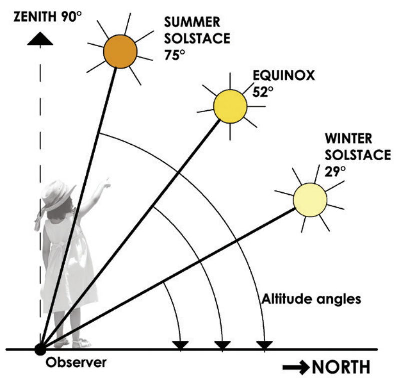

Figure 1.4 Melbourne northern sun angles

For example, in Melbourne during summer, northern sun angles reach their highest point at 75°. In winter the sun is lower, reaching only 29°.

It is best practice to orientate your building to maximise northern sun exposure. This provides an opportunity to use solar heat gain to passively heat your building. Knowing the sun's angles for different seasons means shading devices can be designed to allow beneficial winter sun and shade summer sun.

For sun angles for particular locations visit:
Sun Movement App **www.suncalc.net**

Wind patterns

By analysing wind rose diagrams prevailing wind patterns can be identified. This will inform your design when locating windows to allow cross ventilation for passive cooling. You will need to be aware of unique microclimates and site considerations that wind rose diagrams will not capture.

Example:

Melbourne Airport analysis

- Warm northerly winds prevail in winter.
- Wind direction varies on summer mornings but tend to be southerly during the afternoon.

In this location the installation of some operable windows on the southern facade will provide an opportunity for passive cooling.

For location specific climate data including prevailing wind directions, go to **www.bom.gov.au/climate/data**. Base your search on 'Monthly Climate Statistics'.

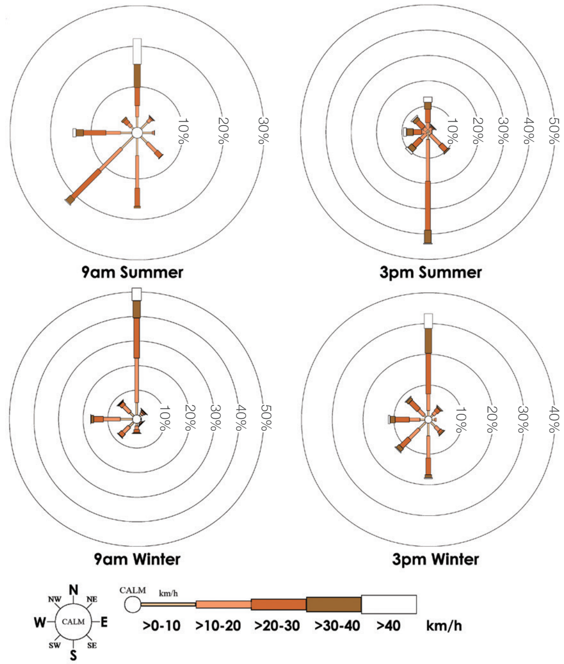

Figure 1.5 Wind rose diagrams – Melbourne Airport - Bureau of Meteorology

Included in this fact sheet:

Sun angles

Wind patterns

Mandatory requirements:

You must meet:
The National Construction Code (NCC) requirements, and the objectives and standards of the local planning scheme.

Macedon Ranges
Shire Council

Sustainable building design

Environmental site analysis

Every site is unique. The varying topography and range of altitudes within the Macedon Ranges will result in localised climatic patterns, meaning a site will have its own microclimate. Site specific variables such as altitude and topography, proximity to vegetation or lack of, will have an effect. Even houses on the same street can have different microclimates. Therefore, it is a valuable exercise to conduct a site analysis before commencing.

A site analysis is a way to graphically collate and summarise this preliminary site research. Combine local climate research findings such as prevailing wind directions and sun angles with site specific observations such as overshadowing and existing vegetation on to a site plan. This is then used as a starting point to identify a sites opportunities and constraints and well help to determine which passive solar strategies are suitable.

Example:

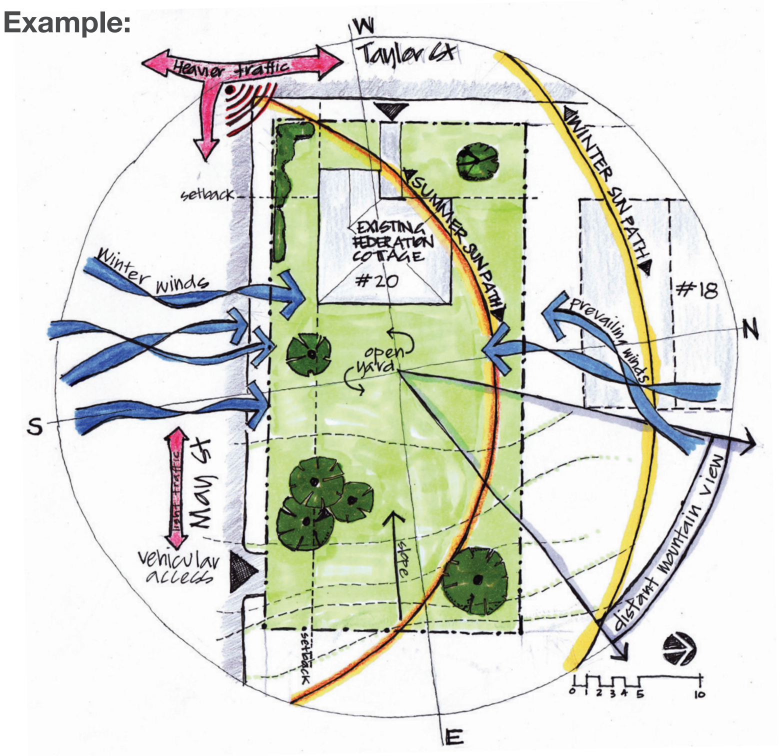

Figure 1.5 Site analysis: study for proposed addition to existing cottage

Items to include when creating a site analysis:

- **existing trees and vegetation**
- **site boundary**
- **setbacks** regulatory prescribed
- **prevailing wind**
- **views, aspects, sightlines**
- **noise arrow**
- **noise source**
- **contours, slope, fall**
- **slope direction**
- **site entry,** vehicular or pedestrian
- **north arrow**
- **scale bar**

Other information to note:

neighbouring buildings: height, proximity to boundary
heritage significance
ecological values: on site and surrounds
overshadowing: by buildings, landforms, vegetation
existing infrastructure: drainage lines, utilities
summer/winter sun path: www.suncalc.net

Included in this fact sheet:

Environmental site analysis

Mandatory requirements:

You must meet: The National Construction Code (NCC) requirements, and the objectives and standards of the local planning scheme.

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Passive design

Paying attention to principles of good passive design suitable for your climate ensures thermal comfort, low heating and cooling bills, and will reduce greenhouse gas emissions for the lifespan of your building.

Passive design utilises natural sources of heating and cooling, such as the sun and cooling breezes. It is achieved by appropriately orientating your building on its site and carefully designing the building envelope (roof, walls, windows and floors).

Window placement

Windows can be a major source of unwanted heat gain in summer and significant heat loss in winter if not designed and located appropriately.

North

Maximise, easy shading with eaves or shading devices.

South

Minimise, but allow sufficient openings to facilitate breeze path.

East

Avoid or minimise, with only small windows when necessary. Provide full external shading.

West

Receives the strongest sun at the hottest part of the day. Avoid or minimise, with only small windows where necessary.

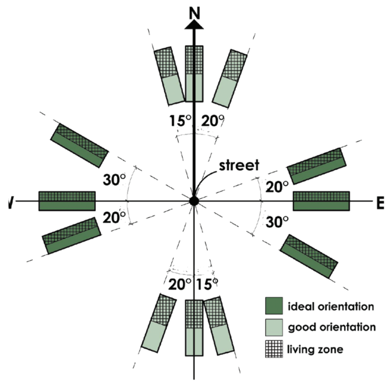
See fact sheets: 06 Sunshading and 07 Choosing the right window type.

Landscaping

Landscaping may be used to enhance solar gain and give protection from cold winds winter, provide shade and funnel cooling breezes into the house in summer.

Planting evergreen trees to the east and of a house can help in shading windows. Deciduous trees to the north will allow penetration to the building in winter, while providing extra shading in summer.

Orientation

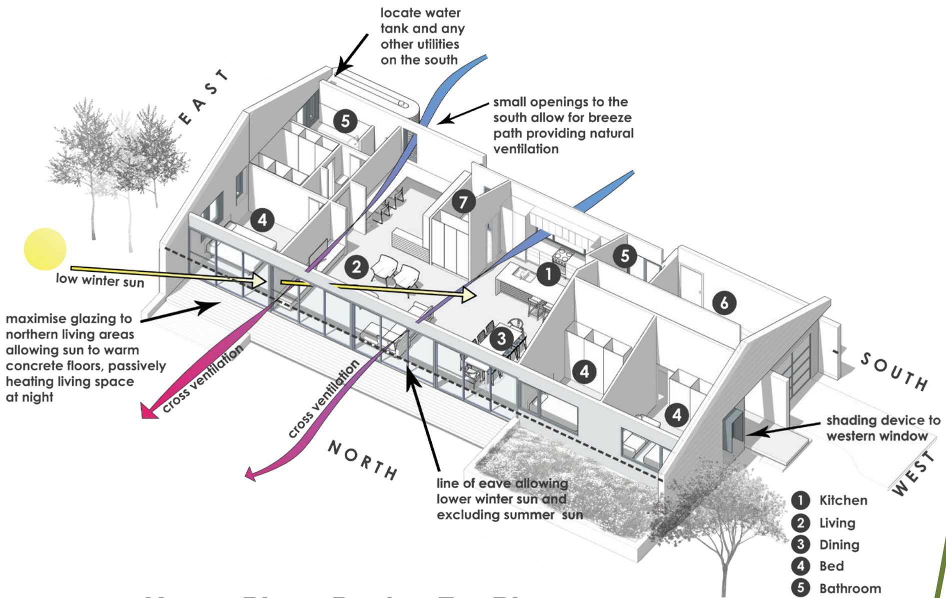


Key design objectives:

Orientate your building to make best use of sunlight and winds.

Key responses:

- Site new homes for solar access and exposures to cooling breezes. Provide protection from cold winds.
- Where passive solar access is unavailable, minimise glass areas and limit thermal mass. See fact sheet 08 Thermal mass.
- Maximise the use of north facing walls and passively shaded glazing. Due to the high sun angle in summer and low angles in winter the northern facade is easily shaded to allow full sun penetration in winter and blocking of unwanted sun in summer. See fact sheet 06 Shading devices.
- Locate living areas on the north and service areas on the south.
- A north facing roof will provide solar access for solar photovoltaics and hotwater panels.



House Plan - Design For Place

www.yourhome.gov.au

Included in this fact sheet:

Window placement

Landscaping

Orientation

Mandatory requirements:

You must meet: The National Construction Code (NCC) requirements, and the objectives and standards of the local planning scheme.

Macedon Ranges Shire Council

Sustainable building design

Daylighting

The controlled distribution of daylight is key to good energy performance, reducing the need for artificial lighting. Daylit buildings also contribute to occupant productivity, health and wellbeing.

A goal of new homes should be to not require electric lighting during daylight hours in habitable spaces.

Daylighting must be addressed early as requirements will have implications for building mass and zoning.

Principles for daylighting strategies:

- Strategically placed and appropriately sized perimeter windows should be provided to all habitable spaces.
- North facing windows should be maximised as they will provide controllable levels of sunlight and daylight.
- Use skylights and skytubes in areas where solar access from windows is not possible.
- High level windows will throw light deeper into rooms.
- Light coloured interior finishes reflect more light.
- Direct sunlight should be excluded from task areas because of glare and discomfort.

See fact sheet 06 Shading devices and 07 Choosing the right window type.

Ventilation

Windows should be located to facilitate cross flow ventilation by prevailing breezes specific to your sites location.

Breeze paths throughout the house should be kept clear to encourage air flow.

For adequate cross-ventilation:

- Breeze path should be no more than 15m.
- For single-sided ventilation, room depth should be no more than 5m.
- Ventilation openings should be at least 1m².

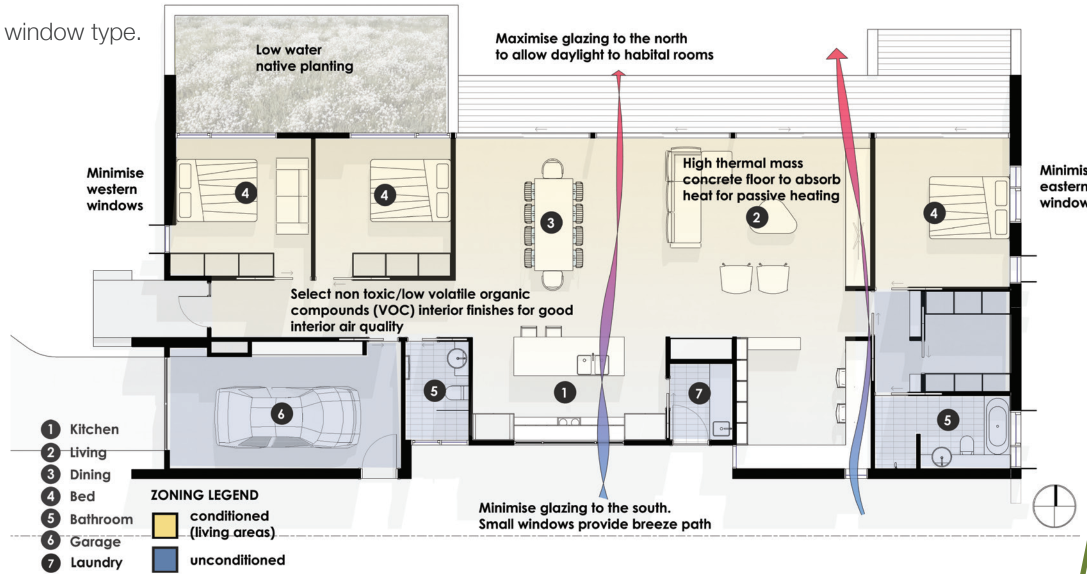
Zoning and internal planning

Internal arrangement of rooms should reflect functional relationships as well as similar heating and cooling needs to help reduce energy requirements.

- Conditioned spaces are habitable rooms frequently used for long lengths of time such as kitchen, living and dining rooms. Ideally these spaces should be located on the northern side allowing good solar access providing natural light and warmth to the space in winter. In summer shading devices such as awnings can be used to block unwanted heat gain. In cooler climates, if your floor has high thermal mass such as concrete or tile maximise glazing to allow floor to absorb heat from the sun and release it later at night. See fact sheet 08 Thermal Mass.
- Unconditioned spaces are used for shorter periods of time and usually do not require heating or cooling. They should be able to be compartmentalised from conditioned rooms so they are not being unnecessarily heated or cooled. Garages, storage spaces, laundries and bathrooms should be set to the less desirable side of a building like the south where possible.

House Plan - Design For Place

www.yourhome.gov.au



Included in this fact sheet:

Daylighting

Ventilation

Zoning and internal planning

Mandatory requirements:

You must meet:
The National Construction Code (NCC) requirements, and the objectives and standards of the local planning scheme.

Macedon Ranges Shire Council

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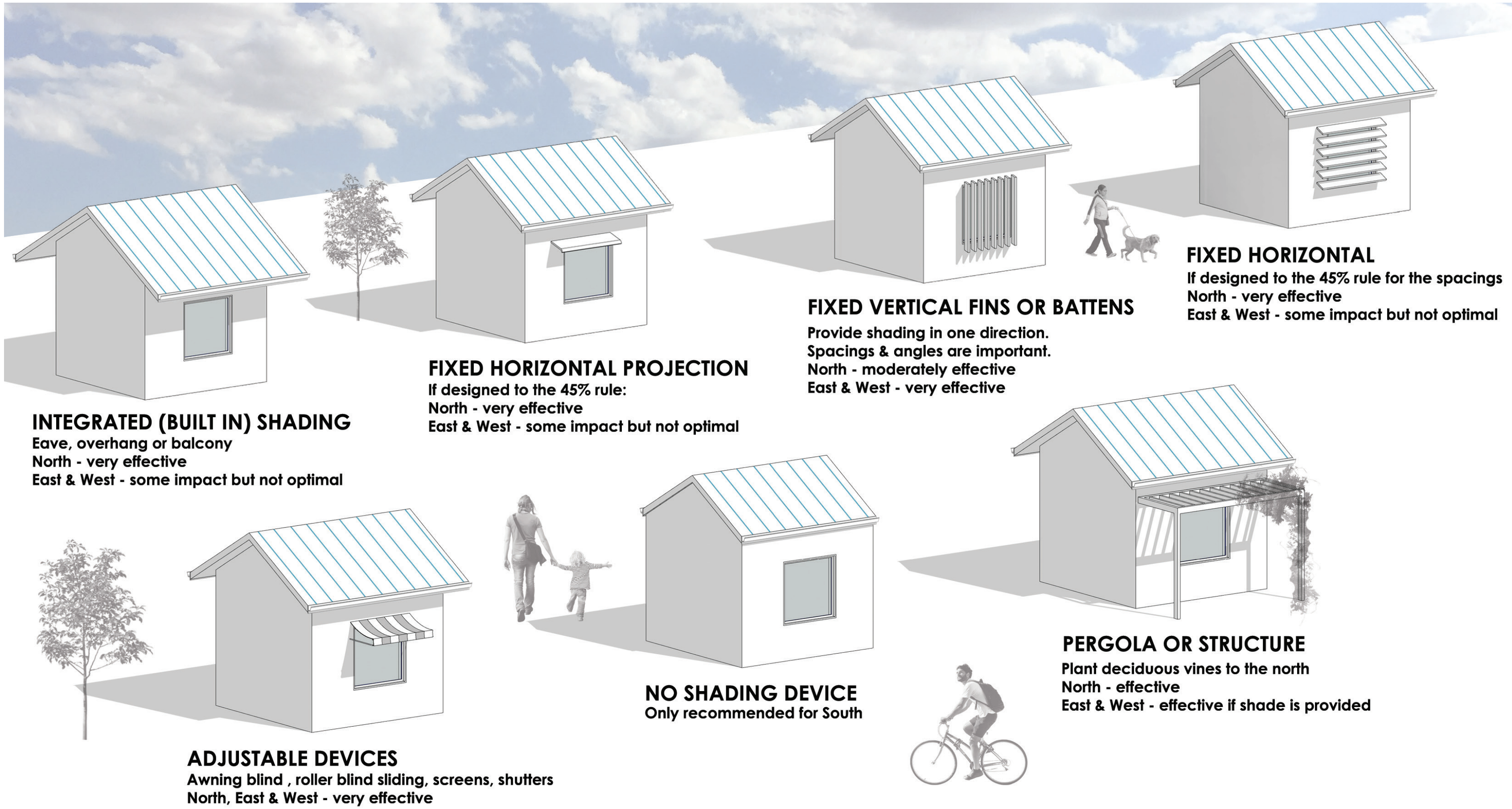
Shading devices

External shading devices protect the building envelope and reduce heat transfer through the building fabric. Appropriately designed sun shading will keep the building temperatures comfortable and will save energy and money on cooling and heating systems. External shading is up to five times more effective than internal shading. Shading should protect windows from unwanted heat gain in summer and allow heat gain in winter.

There is a huge variety of options, from carefully located deciduous plantings to simple solutions like shadecloth on a frame, to awnings, shutters, blinds, and even pergolas with sensor-operated louvre roofs.

To choose the best solution, it's important to consider your location and the orientation of your windows. See image below for different shading options.



Included in this fact sheet:

Shading Devices

Mandatory requirements:

You must meet: The National Construction Code (NCC) requirements, and the objectives and standards of the local planning scheme.

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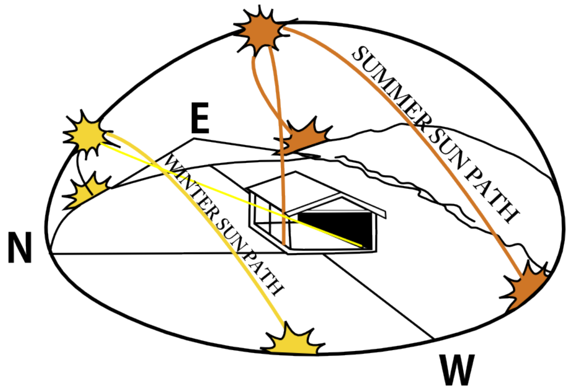


Different facades require different external shading

North

Due to the sun's high angle in summer, shading can be horizontal and fixed. To calculate the depth of the shading device follow the 45% rule pictured. This depth represents a good compromise between shading in summer and allowing winter solar gains.

Fixed horizontal shading includes eaves, awnings, pergolas and verandahs.

Adjustable external shading devices are also an option, provided the occupier uses them when required.

East and West

Even in summer, eastern and western facades are exposed to low sun angles. Due to those low sun angles, normal fixed horizontal sun shading becomes ineffective. Therefore adjustable shading devices are recommended.

Adjustable shading to some west facing glass areas means afternoon solar gains in winter can be utilized. This will also allow variable solar access in spring and autumn. These include canvas blinds, conventional roller shutters, angled vertical louvres or slats and pergolas with shade.

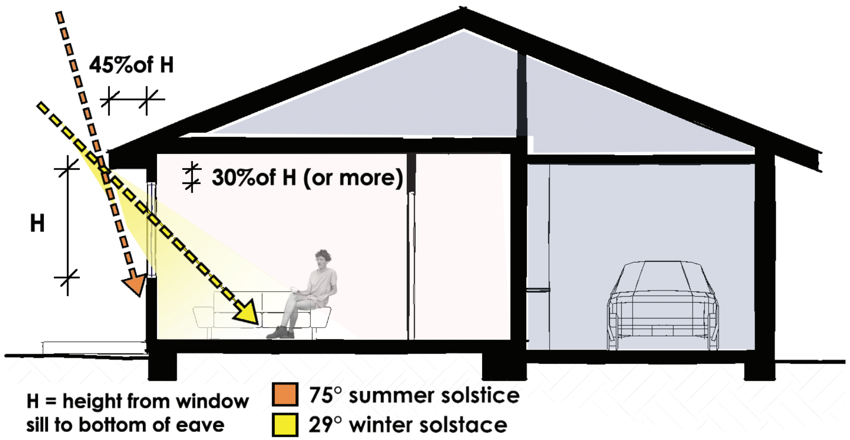
The devices will allow the occupants to respond to different seasons and individual comfort levels.

South

Southern facades receive very little direct sunlight. Therefore it is not essential to provide external shading to south facing windows.

Eaves - 45% rule

Correctly designed eaves are generally the simplest and least expensive method of shading. The following image explains a simple rule of thumb to ensure north facing glass will be fully shaded in summer and receive maximum solar access in winter.



Using this 45% rule, eave overhangs should be:

For window height of:	Eave
900-1200mm	450mm
1200-1350mm	600mm
1350-2100mm	900mm
2100-2700mm	1200mm

06b

Climate Responsive Design
Shading Design

Included in this fact sheet:

North

East and West

South

Eaves - 45% rule

Mandatory requirements:

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Macedon Ranges Shire Council

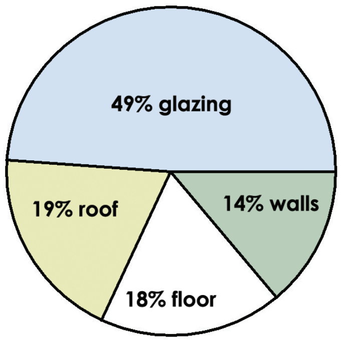
Sustainable building design

Choosing the right window type

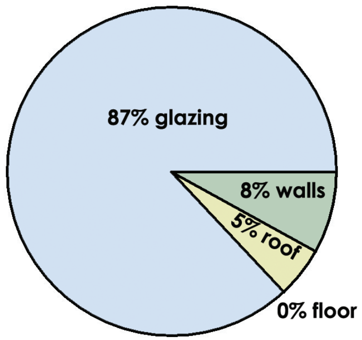
Windows can be complex. There are numerous types of glazing and framing types to choose from. Making the appropriate selection will greatly improve the energy efficiency of your building. Consider the benefits of admitting or rejecting solar heat and begin to think about glazing with solar heat gain coefficient (see definition below).

It is important to consider the interaction of the following aspects:

- climatic–temperature and prevailing winds
- orientation, form and layout
- construction materials-particularly the amount of insulation and thermal mass
- thermal properties of the glazing system
- external views.



Typical heat loss in dwellings:



Typical heat gain in dwellings:

How are windows rated?

The Window Energy Rating Scheme (WERS) rates the energy performance of windows, skylights and glazed doors. They provide a U-value and SHGC (see definitions below) value as well as a star value according to heating and cooling needs.

Conduction: U-value

Measures how readily a window assembly (frame, glass, seals) conducts non-solar heat via heatloss or gain.

The lower the U-value the better it's insulating value.

Note by selecting double glazing you can roughly halve the U-value.

Solar heat gain coefficient (SHGC)

Measures how readily heat from direct solar radiation flows through a window.
It is expressed as a number between 0 and 1.

The lower the SHGC, the less solar heat it transmits.

Example: Energy performance of common window types

Indicative window types	Total window system performance value	
	Uw	SHGCw
Aluminium window-single glazed with 3mm clear glass	6.9	0.77
Timber or uPVC window-single glazed with 3mm clear glass	5.5	0.69
Aluminium window-double glazed with 3mm clear glass/ 6mm air gap/ 3mm clear glass	4.2	0.69
Timber or uPVC window-double glazed with 3mm clear glass/ 6mm air gap/3mm clear glass	3.0	0.61

Note: Values are indicative only-source: Windows Energy Rating Scheme and NCC 2016

Included in this fact sheet:

Chosing the right window type

How are windows rated

Mandatory requirements:

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Macedon Ranges Shire Council

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Glazing types

Clear glass

Thickness has negligible impact on U value and SHGC. It does have effect on noise and strength.

Tinted glass

Has pigment added during manufacture. Usually bronze, grey, blue or green. SHGC depends on the type of tint and thickness of glass. U-value is not changed.

Low emissivity glass (low e)

Is a thin metal of film or coating added during manufacture.

There are 2 types:

High transmission - maximises solar heat gain. High SHGC.
Low transmission - rejects solar heat gain. Lower SHGC.

Note: Low e glass can dramatically improve both U-value and SHGC but must be used correctly or a passive solar building can fail to perform.

Can be used in combination with clear, tinted or reflective glass. Insulated glass units (IGU's): commonly double/ triple glazed. Multiple layers of glass with sealed cavities between each sheet. The cavity is filled with low conductive gas and sealed. Thickness ranges from 6-18mm. Wider cavities provide lower (better) U-values. The best performance levels for both U-value and SHGC can only be achieved using IGUs. Therefore it is benefi cial to all climates.

Framing types

Aluminium window frames

Light, strong and durable with a range of powdercoated and anodised finishes Aluminium is a good conductor of heat so can decrease the insulating value of the unit.

Dark coloured frames especially will absorb heat and conduct it inside. A thermal break is often used to reduce conductivity. It separates the interior and exterior frame pieces using a low conductivity material.

Note large amounts of energy is used to make aluminium but it can be recycled at the end of use.

Timber frames

Good insulator.

They require greater tolerances so be sure to seal gaps.

Timber absorbs carbon dioxide as it grows and retains carbon.

Always check timber is sourced from a sustainablbly managed forest.

Composite frames

Use thin aluminium profiles on the outer sections with either timber or uPVC (see below) inner section.

They combine low maintenance and durability of aluminium with thermal performance of timber.

uPVC (unplasticised polyvinyl chloride) frames

Have insulating properties similar to timber and can be molded into complex profiles to provide excellent door seals.

Rules of thumb for windows in cool climates

The priority is to retain heat in the building and to maximise 'free' solar energy in winter. Best results are obtained by windows that insulate well (low U-value) and admit plenty of free solar energy (high SHGC). When selecting a product look for WERS high heating Star Rating.

North

North windows are the 'solar collectors' so should have high SHGC. Fixed shading should be designed to shade only in summer.

East and West

East and West should have low SHGC. Although it is better to use adjustable external shading where possible.

For all orientations

For all orientations it is better to have a low U-value as it measures the ability to retain heat in winter and cool in summer.

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Understanding thermal mass

Thermal mass describes the ability of a material to absorb heat, store it, and at a later time release it. The denser the material the greater its thermal mass. High thermal mass materials include concrete, brick, mud brick and rammed earth. Lightweight materials such as timber and insulation have low thermal mass.

Appropriate use of thermal mass will make a big difference to the interior comfort of the building and reduces the need for mechanical heating and cooling.

Mass alone will not create a thermally comfortable building. It must form part of an integrated approach using solar passive principles appropriate to your climate. Incorporate good orientation, appropriate sizes and location of windows, appropriate shading, insulation (where required) and the use of natural ventilation.

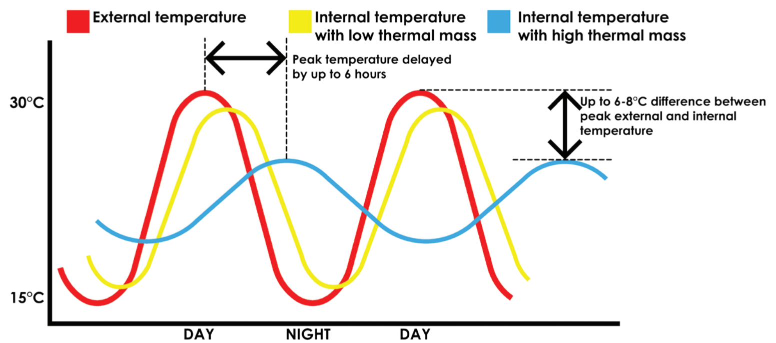

Figure 6.1: Stabilising effect of thermal mass on internal building temperatures.

Thermal mass and climate

High levels of thermal mass are beneficial throughout Victoria, with the exception being alpine regions and areas where solar access is poor. In these locations thermal mass can have a negative effect. With little possibility of solar heat gain, supplementary heating will be required. The mass will absorb this heat before the air temperature rises, increasing the energy needed to heat the building.

Thermal mass is particularly effective in places where there is a big difference in diurnal (day/night) temperature. The difference should be around 10°Celsius.

Where to place thermal mass

Inside the insulated building envelope

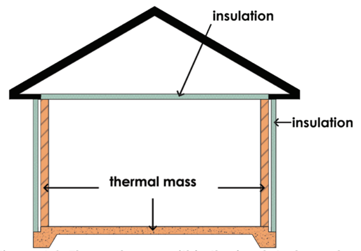

Figure 6.2: Thermal mass within the insulated envelope

For maximum effectiveness, thermal mass should be insulated from external temperatures.

The amount of heat lost in winter and heat gained in summer to internal spaces will be dramatically reduced by installing the correct amount of insulation.

Inside north facing rooms

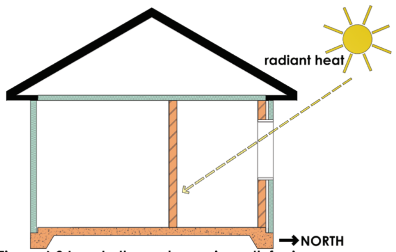

Figure 6:3 Locate thermal mass in north facing rooms.

Floors and walls with high thermal mass are best placed in north facing rooms where winter sun can penetrate the glazing and heat the mass. The mass will store the sun's heat (radiant heat) during the day and release it into the living spaces at night, passively heating the building and reducing the need for mechanical heating.

Conversely, in summer, assuming the northern glazing is properly shaded, excess environmental heat entering the building will be absorbed into the thermal mass, allowing the air in the space to remain cool during the hottest part of the day. At night, any heat gain in the room can be purged through cross flow ventilation. This system is know as passive cooling.

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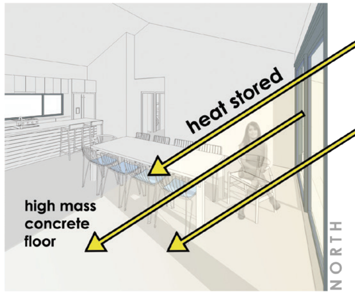
Sustainable building design



Daylight hours
Thermal mass captures and stores solar heat gain

Night time
Thermal mass re-radiates heat after the sun has gone

Thermal mass construction examples

Mud brick/rammed earth are generally thick walls (approximately 300mm) and have high thermal mass.

When outside temperatures fluctuate above and below comfort temperatures, appropriately placed thermal mass evens out internal temperature, performing particularly well in summer. In winter however, the low thermal resistance can lead to poor winter performance as heat is absorbed and lost through the walls.

For example, six times as much heat passes through a mud brick or rammed earth wall compared to an insulated brick veneer wall. To reduce heat loss in winter it is advisable to install external insulation. Do not add insulation to the internal face as the thermal mass benefit will be lost.

How to insulate mud brick or rammed earth:

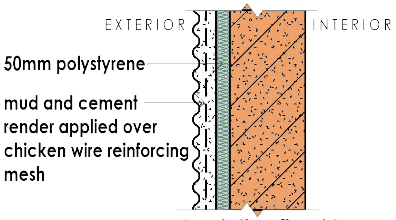


Figure 6.5: Insulation fixed to the outside of the mud brick

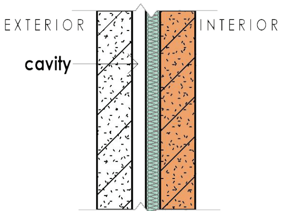


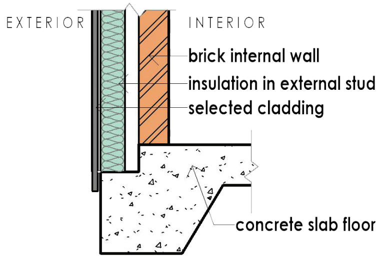
Figure 6.6: Insulation fixed to the outer side of the inner mud brick leaf

Reverse brick veneer

As the name suggests, the brickwork is on the inside and timber framing on the outside (i.e. reverse of traditional construction). This enables a timber style home to achieve the same level of thermal performance as a double brick home.

By placing the brick skin on the inside it sits within the insulated envelope.

Reverse brick veneer does not need to be used for the whole home. It may only be used for the north facing rooms. The external skin can be any type of lightweight cladding suitable for exterior use.



Reverse brick veneer on concrete

Included in this fact sheet:

Thermal mass construction examples

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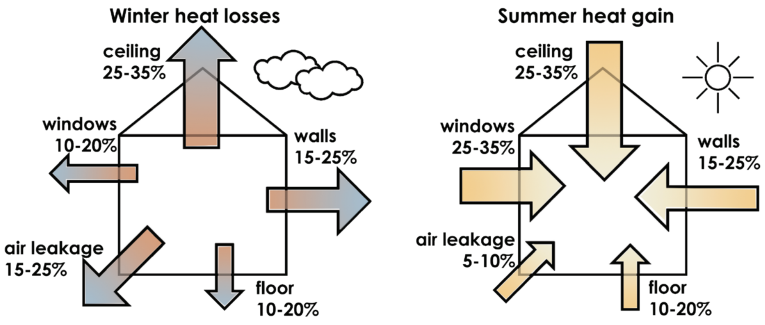
Sustainable building design

Insulation

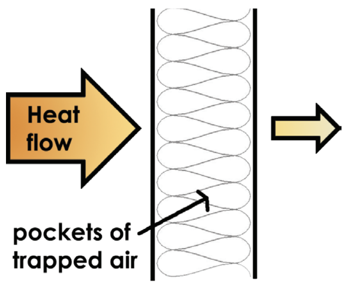


Typical heat losses and gains without insulation in a temperate climate

Most common types of insulation

Bulk insulation

Resists the transfer of heat by trapping air within its structure. It is important not to compress bulk insulation, as the air pockets will be compressed and lose its insulation properties.

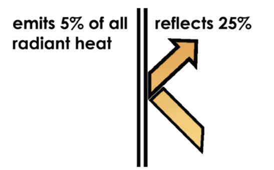


Type	Low toxicity	Environmentally friendly	Soundproof
Polyester	✓✓	✓✓	✓
Natural wool	✓✓✓	✓✓✓	✓
Glass wool	✓	✓	✓✓
Rockwool	✓	✓✓	✓✓
Cellulose fibre	✓✓	✓	✓
Extruded or expandable polystyrene	✓	✓	✓✓

Reflective insulation

Resists radiant heat due to its reflectivity and low emissivity (ability to re radiate heat).

Shiny aluminium foil laminated onto paper or plastic available as sheets (sarking), concertina batts and multi batts known collectively as reflective foil laminate.



Double sided reflective foil

How is insulation rated?

R-value

Measures the material's thermal resistance to heat flow including the amount of heat lost in winter and gained in summer.

The higher the R-value the greater the resistance to heat transfer.

Different products with the same R-value will provide similar insulation performance, regardless of thickness or the type of material.

Place the highest feasible insulation levels. Remember that codes typically require only minimum acceptable insulation values. More insulation will be more cost effective over time.

Given comparable R-values, always choose high recycled content insulation over alternatives made from virgin materials. Require that scrap insulation generated on site be recycled.

Included in this fact sheet:

Types of insulation

How is insulation rated

Mandatory requirements:

You must meet: The National Construction Code (NCC) requirements, and the objectives and standards of the local planning scheme.

Macedon Ranges Shire Council

Sustainable building design

Thermal bridging

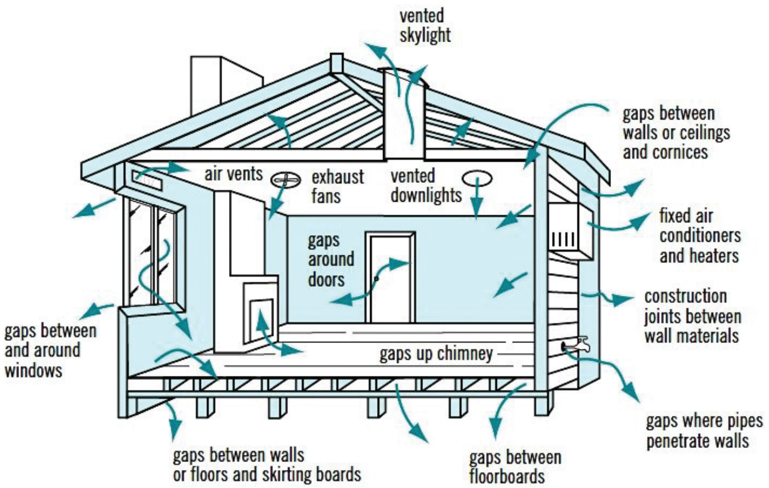
An area of building construction that has received increasing attention in recent years is thermal bridging. It refers to the penetration of the insulation layer by solid non insulating building materials, through which heat can be transferred between the interior to the exterior environment.

For example: timber or metal studs in a building frame. Thermal bridging has been shown to reduce the R-Value of a wood frame by 10% and of steel by 55%.

Continuous insulation

Insulation needs to be continuous. The envelope of a building will be penetrated by windows, doors, piping and wires. Each of these penetrations has potential to create gaps reducing the thermal efficiency. Penetrations should be kept to an absolute minimum. If this can't be avoided, use materials that are less conductive (e.g. timber in place of metal) and/or incorporate thermal breaks (whereby a material that doesn't conduct heat well separates conductive elements). Otherwise your insulated building will have a number of thermal highways that will cause increased energy consumption and impact greatly on thermal comfort.

Common locations for air leakage in house construction:



Other considerations and tips

- The thermal performance claimed on a products packaging assumes no gaps. Often insulation gets moved or shifted for services and not replaced severely reducing the effectiveness.
- Downlights require holes to be cut in insulation plus they often cause considerable air leakage.
- In a cool climate 80% of energy lost through a concrete slab will be lost through the slab edge. Consider insulating the slab edge.
- Pay attention to common areas for air leakage and closing these gaps will increase energy efficiency.
- Light weight construction with good insulation can deliver just as good performance as a home with well placed thermal mass. In areas of great shade, light weight may even outperform high mass.

Included in this fact sheet:

Thermal bridging

Continuous insulation

Other considerations and tips

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