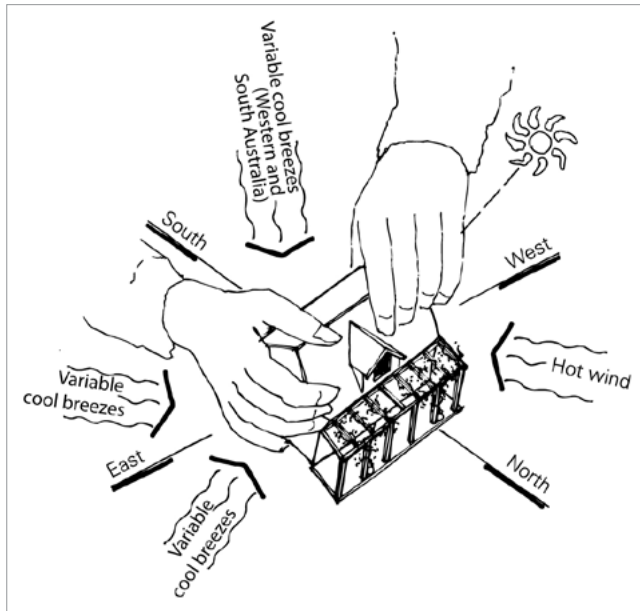


# Orientation

Orientation is the positioning of a building in relation to seasonal variations in the sun's path as well as prevailing wind patterns. Good orientation can increase the energy efficiency of your home, making it more comfortable to live in and cheaper to run.

Read about the principles of good orientation in this article in conjunction with *Passive solar heating*, *Passive cooling* and *Shading*. Identify your climate zone and develop an understanding of appropriate design responses by referring to *Design for climate*.



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

When deciding the best orientation for your home, bear in mind that the climate is warming, and hotter summers with more extreme heat waves will become the norm during its life span. While passive solar heating is still very desirable in climates that require heating, the priority will gradually shift from heating to cooling. Additional attention to shading of windows and walls (particularly west facing) and exposure to cool breezes and other forms of natural cooling is required in all climate zones.

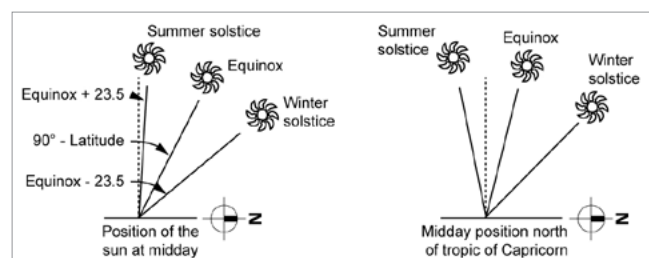
## Principles of good orientation

Good orientation, combined with other energy efficiency features, can reduce or even eliminate the need for auxiliary heating and cooling, resulting in lower energy bills, reduced greenhouse gas emissions and improved comfort. It takes account of summer and winter variations in the sun's path as well as the direction and type of winds, such as cooling breezes.

*Good orientation can help reduce or even eliminate the need for auxiliary heating and cooling, resulting in lower energy bills, reduced greenhouse gas emissions and improved comfort.*

Ideally, choose a site or home with good orientation for your climatic and regional conditions and build or renovate to maximise the site's potential for passive heating and passive cooling, adjusting the focus on each to suit the climate. For those sites that are not ideally orientated, there are strategies for overcoming some of the challenges.

In hot humid climates and hot dry climates with no winter heating requirements, aim to exclude direct sun by using trees and adjoining buildings to shade every façade year round while capturing and funnelling cooling breezes.

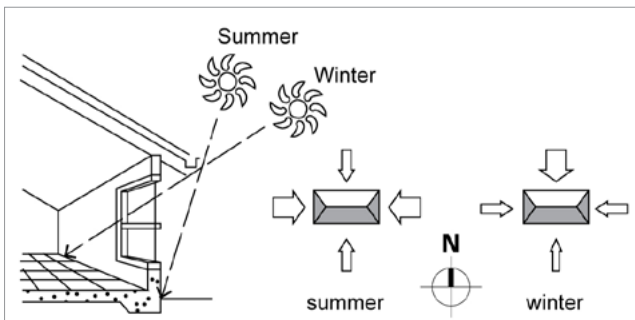


Left: How to calculate sun angles. (See *Shading* for a table of latitudes from which to calculate sun angles for Australian cities.) Right: Midday sun position north of the tropic of Capricorn.

In all other climates a combination of passive solar heating and passive cooling is desirable. The optimum balance between capturing sunlight (solar access) and capturing cooling breezes is determined by heating and cooling needs.

North orientation is generally desirable in climates requiring winter heating, because the position of the sun in the sky allows you to easily shade northern façades and the ground near them in summertime with simple horizontal devices such as eaves, while allowing full sun penetration in winter.

North-facing walls and windows receive more solar radiation in winter than in summer. As shown in the diagram, the opposite is true for other directions — and why, in mixed or heating climates, it is beneficial to have the longer walls of a house facing north to minimise exposure to the sun in summer and maximise it in winter.



Average daily solar radiation on vertical surfaces.

## Choosing the best orientation

Prioritise your heating and cooling needs. Are you in a climate that requires mainly passive heating, passive cooling, or a combination of both?

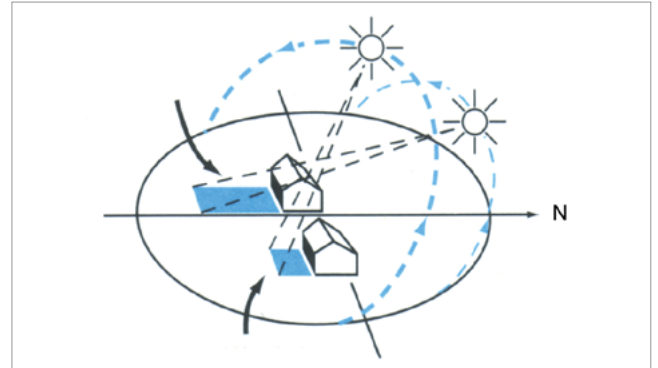
Compare your summer and winter energy bills, consult an architect or designer, ask your local energy authority or refer to local meteorological records.

Your local climate research should study:

- temperature ranges, both seasonal and diurnal (day–night)
- humidity ranges
- direction of cooling breezes, hot winds, cold winds, wet winds
- seasonal characteristics, including extremes
- impact of local geographic features on climatic conditions (see *Choosing a site*)
- impact of adjacent buildings and existing landscape.

The Australian Bureau of Meteorology ([www.bom.gov.au](http://www.bom.gov.au)) provides wind roses for each region in Australia. They are based on daytime data and don't address evening and night breezes that are often the main source of cooling.

## Orientation for passive heating



Sun movement from high angle in summer to low angle in winter.

Orientation for passive heating is about using the sun as a source of free home heating by letting winter sun in and keeping unwanted summer sun out — desirable in the majority of Australian homes. It can be done with relative ease on northern elevations by using horizontal shading devices to exclude high angle summer sun and admit low angle winter sun.

'Solar access' is the term used to describe the amount of useful sunshine striking glass in the living spaces of a home. The desired amount of solar access varies with climate.

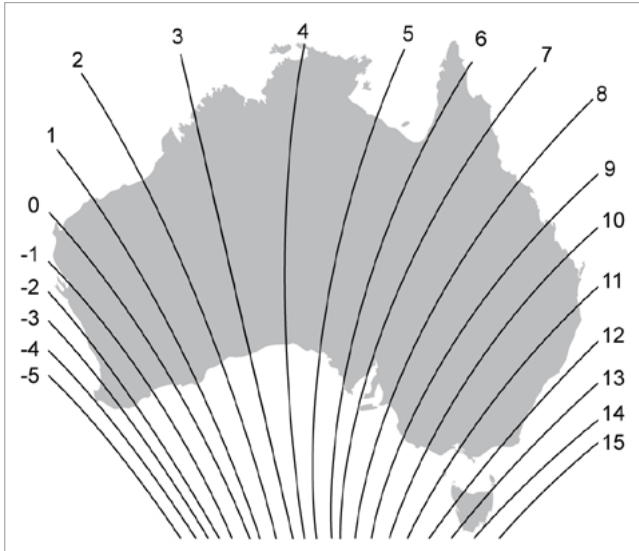


The sun is a source of free home heating.

# Passive design

## Orientation

First, establish true or solar north for your region. This is useful in all climates whether you are encouraging or excluding solar access. Just use maps and street directories, or use a compass to establish magnetic north and then find true or solar north by adding or subtracting the 'magnetic variation' for your area using the map below.



Source: Dr Holger Willrath, Solar Logic

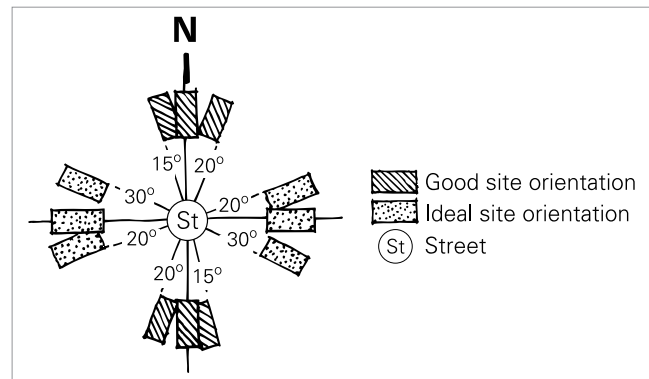
True north as degrees west of magnetic north.

Solar north deviates significantly from magnetic north throughout Australia. Take this into account when orienting a home. All references to north in this guide are to solar north, not magnetic north.

Precise orientation is not as critical as many people think. While ideal orientation (in most climates) is solar north, orientations of up to 20° west of north and 30° east of north still allow good passive sun control. As can be seen from the diagram below, good solar orientation is possible on most sites.

Variations in orientation towards east and west can have advantages in some climates and for some activities. For example, in cold climates, orientations west of north increase solar gains in the afternoon when they are most desirable for evening comfort, but east of north can warm the house more in the mornings, improving daytime comfort for those who are at home then. In warmer climates, orientations east of north can allow better capture of cooling breezes.

Poor orientation and lack of appropriate shading can exclude winter sun and cause overheating in summer by allowing low angle east or west sun to strike glass surfaces at more direct angles, reducing reflection and increasing solar gains.



Orientation does not have to be precise: there is a degree of flexibility.

A range of methods is available for measuring and assessing the amount of solar access required when designing a new home, renovating an existing home or buying a unit. The most thorough (and commonly used) method is to have an accredited thermal performance assessor simulate the home's thermal performance using house energy rating software such as AccuRate, BERS Pro and First Rate. This will identify both problems and opportunities. Accredited assessors can be contacted through the Association of Building Sustainability Assessors or the Building Designers Association of Victoria.

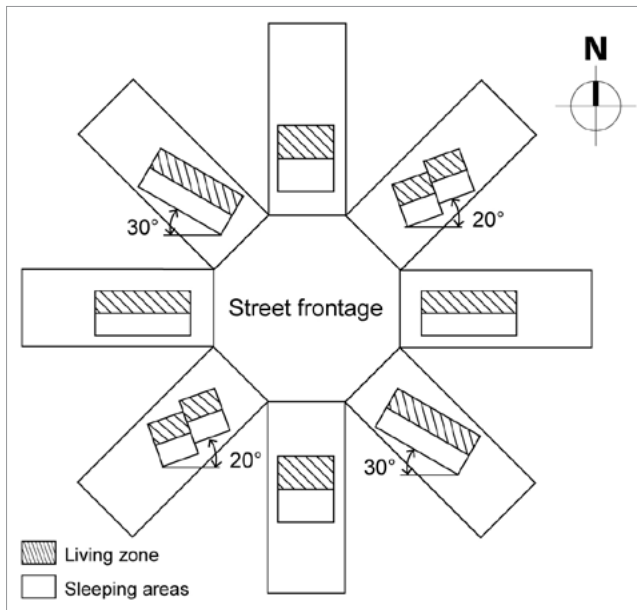
Traditional methods using charts and formulas are rarely used these days because they are unable to model the complex interaction of the multiple variables that determine how a house will perform. These variables are addressed in detail in the *Passive design* articles that follow and include *Shading*, *Insulation*, *Glazing* and *Thermal mass*.

## The site

You can achieve good passive solar performance at minimal cost if your site has the right characteristics. Where possible, choose a site that can accommodate north-facing daytime living areas that flow to outdoor spaces with similar orientation. In tropical areas, northerly solar access is not desirable: sites that allow maximum exposure to cooling breezes and designs that draw or funnel them through the building are preferable. (see *Choosing a site*)

On smaller sites achieving permanent solar access is more likely on north-south blocks because they receive good access to northern sun with minimum potential for overshadowing by neighbouring houses. In summer, neighbouring houses can provide protection from low east and west sun.

However, on narrow blocks, careful design is required to ensure sufficient north-facing glass is included for adequate passive solar heating.

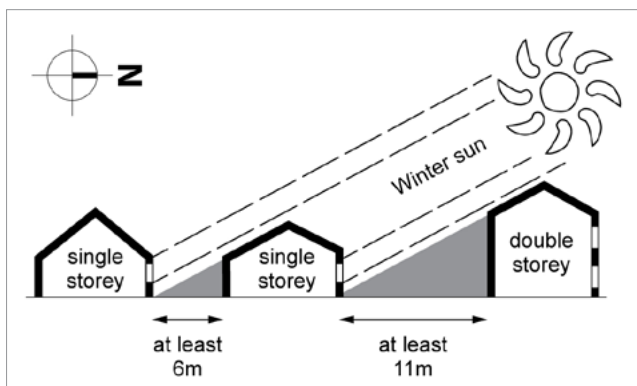


Source: AMCORD

Orientation possibilities on a cul-de-sac.

North-south sites on the north side of the street allow north-facing living areas and gardens to be located at the rear of the house for privacy.

North-south sites on the south side of the street should be wide enough to accommodate an entry at the front as well as private north-facing living areas. Set the house back to accommodate a north-facing garden and consider creating a private outdoor living courtyard with plantings or even a garage on the northern boundary where planning permits.



The lower angle of winter sun can limit solar access.

Sites running east-west should be wide enough to accommodate north-facing outdoor space. Overshadowing by neighbouring houses is more likely on these sites — particularly if multi-level housing is permitted, as winter sun is lower in the sky, particularly in southern latitudes.



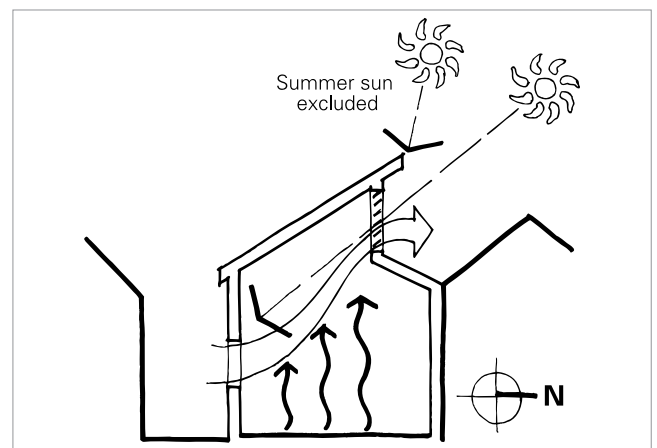
Source: AMCORD

Orientation on slopes.

A north-facing slope increases the potential for access to northern sun and is ideal for higher housing densities. A south-facing slope increases the potential for overshadowing. Your design for solar access should not compromise that of your neighbours.

At subdivision level, smaller individual lots are ideally located on north-facing slopes where they still receive solar access at increased densities.

South-facing slopes are often better suited to medium density where party walls can be designed to provide thermal buffers and smaller floor areas can be solar heated with carefully designed and shaded east or west-facing windows using advanced glazing.



High level openable windows capture winter sun and create cooling currents in summer.

# Passive design

## Orientation

Views to the north are an advantage, as north is the preferable direction to position windows and living areas. If the view is to the south, avoid using large areas of glass in order to minimise winter heat loss or use mirrors to reflect north sun onto the glass (Wrigley 2012).

Clerestory (high level) windows can be used to capture winter sun and create stack ventilation (rising hot air) in summer. Sunlight entering through clerestory windows should strike thermal mass at lower levels so that heat is stored for later release. Failure to do this can produce pockets of heat in high level, uninhabited spaces that is quickly lost through the glass at night.

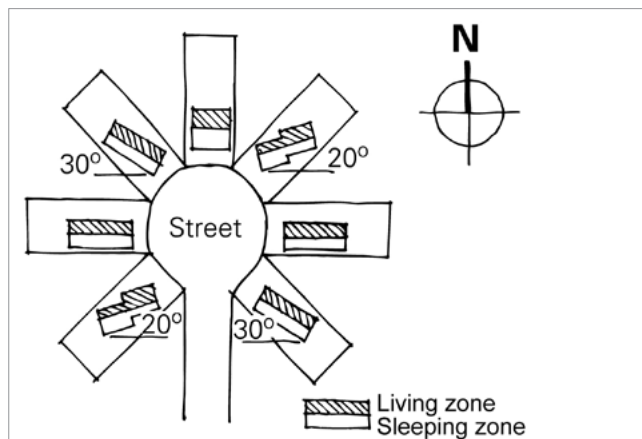
Clerestory windows should not be used in cold climates unless carefully designed, as daytime heat gains rarely offset night-time heat losses and cold draughts are unavoidable.

### The house

The ideal orientation for living areas is within the range 15°W–20°E of true or 'solar' north (although 20°W–30°E of true north is considered acceptable). It allows standard eaves overhangs to admit winter sun to heat the building and exclude summer sun with no effort from the occupants and no additional cost.

Poor orientation can exclude winter sun as well as cause overheating in summer by allowing low angle east or west sun to strike glass surfaces, creating a greenhouse effect where it's not required. Choose a house that has good orientation or can be easily adapted for better orientation.

Build close to the south boundary to maximise sunny, north-facing outdoor living areas and protect solar access but avoid compromising the solar access of neighbours. Choose a home with living spaces that have good access to winter sun.

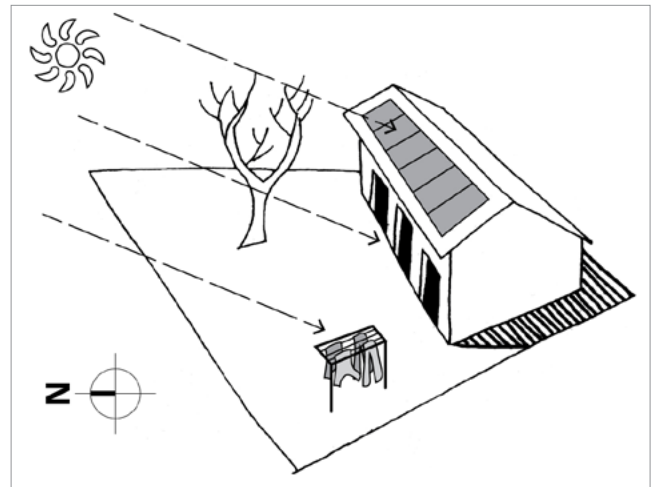


Daytime living areas shown shaded.

Look for a suitable area of glass on north-facing walls with access to winter sun. As a general guide this should be 10–25% of the exposed thermal mass floor area of the room. This rule can vary considerably depending on design, glazing type and exposed thermal mass. (see *Thermal mass*)

Check that west-facing glazing is not excessive in area and is properly shaded to prevent overheating. West-facing walls receive the strongest sun at the hottest part of the day.

Check that there is no significant detrimental overshadowing (of both windows and roof where photovoltaics and solar hot water may be located) by adjacent buildings and trees.



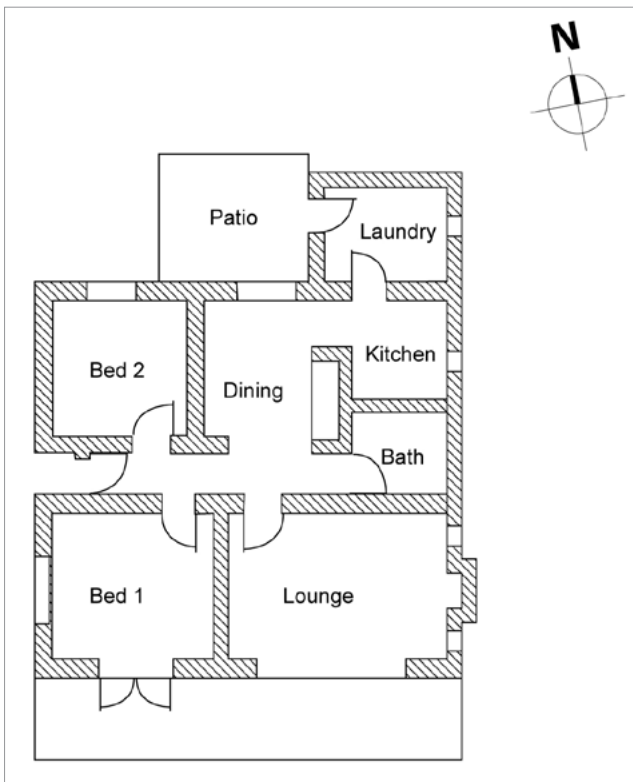
Source: SEAV

Northern side of the house is free from major obstructions.

Ensure year-round solar access for clothes drying and solar collectors.

When renovating, adjust floor plan and orientation to trap the winter sun and encourage summer breeze flow by adding new windows, changing openings and relocating rooms that block breezes and sun.



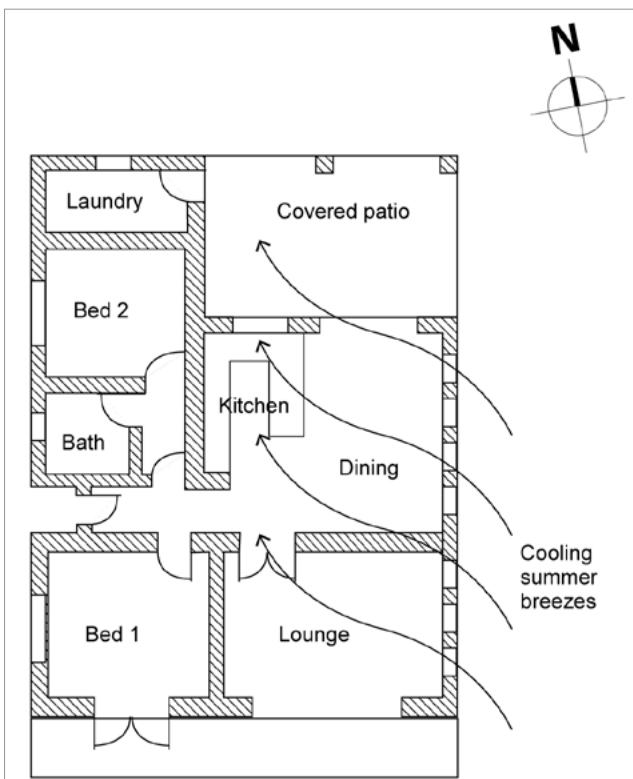


Original floor plan.

## Checklist for designing a new home or renovating

When you build, buy or renovate, there are things you can do or features to look for to achieve the best thermal comfort your site or home can offer. The following points are a brief overview: for more detailed information see *Buying an existing home*.

- Relocate living areas to take advantage of winter sun and cooling summer breezes.
- Maximise north-facing daytime living areas where passive solar access is available.
- Use smaller, well shaded windows to increase cross-ventilation to the south, east and west.
- Avoid west-facing bedrooms to maintain sleeping comfort.
- Locate utility areas (laundries, bathrooms and garages) on the south or west where possible.
- Avoid placing obstructions such as carports or sheds to the north.
- Plant shade trees in appropriate locations; landscape to funnel cool breezes and block or filter harsh winds.
- Prune vegetation that blocks winter sun; alternatively plant deciduous vegetation that allows winter sun in but provides summer shade.



New floor plan.

## Checklist for choosing a project home

For more detailed information than the following brief overview, read *Buying a home off the plan*.

- Select a design that allows daytime living areas to face between 15° west of north and 30° east of north on your site. Most project home companies will mirror or flip a design to suit your needs at no extra cost. East is best in warmer climates and west in cooler climates.
- Turn north-facing verandas into pergolas (including those with adjustable blades) by replacing roofing material such as tiles or metal with slats or louvres, particularly over window areas.
- Shade east and west-facing glass by adding or relocating shade structures including verandas and deep covered balconies.
- Reduce the amount of south, east and especially west-facing glazing, or relocate some to north-facing walls.
- Select smaller windows on south, east and west-facing walls to aid cross-ventilation.

*Most project home companies will mirror or flip a design to suit your needs at no extra cost.*

# Passive design

## Orientation

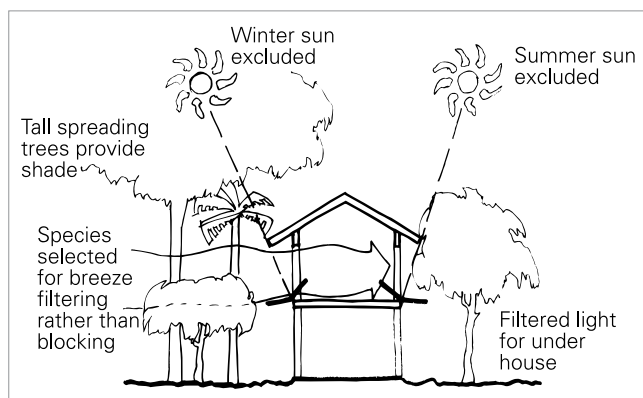
### Checklist for choosing a unit

Orientation is particularly important when buying a unit because external modifications such as shading are often prohibited by body corporate rules intended to preserve the visual amenity of the building. For more detailed information than the following brief summary, see *Buying and renovating an apartment*.

- Solar access to living areas is highly desirable (except in the tropics).
- Good exposure to cooling breezes is essential in hotter climates.
- Look for well-designed cross-ventilation to distribute cooling breezes through the unit.
- North-east corner units, north-south cross-over (split level) or cross-through (one side to the other) are ideal.
- North-facing living areas and balconies or outdoor spaces are ideal.
- Look for passive shading to north glass and well-designed adjustable shading to east and west.
- Avoid units facing west only.
- Look for sheltered balconies or courtyards with winter solar access.
- Sunny, sheltered spaces and facilities for community interaction are a desirable feature.

### Orientation for cooling dominated climates

Good orientation for passive cooling keeps out unwanted sun and hot winds while ensuring access to cooling breezes. A degree of passive cooling is required in most Australian climates but in hot humid climates, orientation should aim to exclude direct sunlight and radiant heat (from nearby structures) at all times of the year while maximising access to cooling breezes.



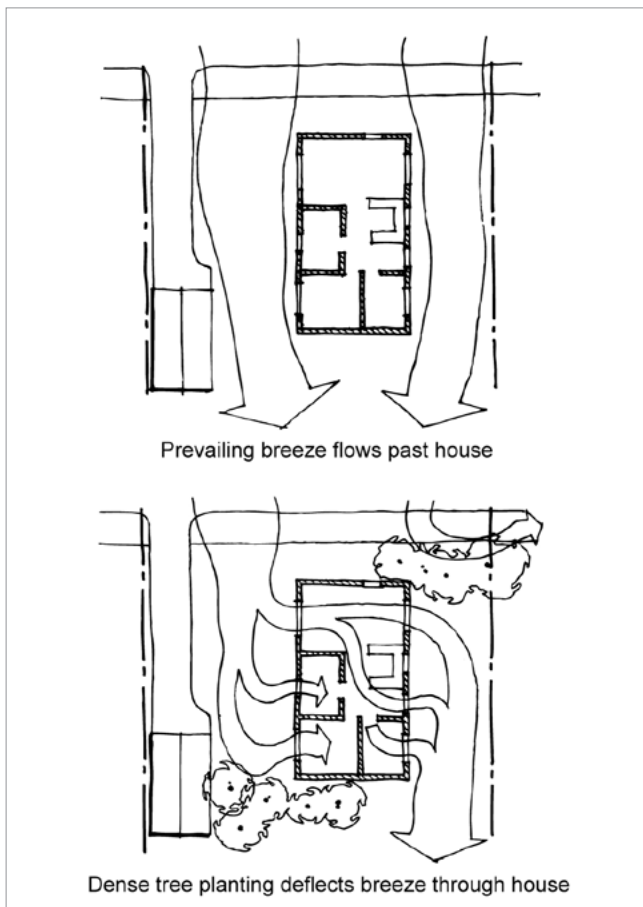
Orientation for an elevated tropical house.

### What is good cool breeze access?

Cool breezes can come from a range of directions but near the coast are generally onshore. On the east coast of Australia, they are generally north-easterly to south-easterly whereas on the west and southern coasts, they are commonly south-westerly. The predominant cooling breezes in Darwin are from the north-west in the wet season and the south-east in the dry season.

Breeze direction can vary within a few hundred metres due to landforms, vegetation or other buildings. Talk to your neighbours or spend time on your site in hotter seasons to establish the direction of your most reliable cooling breezes.

While many inland areas often receive no regular breezes, cool air currents form as cooling night air flows down slopes and valleys (just as water would), and in flat inland regions, thermal currents created by diurnal temperature differences also provide useful cooling. These are often of short duration and occur later at night or in early morning and need to be trapped and stored as 'coolth' for the following day. (see *Thermal mass*)



Cool breeze diversion.

*Unlike sunlight, breezes can be diverted, so find a way to divert them through your home using fences, outbuildings, plantings and windows that open widely.*

### **What other passive cooling options are there?**

**Night purging** of heat from the building to cooler night air is critical for thermal comfort. Because breezes are often unreliable, alternative means of purging are recommended. Among the most effective means is a whole-of-house fan that creates breezes.

**One way roof insulation** uses low emissivity reflective insulation to reduce daytime heat gains while allowing conduction and convection to allow upward flow of heat at night. This is only useful in climates with low or no heating needs. (see *Insulation*)

**Radiant cooling to clear night skies** is also effective but difficult to achieve. Clear night skies provide a limitless source of radiant cooling for areas and surfaces that can be exposed to it. Outdoor living areas and sleep-outs are the most effective but large openings with exposure to night skies are also able to shed heat. Design and orientation of glazing for passive solar heating requires unobstructed sky exposure and this can be very useful for radiant summer cooling.

**Active cooling systems** use roof mounted solar panels that heat the home in winter to cool it in summer by running in reverse — drawing heat out of the building and radiating it to clear night skies and cool night air. Parts of the roof must have unobstructed solar access for this to work.

### **The site**

Look for a site with good access to cooling breezes. Ensure that landscape and adjacent buildings funnel rather than block beneficial breezes and provide shade to all walls.

Land with a south-facing slope provides increased shade. South is ideal for views because south-facing windows require minimal shading. In regions with cooler winters, however, glass areas should be small to limit heat loss. The overhang of eaves should be broader above the tropic of Capricorn because of increased southern solar exposure.

Solar access to some part of the site between 9am and 3pm is beneficial for clothes drying and vegetable gardens in all climates, and uninterrupted solar access to roof areas is highly desirable for solar collectors. Passive solar access becomes increasingly important as heating needs increase.

Innovative design and fans can achieve thermal cooling comfort on sites with limited access to cooling breezes. Use high level windows and vents to create convection currents for cooling in the absence of breezes. Use low mass construction except for regions where earth temperatures maintain earth coupled slab temperatures below 19°C. (see *Thermal mass*)

### **The house**

Choose or design a house with maximum exposure to cooling breezes and limited or no exposure to direct sun, depending on climate. Use careful design to improve performance in the case of poorly oriented sites or existing homes.

- Narrow, elongated or articulated buildings facilitate passive cooling. Ideally the long elevation should open up to cooling breezes.
- Avoid or shade west-facing walls and windows if possible as they receive the strongest radiation at the hottest part of the day.
- Open plan internal layouts facilitate ventilation. Houses of one-room depth are ideal.
- 100% openable windows or openable insulated panels located on more than one side of a room improve ventilation.
- Outdoor living areas (courtyards, verandas and balconies) should be shaded at all times and fitted with ceiling fans.
- Use security screens over openings to allow safe, effective ventilation.
- Alternatively, highly insulated and shaded rooms can be efficiently cooled by the highest energy rated air conditioning and the energy used offset with rooftop photovoltaics. This may provide the 'least cost' solution.

### **Checklist for designing a new home or renovating**

When you build or renovate, maximise what your site has to offer according to this brief overview or see *Buying an existing home* for more detailed information.

- Configure or reconfigure rooms to capture and encourage the flow-through of cooling breezes, and position door and window openings to improve cross-ventilation paths.
- In climates with low or no heating needs, develop the site so that existing buildings and trees shade all walls and deflect cooling breezes into the interior.
- Provide as much roof shading as possible but leave enough solar exposed areas for solar hot water or photovoltaic collectors.



# Passive design

## Orientation

- Design narrow building forms with long walls orientated to cooling breezes.
- Design open plan interiors and one-room depth buildings with 100% openable windows (casement or louvre) either side to improve cross-ventilation.
- Allow for bedrooms to be closed and well insulated if using air conditioning in the hot humid ('build-up') season.
- Elevate the house to allow air to circulate beneath it in hot humid climates.
- Minimise east and west-facing openings because they receive the strongest sun and are the most difficult to shade; however, if they are needed for ventilation, ensure they are well shaded.
- Add small windows to rooms with only one or include vents above internal doors to improve cross-ventilation.
- Consider using high level solid louvre panels in internal walls in hot humid climates where privacy is not an issue.
- Use generous, climate appropriate eaves overhangs (including on the south above the tropic of Capricorn).
- Use clerestory windows or solar chimneys to create convection currents to cool the house in the absence of breezes.
- Use roof ventilators or ridge and eaves vents to cool roof spaces.
- Include shaded, rain-protected outdoor living areas with ceiling fans.

### Checklist for choosing a project home

For more detailed information than this brief overview, read *Buying a home off the plan*.

- Choose a project home designed and built from materials that suit your climate.
- Consider using lightweight construction — often the best option, particularly where walls are exposed to hot summer sun or the home is designed to be air conditioned.
- Avoid inappropriate styles borrowed from different climate zones to yours.
- Make sure your design can be positioned on your site to capture cooling breezes and has a minimal area of west-facing windows.
- Mirror or flip the design to suit your site and breeze paths.
- Move windows or doors from one elevation to another to capture cooling breezes.
- Make sure windows have significant openable area for ventilation (casement or louvre).

- Ensure all openings are shaded by appropriate width eaves or devices.
- Include south eaves in tropical climates.
- Use open carports (not closed garages) to allow for breezes.

### Checklist for choosing a unit

For more detailed information than this brief checklist of important orientation related features, read *Buying and renovating an apartment*.

Choose a unit with good orientation because external modifications such as shading are often prohibited by body corporate rules intended to preserve the visual amenity of the building.

- Units generally use high mass construction, which can be problematic if orientation is not adequately addressed.
- Poorly orientated or inadequately shaded glazing heats thermal mass and makes summer living conditions unbearable.
- Consider a unit with low thermal mass such as MRTFC (multi-residential timber framed construction).
- Well-designed cross-ventilation to distribute cooling breezes through the unit is essential in any warm climate unit.
- North-east corner units, north-south cross-over (split level) or cross-through (one side to the other) are ideal.
- Solar access to living areas and good exposure to cooling breezes are important in climates requiring both heating and cooling.
- North-facing living areas and balconies or outdoor spaces are desirable in climates with winter heating needs, but south-facing or well-shaded orientation to cooling breezes is preferable in tropical climates.
- Passive shading to north glass or well-designed adjustable shading to east and west is essential.
- Avoid units facing west only.
- Shady, sheltered spaces and facilities with winter sun are highly desirable for community interaction.
- In hot humid climates, landscaping that provides shade to building and paved surfaces is highly desirable.

## Orientation for challenging sites

### Limited or no solar or cool breeze access

On sites with poor orientation or limited solar access due to other constraints, high levels of thermal performance are still achievable through careful design.

**Low mass construction:** Consider low mass construction systems with smaller windows, high insulation levels, and active solar or high efficiency heating and cooling systems.

- In hotter climates low mass does not store daytime heat gains and cools quickly when night-time temperatures drop. It also responds more rapidly and efficiently to cooling breezes when available and to active heating or cooling at times when they are not.
- In cooler climates low mass is more responsive to heating input, allowing the use of heating to suit lifestyle patterns. For example, if your house is unoccupied all day and frequently on weekends, heating can be switched off in the knowledge that the home can be warmed quickly on your return.
- In changing climates low mass construction will allow more flexible responses to rising temperatures and more variable weather patterns.

**Active solar space heating and cooling** can also be useful, especially if controlled by 'smart' technologies.

**A combination of high thermal performance, photovoltaics and high efficiency space conditioning** can deliver 'beyond zero emission' comfort year round.

**Advanced glazing and shading systems** can achieve net winter solar gains from windows facing almost any direction while limiting summer heat gains to a manageable level. A larger budget may be required but long term benefits can be gained. (see *Shading; Glazing*).

These solutions require active users or expensive automated shading systems that draw down screens or shades when they sense solar radiation in summer. Active, roof mounted solar heating systems are a viable alternative where the roof has solar access. They can also provide summer cooling if run in reverse to radiate heat to clear night skies.

Manually adjusted shading and active heating systems should also be considered in cooler climates where cold spells can be unpredictable in spring and autumn.

### Small lot housing

The ideal orientation for living areas is within the range 15°W–20°E of true or 'solar' north (20°W–30°E of true north is considered acceptable). This allows standard eaves overhangs to admit winter sun through north-facing glass to heat the building but exclude summer sun, with no effort from the occupants and no additional cost.

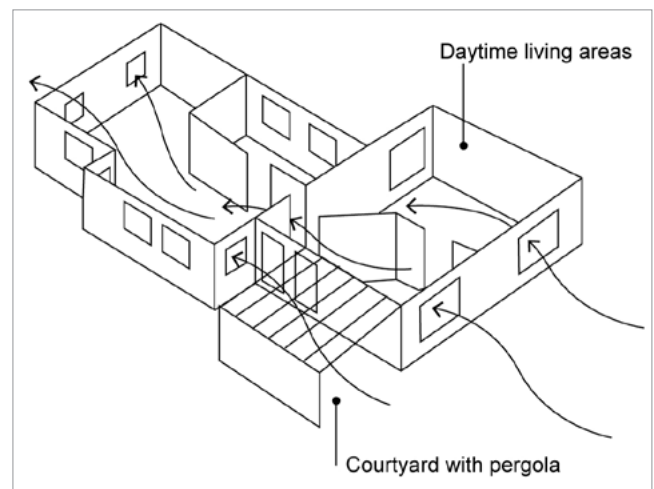
*Smaller lots limit urban sprawl over productive land and reduce infrastructure costs — but may make it harder to achieve ideal orientation.*

Smaller lots limit urban sprawl and reduce infrastructure costs — but may make it harder to achieve ideal orientation.

The simplest and most cost effective solution is to build smaller, better designed homes. The alternative — squeezing oversized homes onto tiny sites — leads to poor orientation and loss of privacy and outdoor living space. It also adds to energy bills through loss of solar access while increasing the amount of floor area to heat and cool.

There are signs that market demand for smaller, better designed homes is growing rapidly, driven largely by affordability and rising energy costs.

**Articulated floor plans** allow for better placement of smaller windows to increase cross-ventilation and night purging in summer. They also offer the opportunity to create private, sunny courtyards and utilise natural daylight that can be either direct or reflected off light coloured walls and buildings on narrow sites. (see *Lighting*)



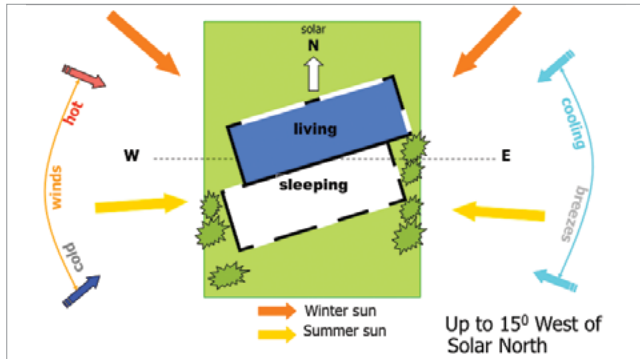
Source: SEAV

Articulated floor plan.

# Passive design

## Orientation

The diagrams below indicate how these principles might be applied on small lots in eastern Australia. Breeze and wind directions should be reversed for Western Australia and adapted to suit local conditions in other regions. The passive heating principles remain the same.



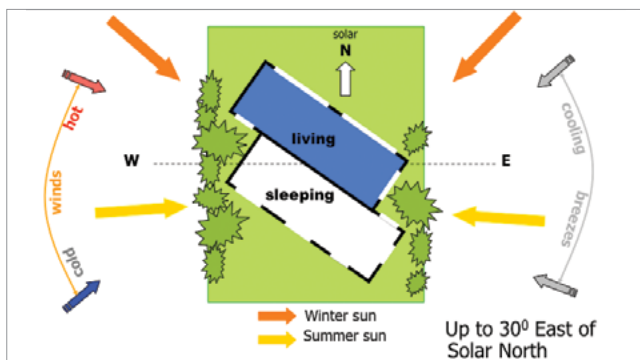
Source: Suntech Design

Cool or cold climate orientation — heating dominant.

This orientation maximises late afternoon solar gains and allows morning sun in winter. It excludes summer sun from west and south-facing windows and minimises exposure to westerly winds while allowing reasonable breeze access.

Dense planting to the west shades walls from summer sun and protects them from cold winter winds.

This configuration is also useful in warmer climates where cooling breezes are from the south-east. Slightly increased overhangs for north eaves reduce solar gains in spring and autumn in these climates, and breeze filtering plantings to the east provide shade from morning sun in summer.

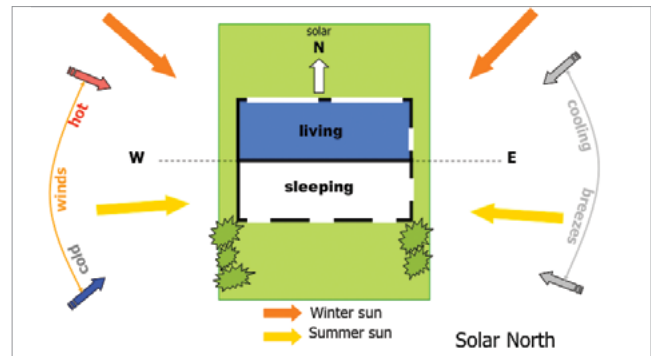


Source: Suntech Design

Mixed climate orientation — cooling dominant.

This orientation maximises exposure to cooling breezes but reduces passive solar heat gains. It requires shade plantings to the west to eliminate solar gains through south-facing windows in summer and protect the house from westerly winds.

In warmer climates, shade plantings on the east are also required but should not block breezes. Clerestory windows along the spine can increase solar and breeze access to sleeping areas.



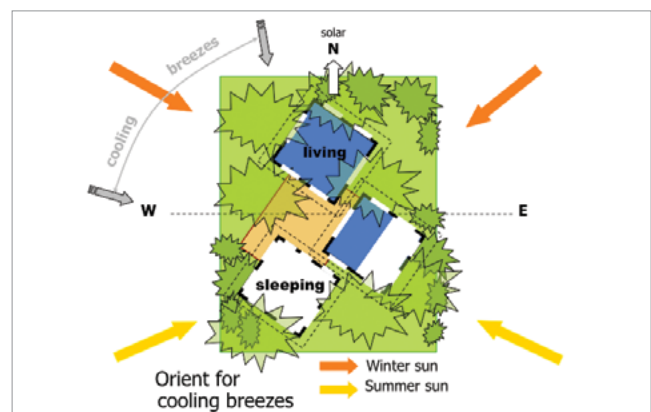
Source: Suntech Design

Temperate climate orientation — daytime heating and cool sleeping required.

This simple configuration allows for passive heating of living areas during the day and cooler, southerly sleeping areas.

In cooler climates, a thermal mass wall separating these zones would transfer solar warmth to sleeping areas.

In warmer regions, passively shaded clerestory windows along the spine would allow hot air to escape from bedrooms in summer while allowing in a small amount of winter sun.



Source: Suntech Design

Hot humid orientation (Darwin).



Although this orientation suits Darwin where cool breezes come predominantly from the north-west, it can be simply reconfigured for east or west coast tropical sites.

It divides the home into separate pavilions to maximise the cross-flow of breezes. Canopy trees partially overhang the roof and shade all walls without blocking breezes. Where such shading can't be achieved, an elongated east-west floor plan will limit low solar access to east and west walls.

Both the building form and understorey plantings are designed to funnel breezes into the building and allow them to escape.

A pavilion design allows hybrid cooling, where two pavilions might be free-running and the third designed and insulated for conditioning. Installing a thermal mass dividing wall in the third pavilion with non-conditioned sleeping spaces behind it would help create night-time sleeping comfort after the early evening conditioning is switched off.

## References and additional reading

Contact your state, territory or local government for further information on passive design considerations for your climate. [www.gov.au](http://www.gov.au)

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## Authors

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Updated by Chris Reardon, 2013

# Shading

Direct sun can generate the same heat as a single bar radiator over each square metre of a surface, but effective shading can block up to 90% of this heat. By shading a building and its outdoor spaces we can reduce summer temperatures, improve comfort and save energy. A variety of shading techniques can help, from fixed or adjustable shades to trees and vegetation, depending on the building's orientation as well as climate and latitude.



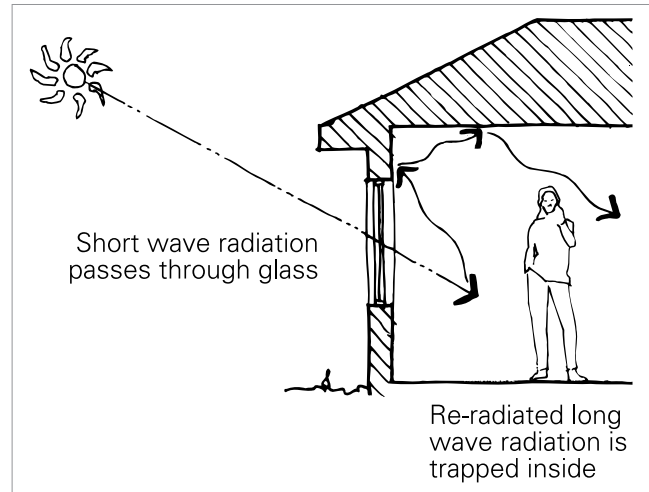
Photo: Architect Brian Meyerson

Shading glass reduces unwanted heat gain.

Shading glass is the best way to reduce unwanted heat gain, as unprotected glass is often the greatest source of heat entering a home. However, fixed shading that is inappropriately designed can block winter sun, while extensive summer shading can reduce incoming daylight, increasing the use of artificial lighting. Shading uninsulated and dark coloured walls can also reduce the heat load on a building.

Radiant heat from the sun passes through glass and is absorbed by building elements and furnishings, which then re-radiate it inside the dwelling. Re-radiated heat has a longer wavelength and cannot pass back out through the glass as easily. In most climates, 'trapping' radiant heat is desirable for winter heating but must be avoided in summer.

Shading of wall and roof surfaces is therefore important to reduce summer heat gain, particularly if they are dark coloured or heavyweight. Light coloured roofs can reflect up to 70% of summer heat gain.



Solar radiation is re-radiated inside.

Shading requirements vary according to climate and house orientation, as shown below.

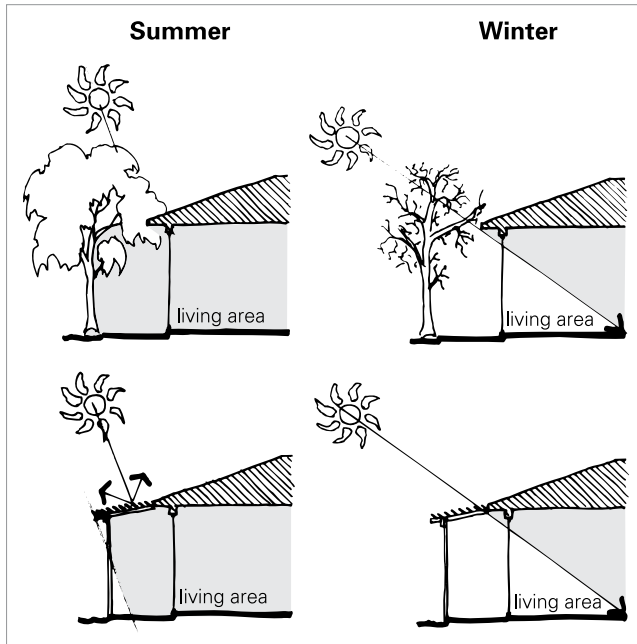
Orientation	Suggested shading type
North	Fixed or adjustable horizontal shading above window and extending past it each side
East and west	Fixed or adjustable vertical louvres or blades; deep verandas or pergolas with deciduous vines
NE and NW	Adjustable shading or pergolas with deciduous vines to allow solar heating or verandas to exclude it
SE and SW	Planting: deciduous in cool climates, evergreen in hot climates

## General guidelines for all climates

Use external shading devices over openings, such as wider eaves, window awnings and deep verandas or pergolas. Lighter-coloured shading devices reflect more heat, and those with light coloured undersides make better use of daylight than dark coloured. Internal shading does not prevent heat gain unless it is reflective: only shiny surfaces can reflect short wave radiation back through the glass without absorbing it.



To reduce unwanted glare and heat gain, use plants to shade the building, particularly windows. Evergreen plants are recommended for hot humid and some hot dry climates. For all other climates use deciduous vines or trees to the north, and deciduous or evergreen trees to the east and west.



External shading devices.

Within the range of north orientation that allows good passive sun control (20°W and 30°E of solar north) sun can be excluded in summer and admitted in winter using simple horizontal devices, including eaves and awnings. For situations where a good northerly orientation cannot be achieved (e.g. existing house, challenging site) it is still possible to find effective shading solutions. (see *Orientation and Passive solar heating*)

North-facing openings (and south-facing ones above the tropic of Capricorn) receive higher angle sun in summer and therefore require narrower overhead shading devices than east or west-facing openings. Fixed horizontal shading above north-facing glazing is all that is required. Examples include eaves, awnings, and pergolas with louvres set to the correct angle (see *'Fixed shading' below*).

East and west-facing openings require a different approach, as low angle morning and afternoon summer sun from these directions is more difficult to shade. Keep the area of glazing on the east and west orientations to a minimum where possible, still allowing for good cross-ventilation (see *Passive cooling*), or use appropriate shading devices. Adjustable shading, such as external blinds, is the optimum solution for these elevations.



This deep veranda provides welcome shade but can admit very low angle sun.

Deep verandas, balconies or pergolas can be used to shade the eastern and western sides of the home, but may still admit very low angle summer sun. Use in combination with planting to filter unwanted sun. Wide verandas can reduce daylight unless carefully designed.



Plantings, deciduous vines, shade cloth and screens can all be used in conjunction with pergolas to provide seasonal shading.

Pergolas covered with deciduous vines provide self-adjusting seasonal shading. A gap between the wall and planted screens should be left for ventilation and cooling. Vines on walls or a trellis (where appropriate) can also provide summer insulation to all orientations. As evergreen vines block winter sun, they should only be used in tropical climates or on problematic west façades.

Use drought tolerant ground cover plants instead of paving where possible, to keep the temperature of the ground and surrounding surfaces lower in summer.

# Passive design

## Shading

Protect skylights and roof glazing with external blinds or louvres. This is crucial as roof glazing receives almost twice as much heat as an unprotected west-facing window of the same area. Quite small skylights can deliver a lot of light, so be conservative when sizing them.

Position openable clerestory windows to face north, with overhanging eaves to exclude summer sun. Double glaze clerestory windows and skylights in cooler climates to prevent excessive heat loss.

*Advanced glazing solutions can exclude up to 60% of heat compared to clear glass.*

Advanced glazing solutions can exclude up to 60% of heat compared to clear glass, and are a useful secondary measure on east and west elevations. They should not be used as a substitute for shading in hotter climates because only effective shading can exclude 100% of direct solar heat gain. Insulative glazing (e.g. double glazing) reduces ambient (conducted) heat gains.

Measurements of heat gains in building elements such as walls, floors or roofs are expressed as U-values. U-values and solar heat gain coefficients (SHGC) are available for all glazing products and require careful selection (see *Glazing*). Use high SHGC glass on north-facing windows when you want to let in winter sun and low SHGC when you want to exclude it.

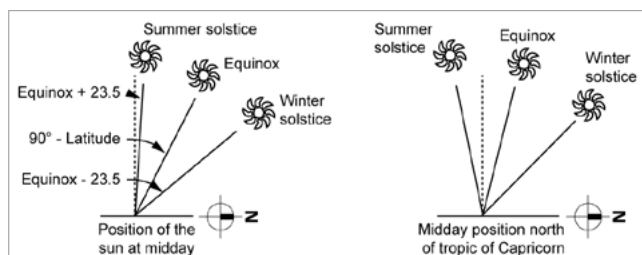
Low U-values (best performance) are desirable in cooler climates and hot climates where windows are kept closed, e.g. because of air conditioning or high external air temperatures. (see *Design for climate; Glazing*)

## Calculating sun angles

The angle of the sun in the sky at noon can be easily calculated for the solstices and equinoxes as follows:

- Equinox =  $90^\circ - \text{latitude}$
- Summer solstice = Equinox +  $23.5^\circ$
- Winter solstice = Equinox -  $23.5^\circ$

The diagram for Darwin below shows why southern façades must be shaded in tropical locations to keep out the summer sun — buildings need to be able to be shaded all year round.



Calculating sun angles.

Many designers have computer aided drafting programs that calculate sun angles and shadows for various locations and topographies based on a digital site survey.

The Geoscience Australia website ([www.ga.gov.au](http://www.ga.gov.au)) allows you to find the latitude of more than 250,000 place names in Australia and calculate the sun angle at any time of the day, on any day of the year.

City	Latitude
Darwin	12°S
Cairns	16.9°S
Broome	18°S
Townsville	19.25°S
Rockhampton	23.4°S
Geraldton	28.8°S
Perth	32°S
Sydney	34°S
Adelaide, Canberra	35°S
Melbourne	37°S
Hobart	48°S

## Fixed shading

Fixed shading devices (eaves, awnings, pergolas and louvres) can regulate solar access on northern elevations throughout the year, without requiring any user effort.

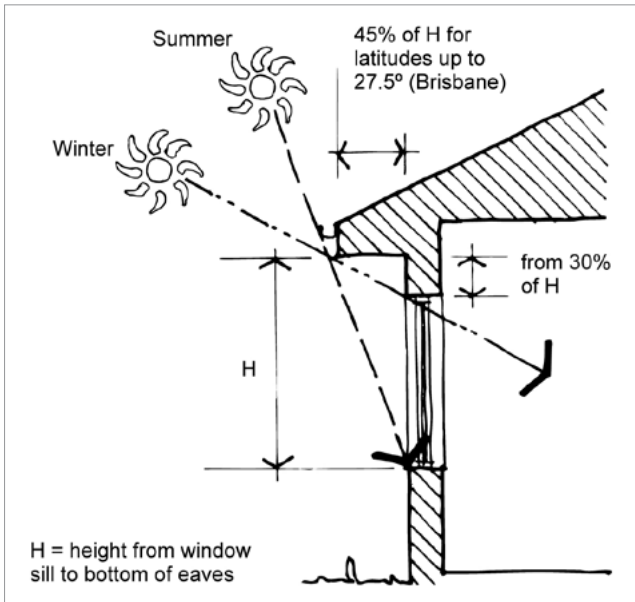
Summer sun from the north is at a high angle and is easily excluded by fixed horizontal devices over openings. Winter sun from the north is at a lower angle and penetrates beneath these devices if correctly designed.

## Eaves

Correctly designed eaves are generally the simplest and least expensive shading method for northern elevations and are all that is required on most single-storey houses. Some designers may avoid sizing eaves properly in the mistaken belief that the process is complex.

Precise angles for each latitude can be calculated using the simple process above. They only vary the day and month that sun begins to strike the glass in autumn and shade it in spring because the movement of the sun is most noticeable to us around the spring and autumn equinoxes. This is due to the 'apparent' movement of the sun slowing as it changes direction at each solstice due to the earth's tilted axis as it orbits around the sun.

The following simple rules of thumb ensure that north-facing glass is fully shaded for a month either side of the summer solstice and receives full solar access for a month either side of the winter solstice.



45% rule of thumb for latitudes south of and including 27.5°S.

As a rule of thumb, eaves width should be 45% of the height from the window sill to the bottom of the eaves. Aim for consistent sill heights where possible and consider extending the eaves overhang over full height doors or windows. This allows the 45% rule to be simply met with the following standard eaves overhangs:

- 450mm where height is 900–1200mm
- 600mm for a height of 1200–1350mm
- 900mm for a height of 1350–2100mm
- 1200mm for a height of 2100–2700mm.

Where sill heights vary on a single north façade, set your eaves overhang to the average sill height of larger glass areas. In warmer climates go up to the nearest size and in cooler climates go down to the nearest size. Think about how climate change and warming might affect the heating requirements of the home.

To avoid having permanently shaded glass at the top of the window, ensure that distances between the top of glazing and the eaves underside are at least 30% of the height — a more important component of eaves design than width of overhang, especially in cool and cold climates where it is a significant source of heat loss at night with no compensating daytime solar gains. It is not always achievable with standard eaves detailing which is flush with the 2100mm head (i.e. height of the top of the window).



The top 20% of this window is in permanent shade.

In the image below, standard 2100mm high doors are shaded by 1000mm eaves (including gutter) set 300mm above the head. Note the sun angle at midday in mid-winter is above the glass line. This configuration provides full shading to the glass from late October to late February at latitude 35°S (near Canberra) and is appropriate for a higher altitude cool climate winter.



Photo: Suntech Design

Eaves can be sized to allow shading in summer and solar access in winter.

North-facing upward raked eaves allow full exposure of glass to winter sun and shade larger areas in summer, without compromising the solar access of neighbours to the south. A separate horizontal projection of louvres shades lower glazing. This allows 100% winter solar access and excludes all sun between the spring and autumn equinoxes.



Photo: Architects: Enviro Studio, Photo: SIMART

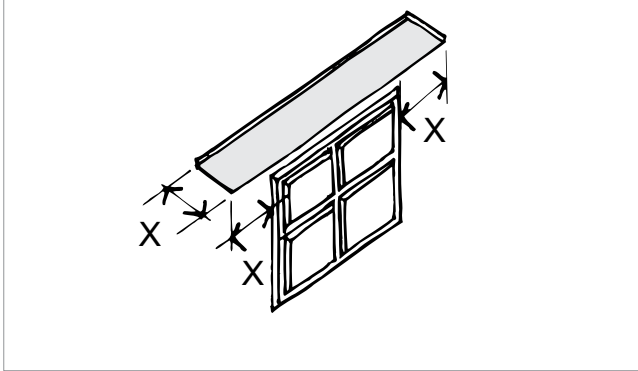
North-facing upward raked eaves.



# Passive design

## Shading

Horizontal shading devices must extend beyond the width of the north-facing opening by the same distance as their outward projection to shade the glass before and after noon.



Source: SEAV

Extend shading beyond the window edges.

### Varying the rule of thumb

Variations to the 45% rule of thumb are beneficial for fine-tuning your passive shading to suit varying heating and cooling requirements determined by regional climate, topography and house design. For example, reduce the overhang by decreasing the percentage of the height by up to 3% to extend the heating season:

- at higher altitudes (e.g. eastern highlands, tablelands and alpine regions)
- where cold winds or ocean currents are prevalent (e.g. southern WA and SA)
- in inland areas with hot dry summers and cold winters (e.g. Alice Springs)
- in cold, high latitude areas (e.g. Tasmania and southern Victoria).

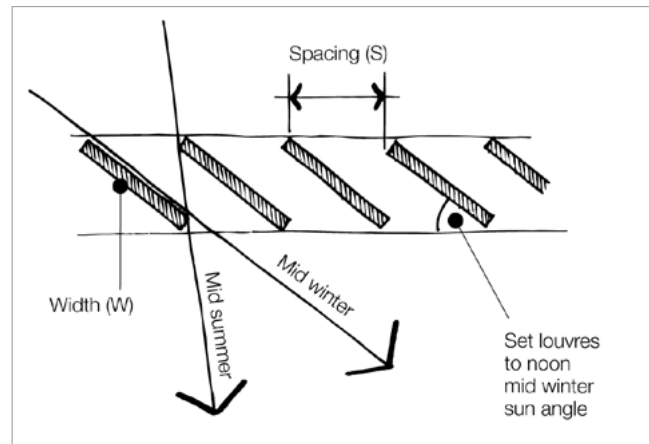
Gradually increase the percentage of height as heating requirements decrease in latitudes north of 27.5°S (Brisbane), to decrease or eliminate the amount of sun reaching glass areas either side of the equinox:

- For hot dry climates with some heating requirements, gradually increase the overhang up to 50% of height (full shading).
- For hot humid climates and hot dry climates with no heating requirements, shade the whole building at all times with eaves overhangs of 50% of height from floor level to both north and south where possible, and use planting or adjoining buildings where it is not possible. East and west elevations require different solutions.

(see *Design for climate; Passive solar heating; Passive cooling*)

### Louvres

Fixed horizontal louvres set to the noon mid-winter sun angle and spaced correctly allow winter heating and summer shading in locations with cooler winters. As a rule of thumb, the spacing (S) between fixed horizontal louvres should be 75% of their width (W). The louvres should be as thin as possible to avoid blocking out the winter sun.

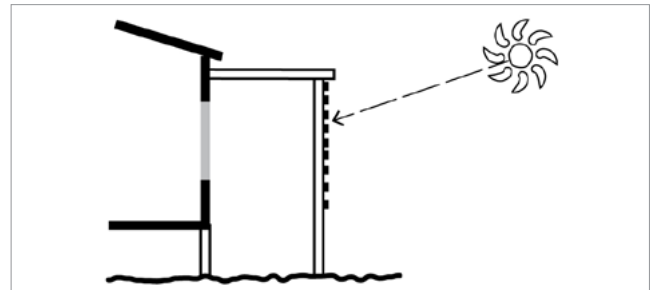


Spacing for fixed louvres.

### Fixed shading for east and west

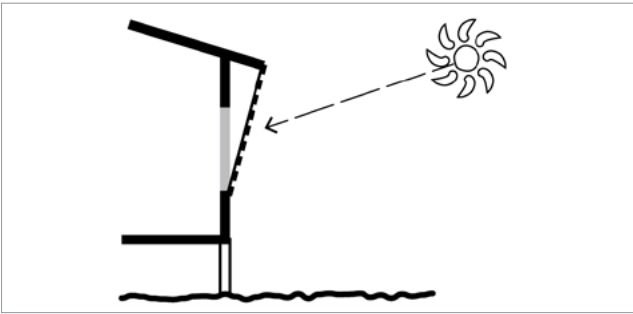
West-facing glass and walls are a significant source of heat gain in hotter climates. East-facing glass can be equally problematic because, while the home is cooler in the morning and heat gains do not cause noticeable discomfort, it is the start of a cumulative process that causes thermal discomfort in the afternoon and early evening. Both east and west require shading in hotter climates. In cooler climates, east shading is a lower priority.

Because east and west sun angles are low, vertical shading structures are useful in allowing light, views and ventilation while excluding sun. Roof overhangs, pergolas and verandas that incorporate vertical structures such as screens, climber covered lattice and vertical awnings are also effective.



Source: Townsville City Council

Pergola with vertical screen to block low-angle sun.



Source: Townsville City Council

Vertical timber batten screen attached to the house.

## Adjustable shading

Adjustable shading allows the user to choose the desired level of shade. This is particularly useful in spring and autumn when heating and cooling needs are variable. (NOTE: Active systems require active users.)

## Climate change

Climate change does not affect sun angles, but the desirability of shade or solar heat gain may change, thus affecting the overall design strategy. Adjustable shading (mechanical or seasonal vegetation) facilitates adaptation to changing climatic conditions.



Photo: Envirova Studio

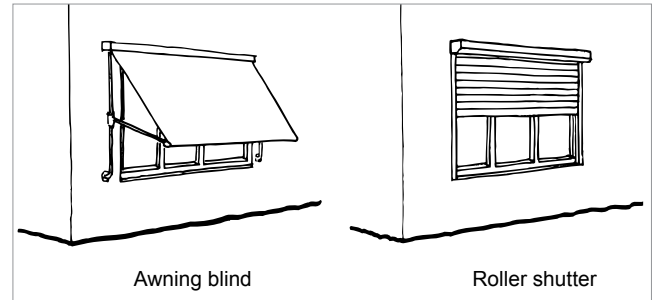
Adjustable louvers can adapt to changing climate conditions.

## Northern elevations

Adjustable shading appropriate for northern elevations includes adjustable awnings or horizontal louvre systems and removable shade cloth over pergolas or sails. Shade cloth is a particularly flexible and low cost solution.

## Eastern and western elevations

Adjustable shading is especially useful for eastern and western elevations, as the low angle of the sun makes it difficult to get adequate protection from fixed shading. Adjustable shading gives greater control while enabling daylight levels and views to be manipulated. Appropriate adjustable systems include sliding screens, louvre screens, shutters, retractable awnings and adjustable external blinds.



Awnings and roller shutters provide adjustable shading on eastern and western elevations.

## North-east and north-west elevations

Adjustable shading is recommended for these elevations as they receive a combination of high and low angle sun throughout the day. Typical responses for northern and eastern or western elevations need to be integrated. Select systems that allow the user to exclude all sun in summer, gain full sun in winter, and manipulate sun levels at other times.



Shade cloth is flexible and low cost.



# Passive design

## Shading

### Climate specific responses

In high humidity climates and hot dry climates with warm winters, shade the building and outdoor living spaces throughout the year. For all other climates, use appropriate passive solar design principles.

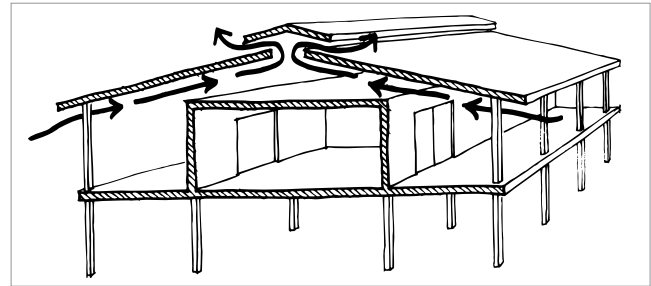
(see *Passive design; Orientation; Passive solar heating; Passive cooling*)

### Hot humid climates

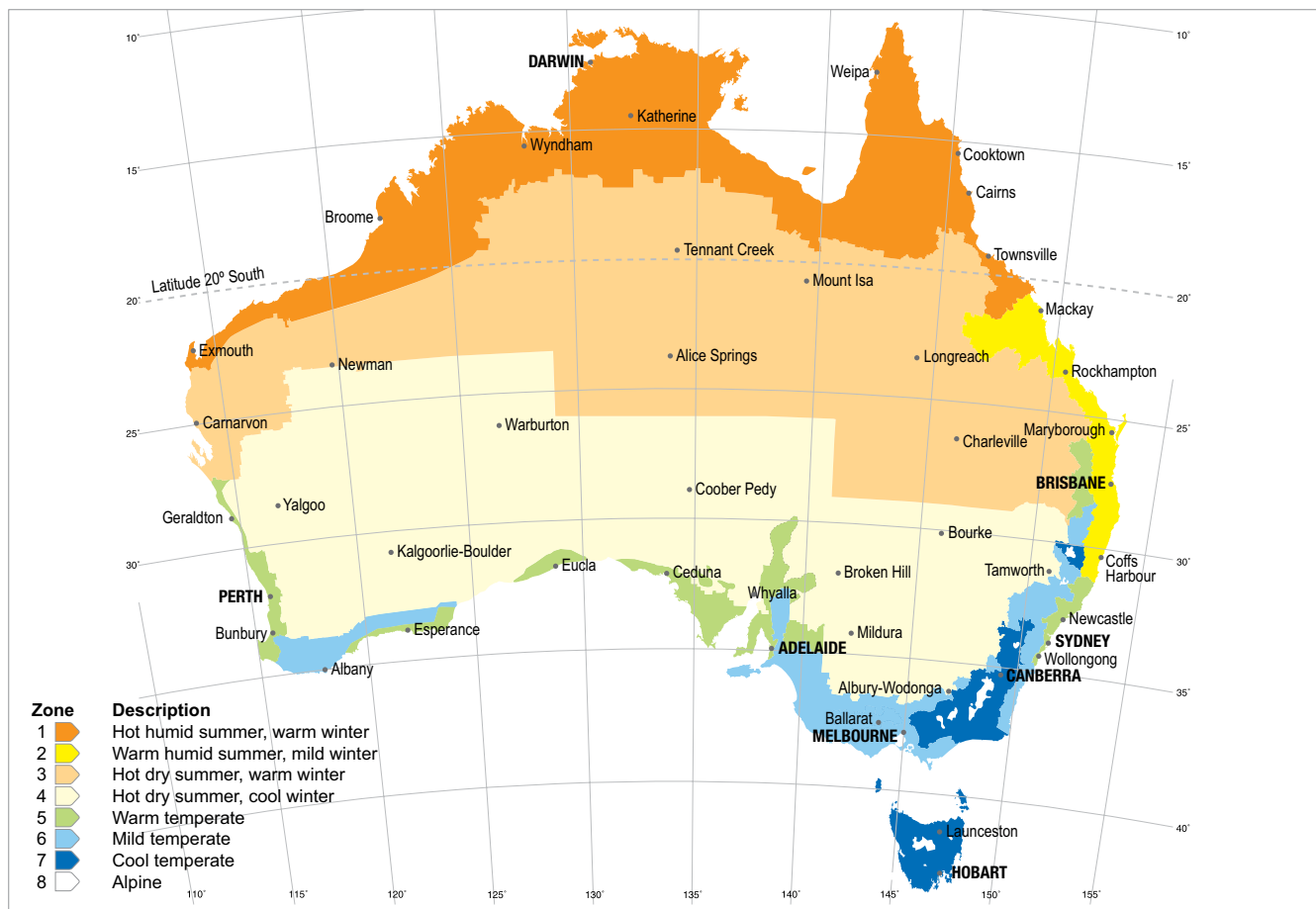
In hot humid climates, it is essential to shade the walls year round and highly advantageous to shade the whole roof.

- Shade all external openings and walls including those facing south.
- Use covered outdoor living areas such as verandas and deep balconies to shade and cool incoming air.
- Use shaded skylights to compensate for any resultant loss of natural daylight.

- Choose and position landscaping to provide adequate shade without blocking access to cooling breezes.
- Use plantings instead of paving to reduce ground temperature and the amount of reflected heat.
- A 'fly roof' can be used to shade the entire building. It protects the core building from radiant heat and allows cooling breezes to flow beneath it.



A fly roof protects a building from radiant heat and encourages cooling breezes.

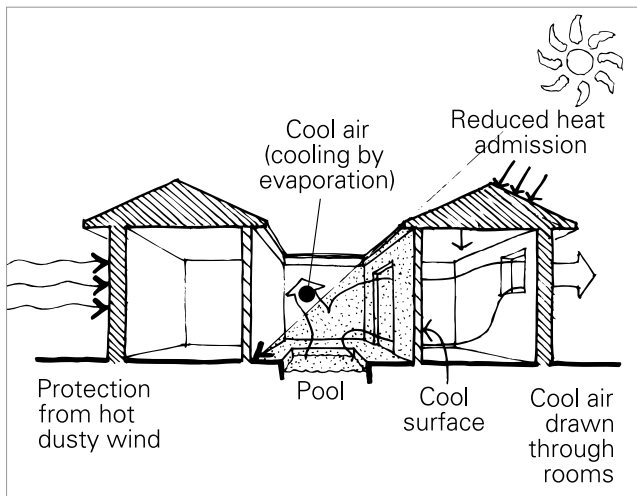


Source: Australian Building Codes Board (ABCB)

Climate zones of Australia.

### Hot dry climates

- Shade all external openings in regions where no winter heating is required.
- Provide passive solar shading to north-facing openings in regions where winter heating is required.
- Avoid shading any portion of the glass in winter when winter heating is required — use upward raked eaves to allow full winter solar access, or increase the distance between the window head and the underside of the eaves.
- Use adjustable shade screens or deep overhangs (or a combination of both) to the east and west. Deep covered balconies or verandas shade and cool incoming air and provide pleasant outdoor living spaces.
- Place a shaded courtyard next to the main living areas to act as a cool air well. Tall, narrow, generously planted courtyards are most effective when positioned so that they are shaded by the house.
- Use plantings instead of paving to reduce ground temperature and the amount of reflected heat.



Courtyard pools cool through evaporation.



This adjustable shade screen can exclude low angle sun.

### Cool temperate climates

- Do not place deep covered balconies to the north as they obstruct winter sun. Balconies to the east or west can also obstruct winter sun to a lesser extent.



Covered balconies should allow winter sun access.

### Warm humid and warm/mild temperate climates

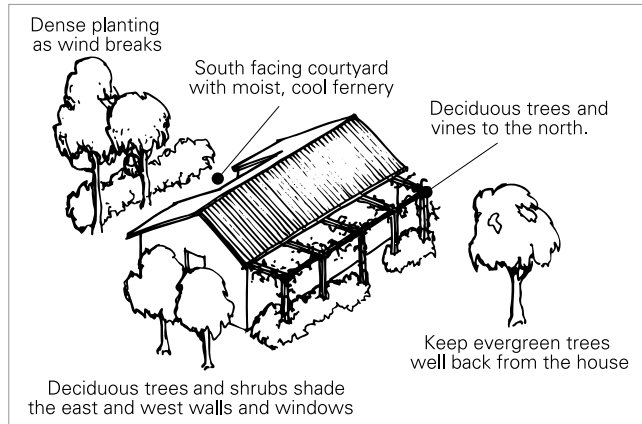
- Provide passive solar shading to all north-facing openings, using shade structures or correctly sized eaves.
- Use adjustable shade screens or deep overhangs to the east and west. Adjustable shade screens exclude low angle sun the most effectively.
- Avoid shading any portion of the north-facing glass in winter — use upward raked eaves to allow full winter solar access, or increase the distance between the window head and the underside of the eaves.
- Use deciduous planting to the east and west. Avoid plantings to the north that would obstruct solar access.

# Passive design

## Shading

### Using plants for shading

Match plant characteristics (such as foliage density, canopy height and spread) to shading requirements. Choose local native species with low water requirements wherever possible.



Plants can provide shade and act as windbreaks.

In addition to providing shade, plants can assist cooling by transpiration. Plants also enhance the visual environment and create pleasant filtered light. (see the appendix *Landscaping and garden design*)

- Deciduous plants allow winter sun through their bare branches and exclude summer sun with their leaves.
- Trees with high canopies are useful for shading roofs and large portions of the building structure.
- Shrubs are appropriate for more localised shading of windows.
- Wall vines and ground cover insulate against summer heat and reduce reflected radiation.

### Shading for a healthier environment

Appropriate shading practices reduce the chance of exposure to harmful ultraviolet rays. Planting is a low cost, low energy provider of shade that improves air quality by filtering pollutants.

### Shading and daylight

Choose shading methods that allow adequate amounts of daylight into the building while preventing unwanted heat gain.

- Select plants that allow filtered light into the building. (see the appendix *Landscaping and garden design*)
- Design glazing to admit maximum light for minimum heat gain. Clear sections in veranda roofs can be useful. (see *Glazing*)
- Light coloured external surfaces or shading devices reflect more sunlight into the building. Depending on the situation this can be beneficial, or it can create unwanted glare. (see *Lighting*)

### References and additional reading

Contact your state, territory or local government for further information on passive design considerations for your climate.

For sun paths (including best orientation for Queensland locations) see: [www.works.qld.gov.au](http://www.works.qld.gov.au)

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### Authors

Principal author: Caitlin McGee

Updated by Chris Reardon, 2013

# Passive solar heating

**Passive solar heating uses free heating direct from the sun to dramatically reduce the estimated 40% of energy consumed in the average Australian home for space heating and cooling (DEWHA 2008).**

Most Australian climates require both passive heating and cooling. Many heating and cooling design objectives overlap but different emphasis is required depending on your climate needs. Read *Design for climate* before this article to determine your climate zone and get an understanding of the strategies you'll need. The detailed advice in this article and the one that follows it, *Passive cooling*, is complemented by advice relevant to specific types of home in the section *Before you begin*.

## What is passive solar heating?

Passive solar heating is the least expensive way to heat your home. Put simply, design for passive solar heating aims to keep out summer sun and let in winter sun while ensuring the building's overall thermal performance retains that heat in winter but excludes it and allows it to escape in summer. Passive solar design also depends on informed, active occupants who remember to open and close windows and isolate zone spaces, for example, each day.

It is also:

- low cost when designed into a new home or addition
- achievable using all types of Australian construction systems
- appropriate for all climates where winter heating is required
- achievable when buying a project home through attention to correct orientation, slight floor plan changes and appropriate glazing selection
- achievable when choosing an existing house, villa or apartment through looking for good orientation and shading.

Passive solar heating requires careful application of the following passive design principles:

- northerly orientation of daytime living areas (see *Orientation*)
- passive shading of glass (see *Shading*) and selection of appropriate glazing (see *Glazing*)

- appropriate areas of glass on northern façades (see *Glazing*; *Thermal mass*)
- thermal mass for storing heat (see *Thermal mass*)
- insulation and draught sealing (see *Insulation*; *Sealing your home*)
- floor plan design to address heating needs including zoning
- climate appropriate glazing solutions (see *Glazing*).

This maximises winter heat gain, minimises winter heat loss and concentrates heating **where it is most needed**.



Photo: Centre for Sustainable Design, University of Queensland

Passive solar heating is low cost when designed into a new home.

*Passive solar houses can look like other homes but cost less to run and are more comfortable to live in.*

## How passive solar heating works

Solar radiation is trapped by the greenhouse action of correctly oriented (north-facing) glass areas exposed to full sun. Window orientation, shading, frames and glazing type have a significant effect on the efficiency of this process. (see *Orientation*; *Shading*; *Glazing*)

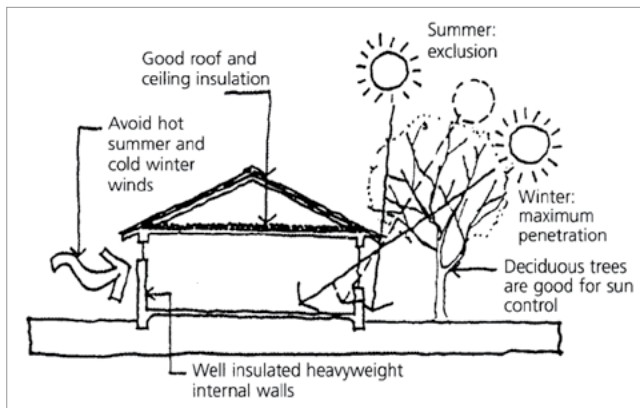


# Passive design

## Passive solar heating

Trapped heat is absorbed and stored by materials with high thermal mass (usually masonry) inside the house. It is re-released at night when it is needed to offset heat losses to lower outdoor temperatures. (see *Thermal mass*)

Passive solar heating is used in conjunction with passive shading, which allows maximum winter solar gain and prevents summer overheating. This is most simply achieved with northerly orientation of appropriate areas of glass and well-designed eaves overhangs. (see *Orientation*; *Shading*)



Passive shading features can control the entry of sunlight and wind.

Re-radiated heat is distributed to where it is needed through good design of air flow and convection. Direct re-radiation is most effective but heat is also conducted through building materials and distributed by air movement. Floor plans should be designed to ensure that the most important rooms (usually day-use living areas) face north and receive the best winter solar access.

Heat loss is minimised with appropriate window treatments and well-insulated walls, ceilings and raised floors. Thermal mass (the storage system) must be insulated to be effective. Slab-on-ground edges should be insulated in colder climates, or when in-slab heating or cooling is installed within the slab. (see *Insulation*; *Thermal mass*)

Air infiltration is minimised with airlocks, draught sealing, airtight construction detailing and quality windows and doors.

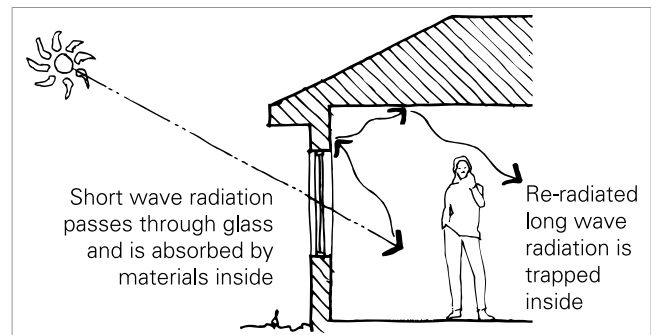
Appropriate house shape and room layout is important to minimise heat loss, which takes place from all parts of the building, but mostly through the roof. In cool and cold climates, compact shapes that minimise roof and external wall area are more efficient. As the climate gets warmer more external wall area is appropriate, to allow for better cross-ventilation.

## Passive solar design principles

### Greenhouse (glasshouse) principles

Passive design relies on greenhouse principles to trap solar radiation.

Heat is gained when short wave radiation passes through glass, where it is absorbed by building elements and furnishings and re-radiated as long wave radiation. Long wave radiation cannot pass back through glass as easily.



Solar heat gain through standard 3mm glazing. (For comparison to advanced glazing materials, see *Glazing*.)

Heat is lost through glass (and other building materials) by conduction, particularly at night. Conductive loss can be controlled by window insulation treatments such as close fitting heavy drapes with snug pelmets, double glazing and other advanced glazing technology.

### Heat flow through building elements

Heat flow through any building element (e.g. wall, floor ceiling, window) is directly proportional to the temperature difference on either side of that element. This is called the temperature differential (also referred to as delta T or  $\Delta T$ ). The greater the temperature differential, the greater the heat flow through the element.

Think about temperature differential as pressure in your garden hose. The greater the pressure, the more water flows through the same hose. While the heat flow through different materials varies depending on their insulation properties (R-value), heat flow through each element with a similar R-value is directly proportional to temperature differential. Heat flow through windows is much higher because they typically have the lowest R-value of any construction material.

Because hot air rises convectively, air temperatures stratify in a home with the hottest air at the highest point. For example if you, on a cold  $-5^{\circ}\text{C}$  Canberra night, are trying to keep your main living area at around  $22^{\circ}\text{C}$  (although most acclimatised Canberra residents find  $19\text{--}20^{\circ}\text{C}$  quite



comfortable), temperature stratification might lead to 30°C ( $\Delta T$  35°C) at the highest point in the room and 18°C ( $\Delta T$  23°C) at the lowest. That means that 33% more heat is flowing through higher level building elements than lower ones because the temperature differential is 33% higher. Again, windows are the weakest point.

### Orientation for passive solar heating

For best passive heating performance, daytime living areas should face north. Ideal orientation is true north but orientations of up to 20° west of north and 30° east of north still allow good passive sun control. (see *Orientation*)

Where solar access is limited, as is often the case in urban areas, energy efficiency can still be achieved with careful design. Homes on poorly orientated or narrow blocks with limited solar access can employ alternative passive solutions to increase comfort and reduce heating costs. (see *Challenging sites*; *Shading*; *Insulation*; *Thermal mass*; *Glazing*)

Active solar heating systems that use roof mounted, solar exposed panels to collect heat and pump it to where it is needed are a viable solution where solar exposure of glass for passive heating can't be achieved. This provides a more flexible solution that is more easily adjusted to adapt to climate change warming. (see *Heating and cooling*)

### Passive solar shading

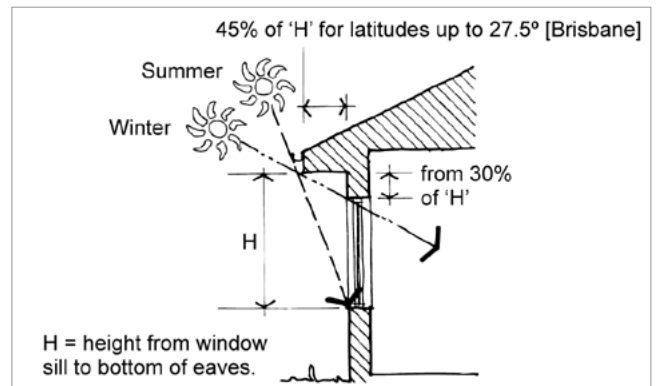
Fixed horizontal shading devices can maximise solar access to north-facing glass throughout the year, without requiring any user effort. Good orientation is essential for effective passive shading.

Fixed shading above openings excludes high angle summer sun but admits lower angle winter sun. Correctly designed eaves are the simplest and least expensive shading method for northern elevations.

Use adjustable shading to regulate solar access on other elevations. This is particularly important for variable spring and autumn conditions and allows more flexible responses to climate change.

The 'rule of thumb' for calculating the width of eaves is given below. This rule applies to all latitudes south of and including 27.5° (Brisbane, Geraldton). For latitudes further north, the response varies with climate. (see *Shading*)

Permanently shaded glass at the top of the window is a significant source of heat loss with no solar gains to offset it. To avoid this, the distance between the top of glazing and underside of eaves or other horizontal projection should be 50% of overhang or 30% of window height where possible. (see *Shading*)



Rule of thumb for calculating the width of eaves.

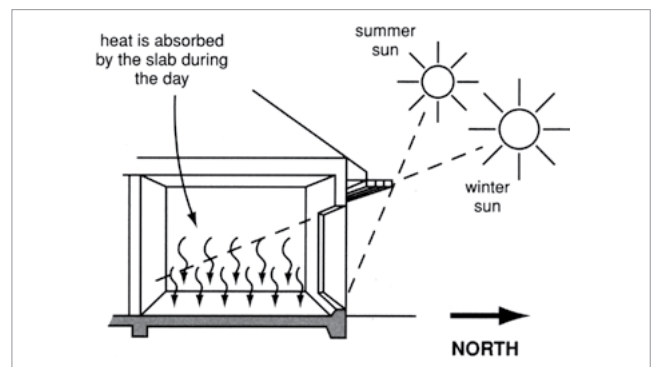
Heat loss through glass (and walls) is proportional to the difference between internal and external temperatures. Because the hottest air rises to the ceiling, the greatest temperature difference occurs at the top of the window.

### Thermal mass and thermal lag

Thermal mass is used to store heat from the sun during the day and re-release it when it is required, to offset heat loss to colder night-time temperatures. It effectively 'evens out' day and night (diurnal) temperature variations. (see *Thermal mass*)

*Thermal mass can significantly increase comfort and reduce energy consumption.*

When used correctly, thermal mass can significantly increase comfort and reduce energy consumption. Thermal mass is very useful for some climates but can be a liability if used incorrectly. Thermal mass must be externally insulated (so the stored heat is not lost) and internally exposed (so solar heat can flow easily into the material).



Source: Sustainable Energy Authority Victoria (SEAV)

Thermal mass must be externally insulated and internally exposed.

# Passive design

## Passive solar heating

Adequate levels of exposed internal thermal mass (i.e. not covered with insulative materials such as carpet) in combination with other passive design elements, ensure that temperatures remain comfortable all night and, if well-designed, on successive sunless days. This is due to a property known as thermal lag — the amount of time taken for a material to absorb and then re-release heat, or for heat to be conducted through the material.

Thermal lag times are influenced by:

- temperature differentials ( $\Delta T$ ) between each face
- thickness
- conductivity and density
- texture, colour and surface coatings
- exposure to air movement and air speed.

Rates of heat flow through materials are proportional to the temperature differential between each face. External walls have significantly greater temperature differential than internal walls and thermal mass must be insulated externally. The more extreme the climate, the greater the temperature differential and the more insulation required. Even 300mm-thick adobe and rammed earth walls require external insulation in cool and cold climates. Avoid using high mass in hot climates.

The useful thickness of thermal mass is the depth of material that can absorb and re-release heat during a day–night cycle. For most common building materials this is 50–150mm depending on their conductivity. Longer lag times are useful for lengthy cloudy periods but must be matched by solar input (see 'Glass to mass ratios' below).



Photo: Mike Cleaver, Clever Design

These water filled balustrades provide high thermal mass suitable for current climate conditions but have the potential for low cost mass reduction (if drained) as climate change progresses.

In warmer temperate climates, external wall materials with a minimum time lag of 10 to 12 hours can effectively even out internal–external diurnal temperature variations. In these climates, external walls with sufficient thermal mass moderate internal–external temperature variations to create comfort and eliminate the need for supplementary heating and cooling.

NOTE: The use of high mass solutions is becoming questionable because climate change will increase

summer temperatures and cause longer and more extreme heatwaves. In general, moderate mass or well-insulated lightweight construction is generally a more appropriate solution for the life span of housing built today.

Extremely high thermal mass levels (e.g. earth covered housing) can even out seasonal temperature variations. Summer temperatures warm the building in winter and winter temperatures cool it in summer. In these applications, lag times of 30 days are required in combination with the stabilising effect of the earth's core temperature.

Relative thermal lag of some common building materials

Material	Thickness (mm)	Time lag (hours)
AAC	200	7.0
Adobe	250	9.2
Compressed earth blocks	250	10.5
Concrete	250	6.9
Double brick	220	6.2
Rammed earth	250	10.3
Sandy loam	1000	30 days

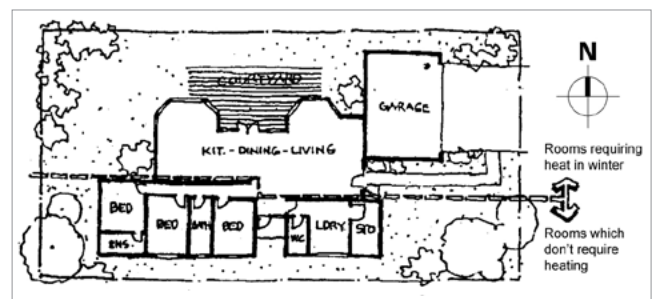
Source: Baggs 2009

Low mass solutions with high insulation levels work well in milder climates with low diurnal ranges. Low mass construction gives faster response times to auxiliary heating and will prove more flexible in warming climates. Additional flexible thermal mass options are available. (see *Thermal mass*)

## Planning and design

### Floor planning

Plan carefully to ensure passive solar gain to the rooms that most need it.



Source: Amcord 1995

This plan places living areas to the north and bedrooms to the south.

In general, group living areas along the north façade and bedrooms along the south or east façade.

Living areas and the kitchen are usually the most important locations for passive heating as they are used day and evening. Bedrooms generally require less heating. It is easy to get warm and stay warm in bed. Children's bedrooms can be classified as living areas if considerable hours are spent there.

Utility and service areas such as bathrooms, laundries and garages are used for shorter periods, require smaller windows and generally require less heating. These areas are best located:

- to the west or south-west, to act as a buffer to hot afternoon sun and the cold westerly winds common to many regions
- to the east and south-east, except where this is the direction of cooling breezes.

Detached garages to the east and west can create protected north-facing courtyards, provide shade from low angle summer sun and direct cooling breezes into living spaces.

Compact floor plans minimise external wall and roof area, thereby reducing heat loss and construction cost. Determine a balance between minimising heat loss and achieving adequate daylighting and ventilation.

Consider specific regional heating and cooling needs and the site characteristics to determine an ideal building shape.

### Locating thermal mass

As a first priority, locate thermal mass where it is exposed to direct solar radiation or radiant heat sources. Insulated or internal suspended slabs that are not earth-coupled make ideal thermal mass storage for solar heat gains, as do masonry walls, water filled containers and phase change materials. They should receive direct solar radiation. (see *Thermal mass*)

Thermal mass also absorbs reflected radiant heat. Thermal mass walls between northern living areas and southern sleeping areas are ideally located as thermal lag radiates daytime solar gains into sleeping areas at night and provides acoustic separation. Locate additional thermal mass predominantly in the northern half of the house where it absorbs most passive solar heat.

Earth-coupled concrete slabs-on-ground are not an ideal storage medium for solar gains. They have an almost endless capacity to absorb heat with very little temperature rise due to their capacity to 'wick' heat away through earth-coupling. Their main role in passive design

is to maintain overnight temperatures at deep earth temperature levels (16–19°C at 3m depth) that can easily be topped up by solar gains or auxiliary heating next day.

In cold climates, insulate under areas of slab-on-ground that are exposed to direct solar radiation and insulate all edges.

*Consider use of low thermal mass materials and high levels of insulation in south-facing rooms.*

Air movement within the house heats or cools thermal mass. Locate mass away from cold draught sources (e.g. entries) and expose it to convective warm air movement in the house (e.g. hallways to bedrooms). Consider the balance between heating and cooling requirements. (see *Thermal mass*)



Locate thermal mass where it is exposed to direct solar radiation.

Edge insulation is desirable for earth-coupled slabs, especially in colder areas. Earth-coupling should be avoided where groundwater action or temperatures can draw heat from slabs.

### Air movement and comfort

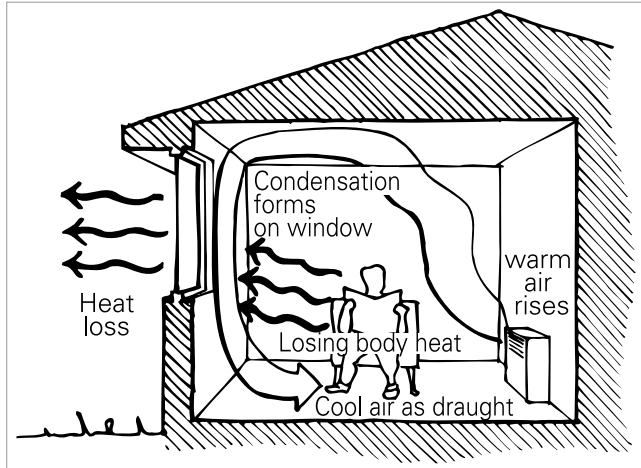
Air movement creates a cooling effect on our bodies by increasing the evaporation of perspiration. Draughts increase the perception of feeling cold. Air movement of 0.5m/s (barely enough to move a sheet of paper) creates a cooling effect equivalent to a 3°C drop in temperature. (see *Design for climate; Passive cooling*)

Avoid convection draughts by designing floor plans and furnishing layouts so that cool air flowing from windows and external walls towards heaters or thermal mass sources is directed through traffic areas such as hallways and stairs. Create draught free nooks for sitting, dining and sleeping.

# Passive design

## Passive solar heating

Use ceiling fans to circulate warm air evenly in rooms and push it down from the ceiling to living areas. For low ceilings, use fans with reversible blade direction to minimise draughts.



Adverse effects of draughts.

### Locating heaters

Internal thermal mass walls provide an ideal location for heaters, especially radiant units such as wood heaters or hydronic heating panels. Thermal lag will transfer heat to adjoining spaces over extended periods. (see *Heating and cooling*)

Locating heaters next to an outside wall can result in additional heat loss (unless they are well insulated), as increasing the temperature differential between inside and out increases the rate of heat flow through the wall. Do not locate heaters under windows.

As heaters create draughts when operating, try to locate them where they can draw cooled air back through passageways rather than sitting areas.

### Design for heat distribution

Convection currents are created when warmer air rises to the ceiling and air cooled by windows and external walls is drawn back along the floor to the heat source. With careful design, convective air movement can be used to great benefit but with poor design can be a major source of thermal discomfort.

Analyse warm air flows by visualising a helium filled balloon riding the thermal currents. Where would it go? Where would it be trapped? Cool air flows are drawn by gravity and fall towards the lower levels of your rooms — use incense sticks to track air flows in your existing home.

### Single storey homes

- Minimise convective air movement in winter with wall and ceiling insulation and glazing. The convection that still occurs is a major means of passive heat distribution in any home.
- Controlled convection can be used to warm rooms not directly exposed to heat sources; it can also reduce unwanted heat loss from rooms that do not require heating.
- Opening or closing doors controls the return air flow but impacts on privacy. Use vents that can be opened or sealed.
- Openable panels (louvres or transom windows) over doors promote and control movement of the warmest air at ceiling level while retaining privacy.
- Floor to ceiling doors are effective in facilitating air movement but are often closed for privacy.

### Multi-storey homes

- Place most thermal mass and the main heating sources at lower levels.
- Use high insulation levels and lower (or no) thermal mass at upper levels.
- Ensure upper levels can be closed off to stop heat rising in winter and overheating in summer.
- Use stairs to direct cool air draughts back to heat sources, located away from sitting areas.
- Avoid open rails on stairwells, balconies and voids. They allow cool air to fall like a waterfall into spaces below.
- Use ceiling fans or heat shifters (see *Heating and cooling*) to push warm air back to lower levels.
- Minimise window areas at upper levels and double glaze. Use close fitting drapes with snug pelmet boxes.
- Maximise the openable area of upper level windows for summer ventilation. Avoid fixed glazing.
- Locate bedrooms upstairs in cold climates so they are warmed by rising air.

## Preventing heat loss

Preventing heat loss is an essential component of efficient home design in any climate. It is even more critical in passive solar design as the primary heat source is only available during the day.

The building fabric must retain energy collected during the day for up to 16 hours and considerably longer in



cloudy weather. To achieve this, pay careful attention to each of the following factors:

- windows and glazing
- insulation
- draught sealing
- air locks.

## Windows and glazing

In terms of energy efficiency, glazing is a critical element of the building envelope, transferring both radiant and conducted heat. In insulated buildings it is where most heat is lost and gained.

*Avoid over-glazing — excessive areas of glass can be an enormous energy liability.*

Daytime heat gain must be balanced against night-time heat loss when selecting glazing and sizing windows. In winter, there are five hours or less of solar heat gain but 19 or more hours of night-time heat loss. Low conductivity or U-value (e.g. double glazing) and high solar heat gain coefficients (SHGC) are required in cool and cold climates but should be adjusted as cooling needs increase. (see *Glazing* for an explanation of U-value and SHGC)

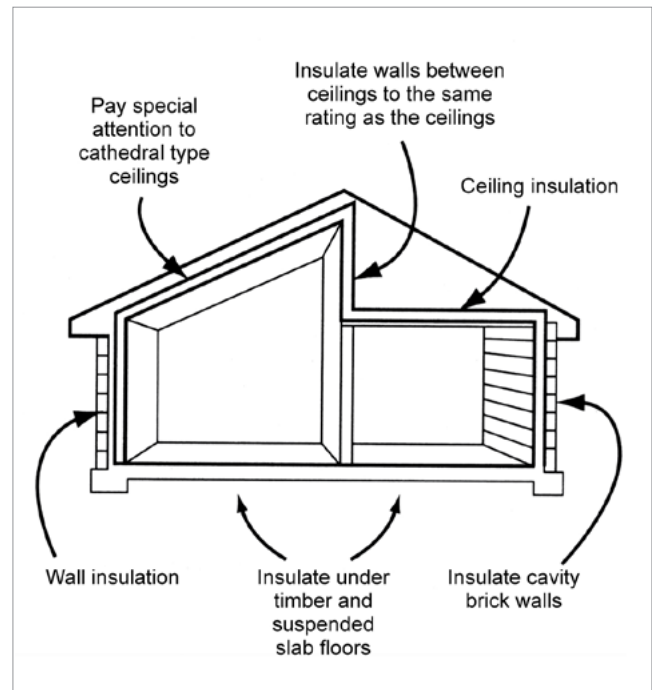
Window frames also conduct heat. Use timber, PVC or thermally separated metal window frames in cooler climates (and hotter climates where air conditioning is used).

Views are an important consideration and are often the cause of over-glazing or inappropriate orientation and shading. Plan carefully, especially for shading and advanced glazing options, to capitalise on views without decreasing energy efficiency. There are many ways to reduce heat loss through glazing. (see *Glazing*)

## Insulation

High insulation levels are essential in passive solar houses. Try to insulate above the minimum levels required by the current Building Code of Australia (BCA), Volume Two, Part 3.12.1. The BCA reference is AS/NZS 4859.1:2002 Materials for the thermal insulation of buildings — General criteria and technical provisions (incorporating Amendment 1). (see also *Insulation*)

**Ceilings and roof spaces** account for 25–35% of winter heat loss and must be well insulated. To prevent heat loss, place most of the insulation next to the ceiling as this is where the greatest temperature control is required.



Principles of good insulation.

**Floors** account for 10–20% of winter heat loss. In cool climates insulate the underside of suspended timber floors and suspended concrete slabs. Insulate the edges of ground slabs. Insulation is not required beneath earth-coupled concrete slabs; however, installation may be desirable when groundwater is present (see *Insulation installation*). Waffle pod construction helps to insulate under slabs.

**Walls** account for 15–25% of winter heat loss. Insulation levels in walls are often limited by cavity or frame width. In cold climates, alternative wall construction systems that allow higher insulation levels are recommended. (see *Lightweight framing*)

In high mass walls such as double brick, rammed earth and reverse brick veneer, thermal lag slows heat flow on a day–night basis. Insulation is still required in most instances; strawbale walls are an exception as they have a high insulation value. (see *Thermal mass; Construction systems*)

Internal walls and floors between heating and non-heating zones can be insulated to minimise heat loss and help reduce noise.

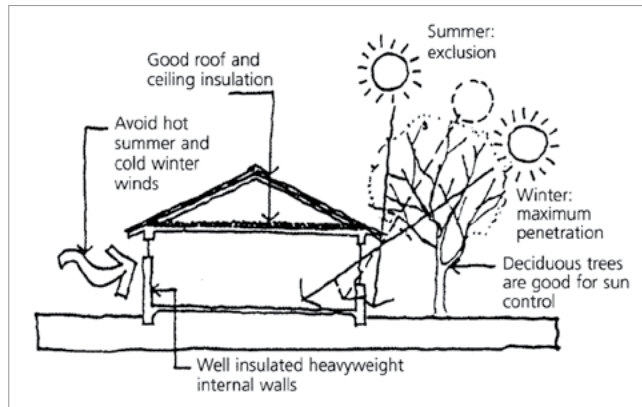


# Passive design

## Passive solar heating

### The role of the roof space

Sealed roof spaces provide a thermal buffer zone that increases the effectiveness of insulation.



Sealed roof spaces provide a thermal buffer zone.

Some heat always escapes into the roof space through your insulation. If the roof space is sealed, this escaping heat is trapped and can raise the temperature of the roof space by up to 17°C and reduce the temperature differential across both your ceiling insulation and roofing material (which should include insulation in cooler climates).

As discussed earlier, heat flow through any building element is directly proportional to the temperature differential on either side. Sealed roof spaces are warmer and this reduces the differential and increases the effectiveness of your insulation in the cooler months.

Roof spaces should be able to be ventilated in summer — often best achieved with thermostat controlled, self-sealing exhaust fans in gables or ridges that can be switched off in winter. When activated in summer, the fan only operates when the roof space is warmer than the outside air. (see *Passive cooling*)

Whirly bird roof ventilators are less effective in mixed (heating and cooling) climates because most are unable to be sealed in winter and automated in summer.

It is important to vent exhaust fans and range hoods to the outside in all cases to avoid condensation and fire risk from the build-up of cooking by-products.

### Glass to mass ratios

The ratio of solar exposed glass to exposed thermal mass in a room is critical and varies significantly between climates and designs. This is due to variations in diurnal and climatic temperature ranges. (see *Design for climate; Thermal mass*)

*Too much thermal mass for the available solar heat input creates a heat sink and increases auxiliary heating needs. Insufficient thermal mass causes daytime overheating and rapid heat loss at night.*

The amount of thermal mass used should be proportional to the diurnal temperature range. Higher diurnal ranges (inland) require more mass; lower diurnal ranges (coastal) require less. As a rule of thumb, in climates where diurnal ranges are consistently less than 6–8°C, low thermal mass construction performs better. Consider climate warming when making decisions.

The area of north-facing glass with solar access should range between 15% (temperate climates) and up to 25% (cold climates) of the area of exposed thermal mass in a room. Double glazing with heavy drapes and pelmets or equivalent window coverings is highly desirable in cool and cold climates.

In cooling climates with minor heating requirements (e.g. Brisbane) thermal mass levels are dependent on the diurnal range as above but, additionally, the cooling effect of earth-coupling of concrete slabs (where achievable) can provide significant benefits. Slab-on-ground construction is ideal provided that slabs are protected from summer heating and contact with sunlight.

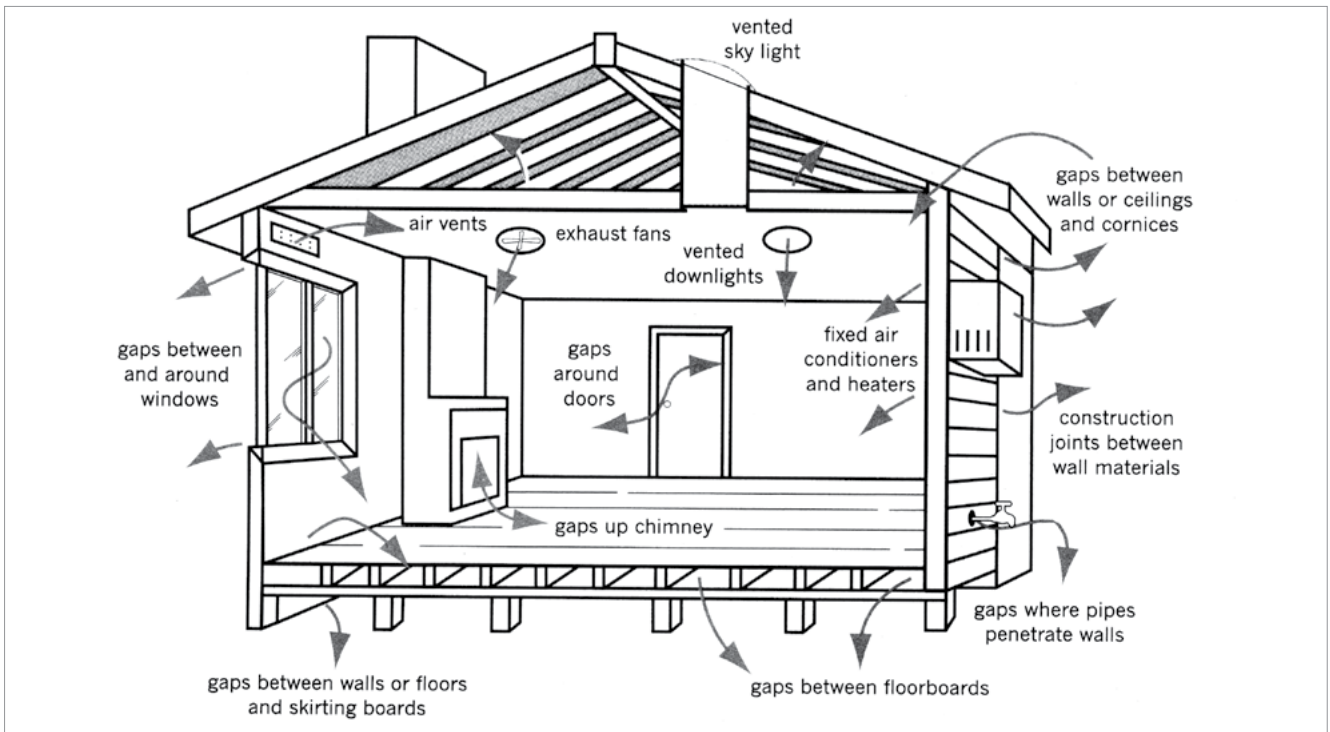
Detailed analysis of glass to mass ratios is complex. House energy rating software such as that developed by the Nationwide House Energy Rating Scheme (NatHERS) can simulate the interaction of the complex range of variables in any design for 69 different Australian climate zones.

While the NatHERS software is most commonly used as a rating tool for council approval, its capacity as a design tool in 'non-rating mode' is currently under-used. Seek advice from an assessor accredited by the Association of Building Sustainability Assessors or the Building Designers Association of Victoria, who is skilled in using the software in non-rating mode. (see *Thermal mass*, especially 'References and additional reading')

### Draught sealing

Air leakage accounts for 15–25% of winter heat loss in buildings.

- Improve the performance of existing windows and doors by using draught-proofing strips. Install these between the door and frame, at the door base and between the openable sash of the window and the frame.
- Use airtight construction detailing, particularly at wall-ceiling and wall-floor junctions.



Source: SEAV

Sources of air leakage.

- Control ventilation so it occurs when and where you want it.
- Choose quality windows and doors with airtight seals.
- Seal gaps between the window and door frames and the wall before fitting architraves in new homes and additions.
- Avoid using downlights that penetrate ceiling insulation (see *Lighting*).
- Duct exhaust fans and install non-return baffles.
- Avoid open fires and fit dampers to chimneys and flues or block them off if unused.
- Do not use permanently ventilated skylights.
- Use tight fitting floorboards and insulate the underside of timber floors.
- Seal off air vents; use windows and doors for ventilation as required. This may not be advisable for homes with unflued gas heaters that require a level of fixed ventilation. (see *Sealing your home*)

### Airlocks

Airlocks at all frequently used external openings (include wood storage areas if wood heating is used) are essential in cool and cold climates, preventing heat loss and draughts. For efficient use of space, airlocks

can be double purpose rooms: laundries, mud rooms and attached garages are excellent functional airlocks. Main entry airlocks can include storage spaces for coats, hats, boots and a small bench.

Allow sufficient space between doors so that closing the outer door before opening the inner door (or vice versa) can be done easily. Inadequate space often leads to inner doors being left open. Avoid using sliding doors in airlocks. They are invariably left open, are difficult to seal and can't be closed with a hip or elbow when both hands are full.

Always design doors to blow closed if left open in strong winds, or consider using spring closers on external doors.

### Passive heating in renovations

Passive heating in renovations is examined in much greater detail in *Renovations and additions*. The following summary lists key additional issues to consider when applying passive solar principles.

Existing brick homes often have adequate thermal mass. To improve passive heating in these homes, insulate external cavity walls, ensure that thermal mass is balanced by increased solar access, and design openings and convective flow paths to ensure that additional solar gains are distributed effectively within the home.

# Passive design

## Passive solar heating

Existing lightweight homes (including brick veneer) lack thermal mass. It can be simply and cost effectively added with water-filled containers and phase change materials. (see *Thermal mass*)

Opportunities for improving or adding passive solar design features when renovating an existing home include the following:

- Increase existing insulation levels and insulate any previously uninsulated ceilings and walls (and floors in cool climates) while they are exposed or during re-cladding or re-roofing.
- Design additions to allow passive solar access and facilitate movement of passive heat gains to other parts of the house.
- Relocate or resize poorly orientated or oversized windows and increase the size of solar exposed north windows.
- Use high performance windows and glazing for all new windows and doors. Replace poorly performing windows where possible — glazing is normally the biggest area of heat loss in any building.



Glazing is normally the biggest area of heat loss.

- Double glaze windows to reduce winter heat loss.
- Seal existing windows and external doors, and replace warped or poorly fitted doors. A wide range of seals is available from hardware retailers.
- Reorientate as much of the living space as possible to the north side of the house. North-facing bedrooms can become living rooms, while south-facing living areas can become bedrooms. This change can often be achieved without increasing the scale of the renovations.
- Create airlocks at entrances in cool and cold climates.
- Add doors and walls to create zones with similar heating needs.

- Consider adding a solar conservatory to maximise solar gains in cool climates. Ensure the heat it traps can be distributed to thermal mass within the home during the day and that it can be sealed off from the rest of the house at night.
- Install curtains with pelmet boxes or equivalent where practicable.
- Note that cool, cold and temperate climates all require varying degrees of passive cooling.
- Use window styles that allow maximum opening area. Casement windows or louvres are most appropriate but louvres should be well sealed (they cannot be double glazed).

### References and additional reading

Contact your state, territory or local government for further information on passive design considerations for your climate. [www.gov.au](http://www.gov.au)

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