Passive cooling design principles
http://www.yourhome.gov.au/passive-design/passive-cooling

To achieve thermal comfort in cooling applications, building envelopes are designed to minimize daytime heat gain, maximize night-time heat loss, and encourage cool breeze access when available. Considerations include:

- designing the floor plan and building form to respond to local climate and site
- using and positioning thermal mass carefully to store coolness, not unwanted heat
- choosing climate appropriate windows and glazing
- positioning windows and openings to enhance air movement and cross ventilation
- shading windows, solar exposed walls and roofs where possible
- installing and correctly positioning appropriate combinations of both reflective and bulk insulation
- using roof spaces and outdoor living areas as buffer zones to limit heat gain.

Integration of these variables in climate appropriate proportions is a complex task. Energy rating software, such as that accredited under the Nationwide House Energy Rating Scheme (NatHERS), can simulate their interaction in any design for 69 different Australian climate zones.

While the NatHERS software tools are most commonly used to rate energy efficiency (thermal performance) when assessing a house design for council approval, their capacity, in 'non-rating mode', as a design tool is currently under-used. Seek advice from an accredited assessor (Association of Building Sustainability Assessors or Building Designers Association of Victoria) who is skilled in using these tools in non-rating mode.

Envelope design - floor plan and building form
Envelope design is the integrated design of building form and materials as a total system to achieve optimum comfort and energy savings.

Heat enters and leaves a home through the roof, walls, windows and floor, collectively referred to as the building envelope. The internal layout - walls, doors and room arrangements - also affects heat distribution within a home.

Good design of the envelope and internal layout responds to climate and site conditions to optimise the thermal performance. It can lower operating costs, improve comfort and lifestyle and minimise environmental impact.

All Australian climates currently require some degree of passive cooling; with climate change this is expected to increase.

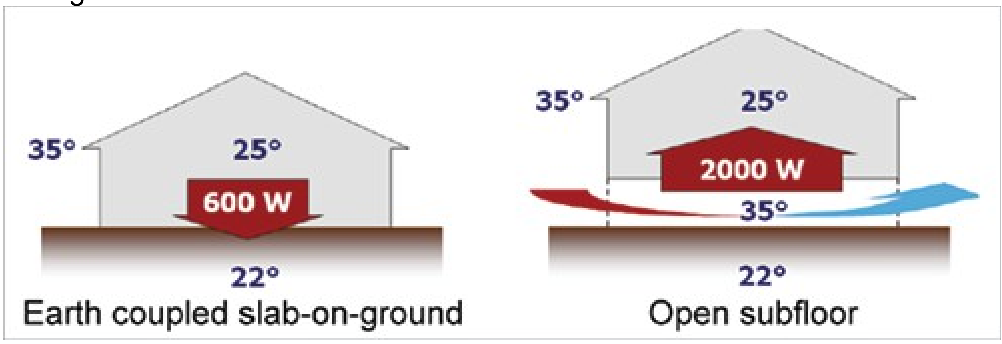
Varied responses are required for each climate zone and even within each zone depending on local conditions and the microclimate of a given site.

- Maximize the indoor−outdoor relationship and provide outdoor living spaces that are screened, shaded and rain protected.
- Maximize convective ventilation with high level windows and ceiling or roof space vents.
- Zone living and sleeping areas appropriately for climate — vertically and horizontally.
- Locate bedrooms for sleeping comfort.
- Design ceilings and position furniture for optimum efficiency of fans, cool breezes and convective ventilation.
- Locate mechanically cooled rooms in thermally protected areas (i.e. highly insulated, shaded and well sealed).

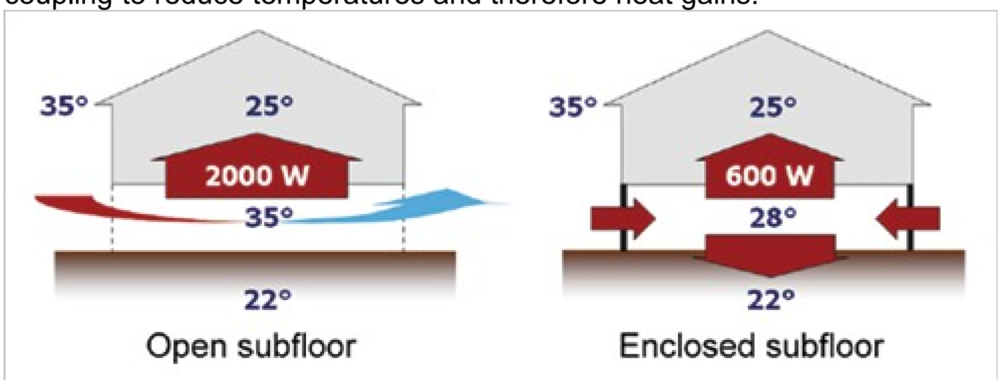
Thermal mass
Thermal mass is the storage system for warmth and 'coolth' (the absence of warmth) in passive design.

Climate responsive design means positioning thermal mass where it is exposed to appropriate levels of passive summer cooling (and solar heating in winter). Badly positioned mass heats up and radiates heat well into the night when external temperatures have dropped. As a rule of thumb, avoid or limit thermal mass in upstairs sleeping areas. In climates with little or no heating requirement, low mass is generally the preferred option (see Thermal mass).

Earth-coupled concrete slabs-on-ground provide a heat sink where deep earth temperatures (at 3m depth or more) are favorable, but should be avoided in climates where deep earth temperatures contribute to heat gain. In these regions, use open vented floors with high levels of insulation to avoid heat gain.

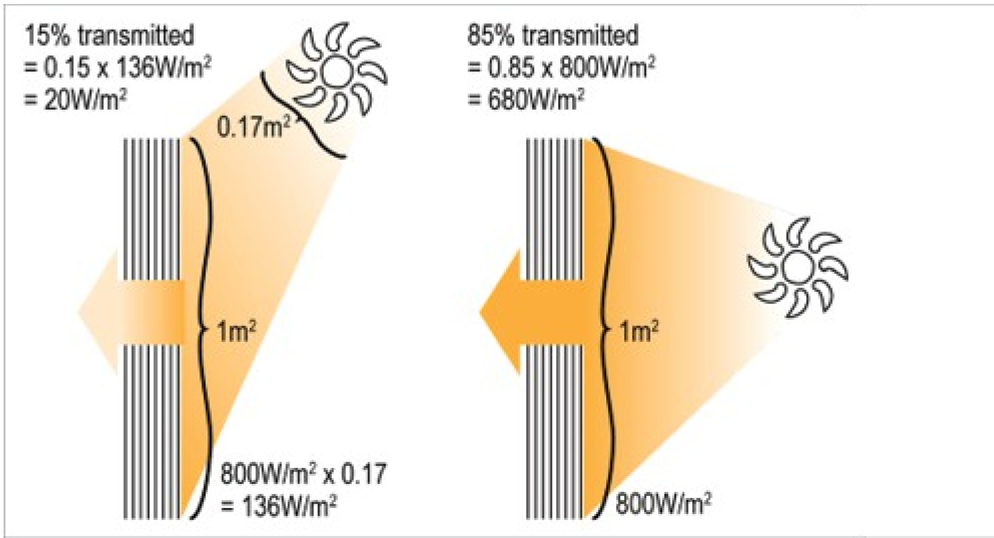


In regions where deep earth temperatures are lower, consider enclosing subfloor areas to allow earth coupling to reduce temperatures and therefore heat gains.



Windows and shading
Windows and shading are the most critical elements in passive cooling. They are the main source of heat gain, via direct radiation and conduction, and of cooling, via cross, stack and fan-drawn ventilation, cool breeze access and night purging (see Glazing; Shading).

Low sun angles through east and west-facing windows increase heat gain, while north-facing windows (south in tropics) transmit less heat in summer because the higher angles of incidence reflect more radiation.

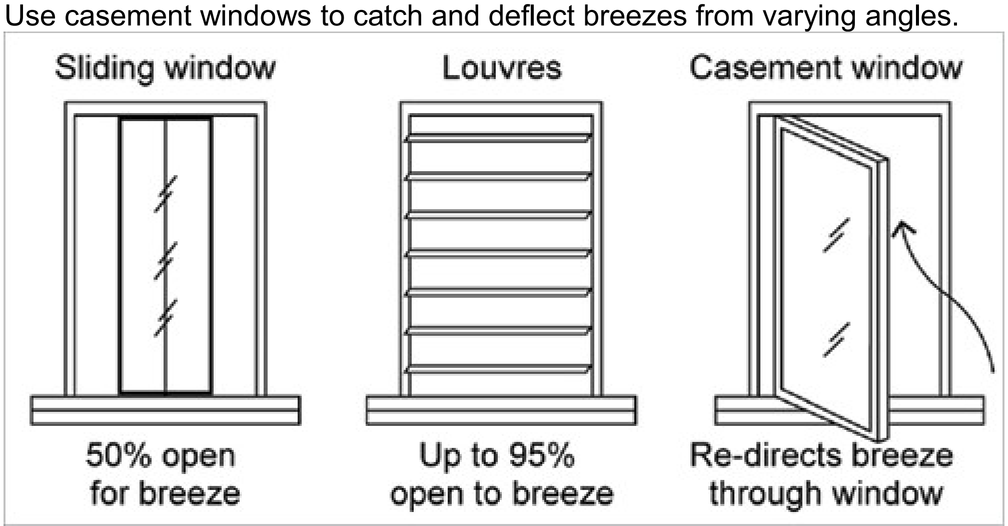


Source: Association of Building Sustainability Assessors (ABSA)
Relationship between sun angle and heat gain.

Air movement and ventilation
Design to maximise beneficial cooling breezes by providing multiple flow paths and minimising potential barriers; single depth rooms are ideal in warmer climates.

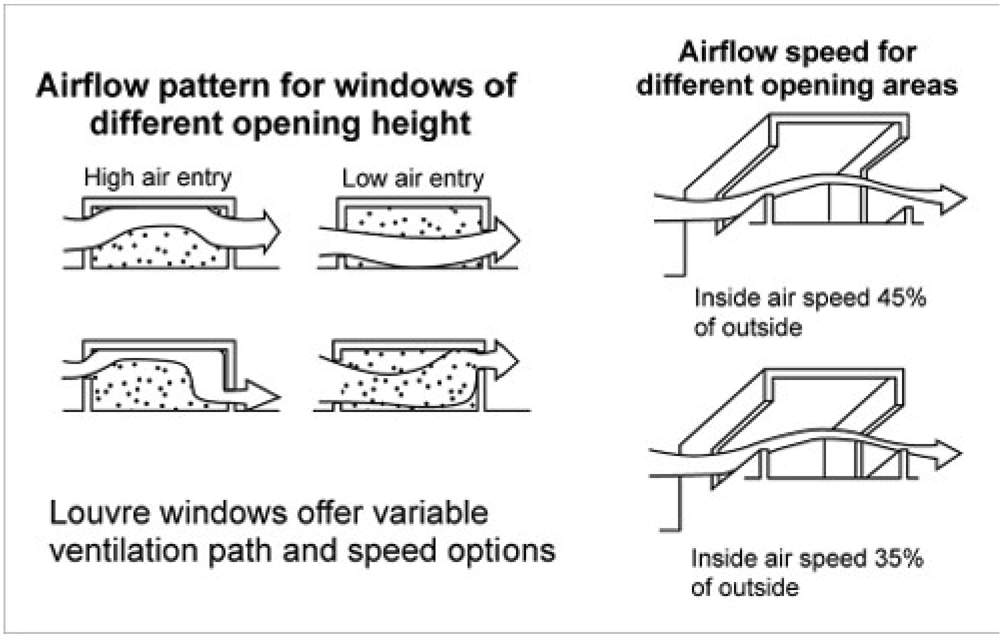
Because breezes come from many directions and can be deflected or diverted, orientation to breeze direction is less important than the actual design of windows and openings to collect and direct breezes within and through the home.

Use casement windows to catch and deflect breezes from varying angles.



Source: Dept of Environment and Resource Management, Qld

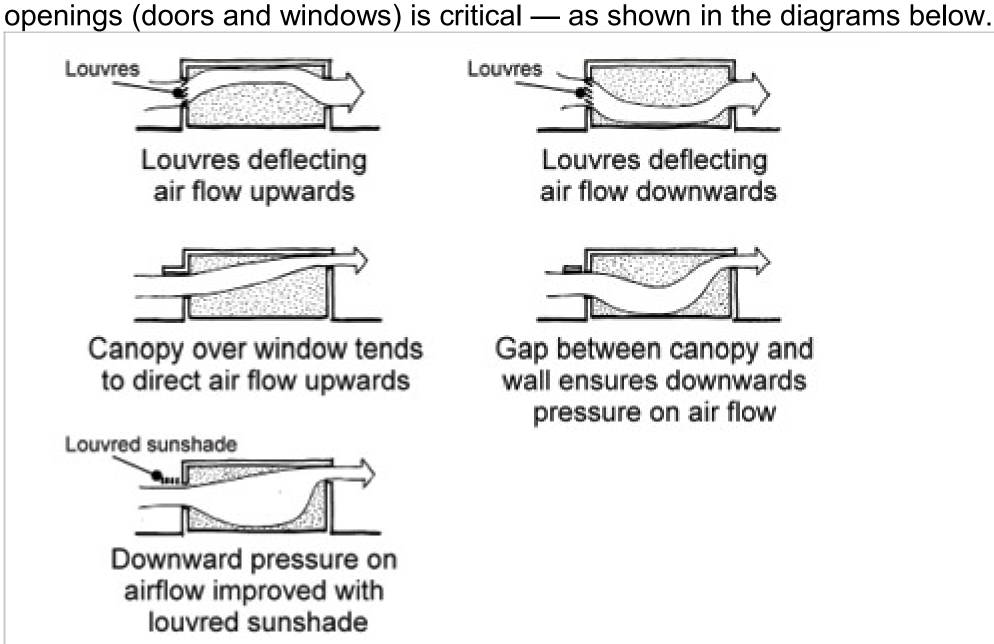
For breeze collection, window design is more important than orientation.
Wind doesn't blow through a building - it is sucked towards areas of lower air pressure. To draw the breeze through, use larger openings on the leeward (low pressure or downwind) side of the house and smaller openings on the breeze or windward (high pressure or upwind) side. Openings near the centre of the high pressure zone are more effective because pressure is highest near the centre of the windward wall and diminishes toward the edges as the wind finds other ways to move around the building.



Airflow pattern and speed for different opening areas.

In climates requiring winter heating the need for passive solar north sun influences these considerations; designers should strive for a balanced approach.

The design of openings to direct airflow inside the home is a critical but much overlooked design component of passive cooling. Size, type, external shading and horizontal/vertical position of any openings (doors and windows) is critical — as shown in the diagrams below.



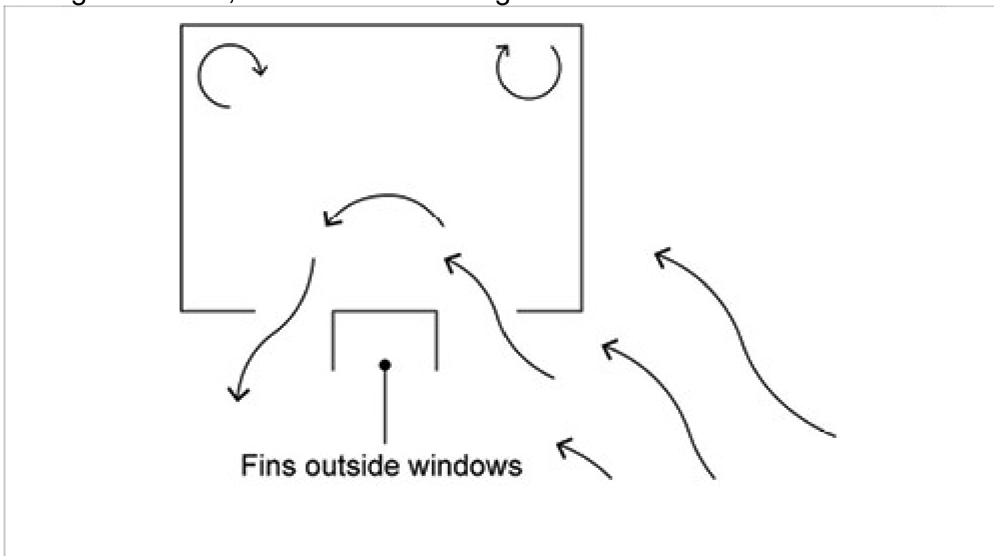
Source: Steve Szokolay

Airflow pattern for windows of different opening height. Louvre windows help to vary ventilation paths and control air speed.

Consider installing a louvre window above doors to let breezes pass through the building while maintaining privacy and security. In climates requiring cooling only, consider placing similar panels above head height in internal walls to allow cross-ventilation to move the hottest air.

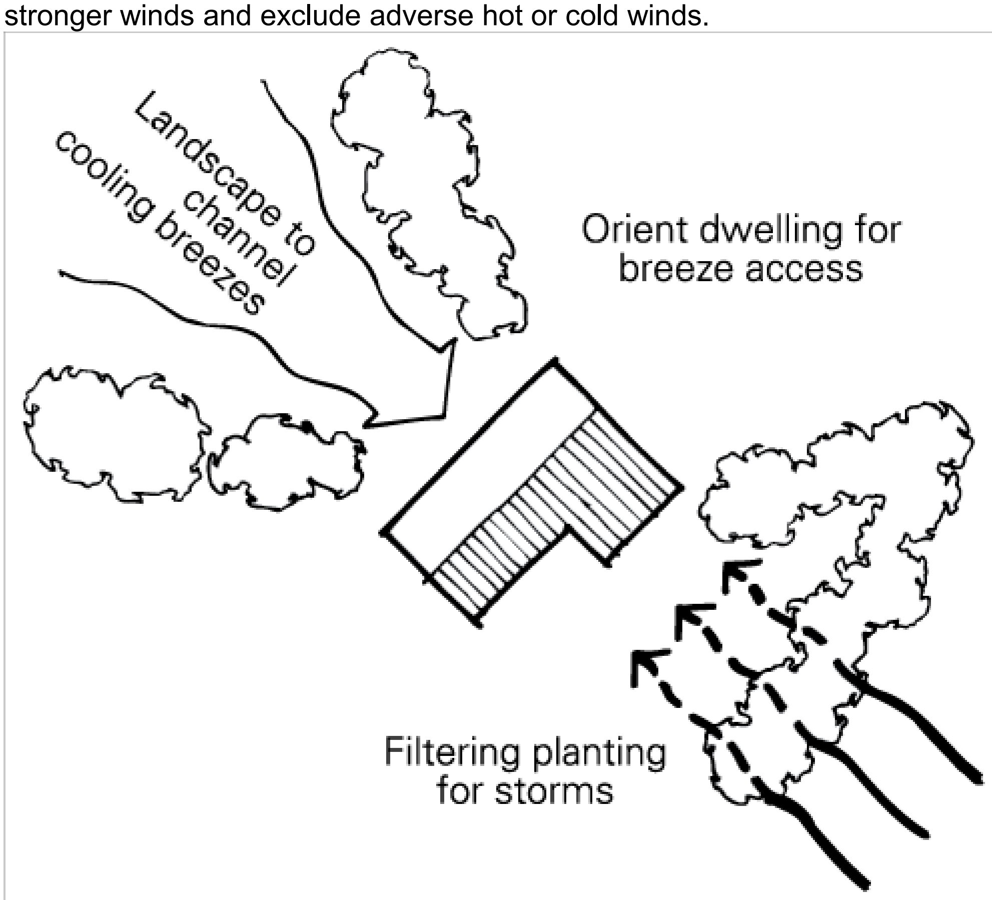
Position windows (vertically and horizonally) to direct airflow to the area where occupants spend most time (e.g. dining table, lounge or bed).

In rooms where it is not possible to place windows in opposite or adjacent walls for cross-ventilation, place projecting fins on the windward side to create positive and negative pressure to draw breezes through the room, as shown in the diagram below.

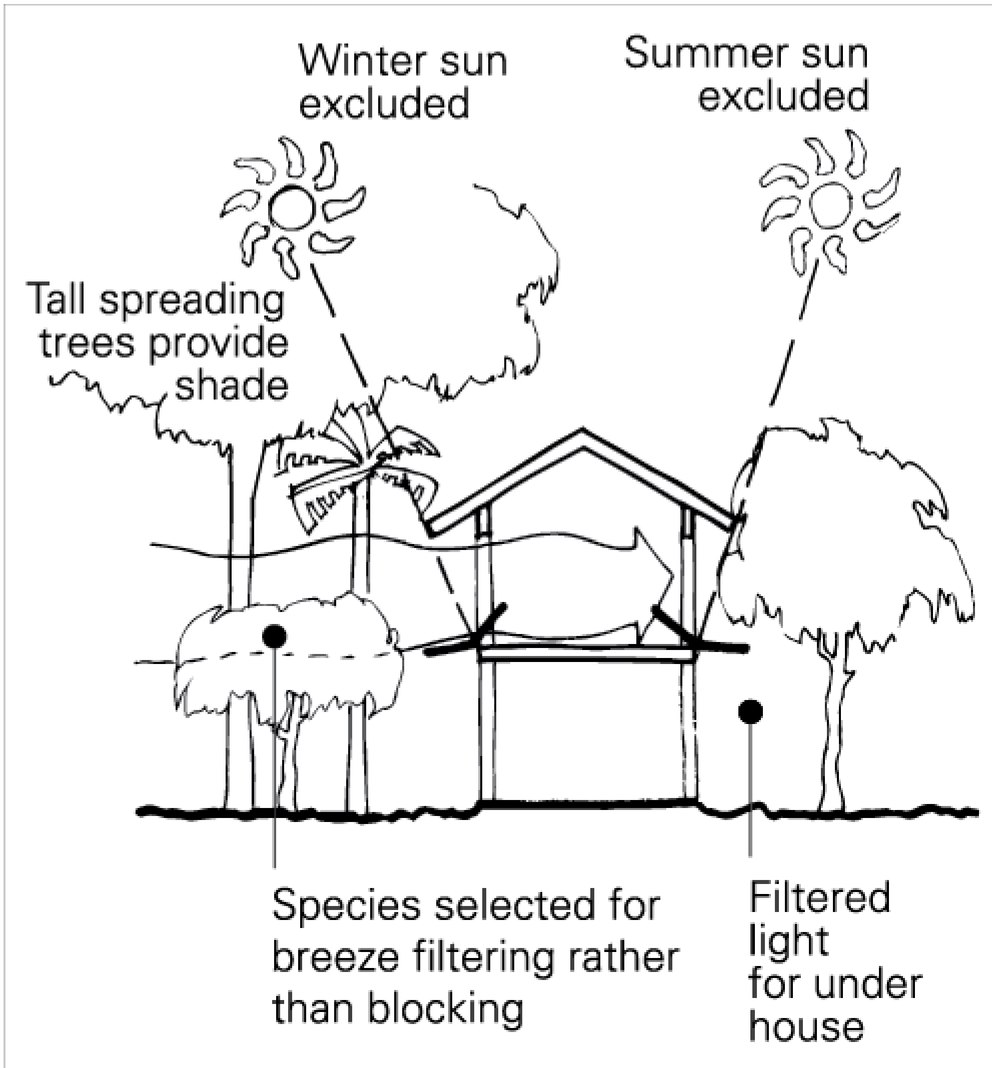


Use fins to direct airflow.

Design and locate planting, fences and outbuildings to funnel breezes into and through the building, filter stronger winds and exclude adverse hot or cold winds.



Plant trees and shrubs to funnel breezes.



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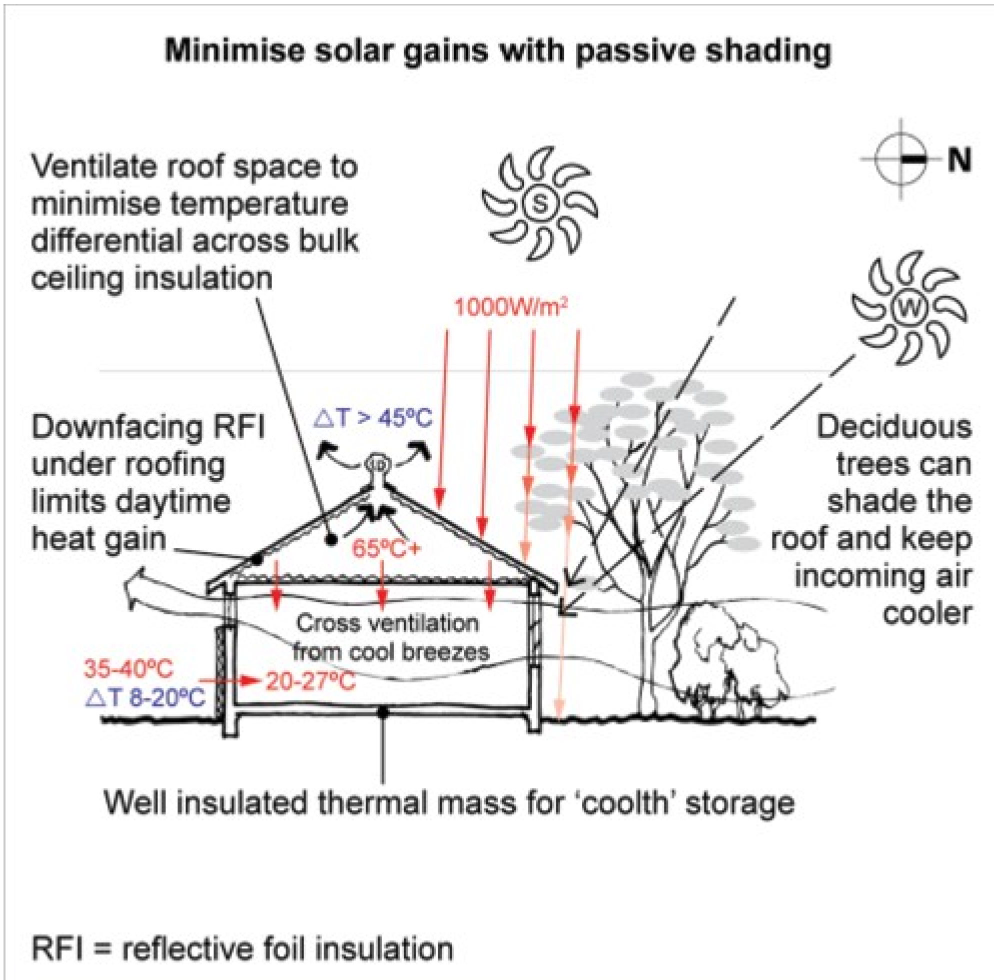
Insulation
Insulation is critical to passive cooling - particularly to the roof and floor. Windows are often left open to take advantage of natural cooling and walls are easily shaded; roofs, however, are difficult to shade, and floors are a source of constant heat gain through conduction and convection, with only limited cooling contribution to offset it.

Insulation levels and installation details for each climate zone are provided in Insulation and Insulation installation. Pay careful attention to up and down insulation values and choose appropriately for purpose and location.

In climates that require only cooling or those with limited cooling needs, use multiple layers of reflective foil insulation in the roof instead of bulk insulation to reduce radiant daytime heat gains while maximizing night-time heat loss through conduction and convection. This is known as the one-way insulation valve. Reflective foil insulation is less affected by condensation and is highly suited to cooling climate applications as it reflects unwanted heat out while not re-radiating it in.

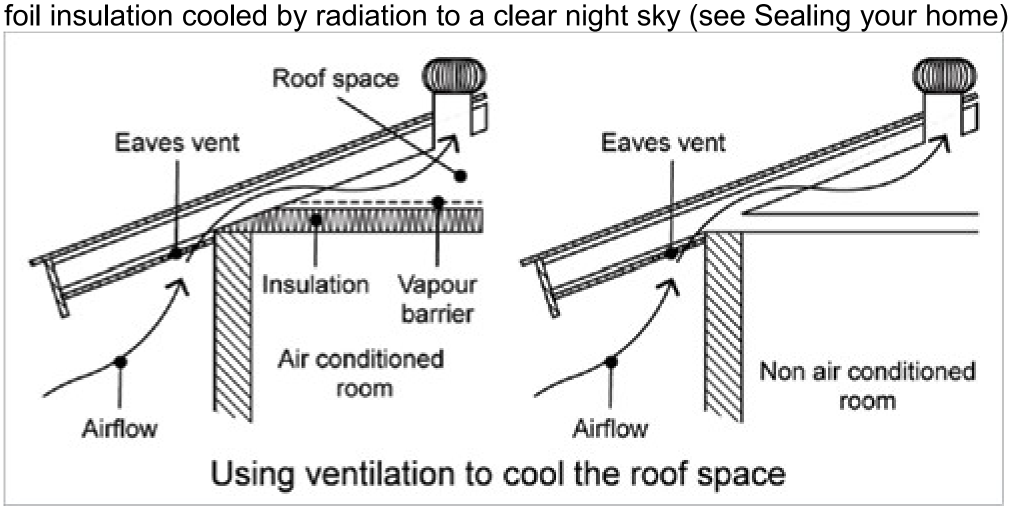
Roof space
Well-ventilated roof spaces (and other non-habitable spaces) play a critical role in passive cooling by providing a buffer zone between internal and external spaces in the most difficult area to shade, the roof.



Well-ventilated roof spaces form a buffer between internal and external areas.

Ventilators can reduce the temperature differential (see Passive heating) across ceiling insulation, increasing its effectiveness by as much as 100%. The use of foil insulation and light coloured roofing limits radiant heat flow into the roof space.

Use careful detailing to prevent condensation from saturating the ceiling and insulation. Dew-points form where humid air comes into contact with a cooler surface, e.g. the underside of roof sarking or reflective foil insulation cooled by radiation to a clear night sky (see Sealing your home).

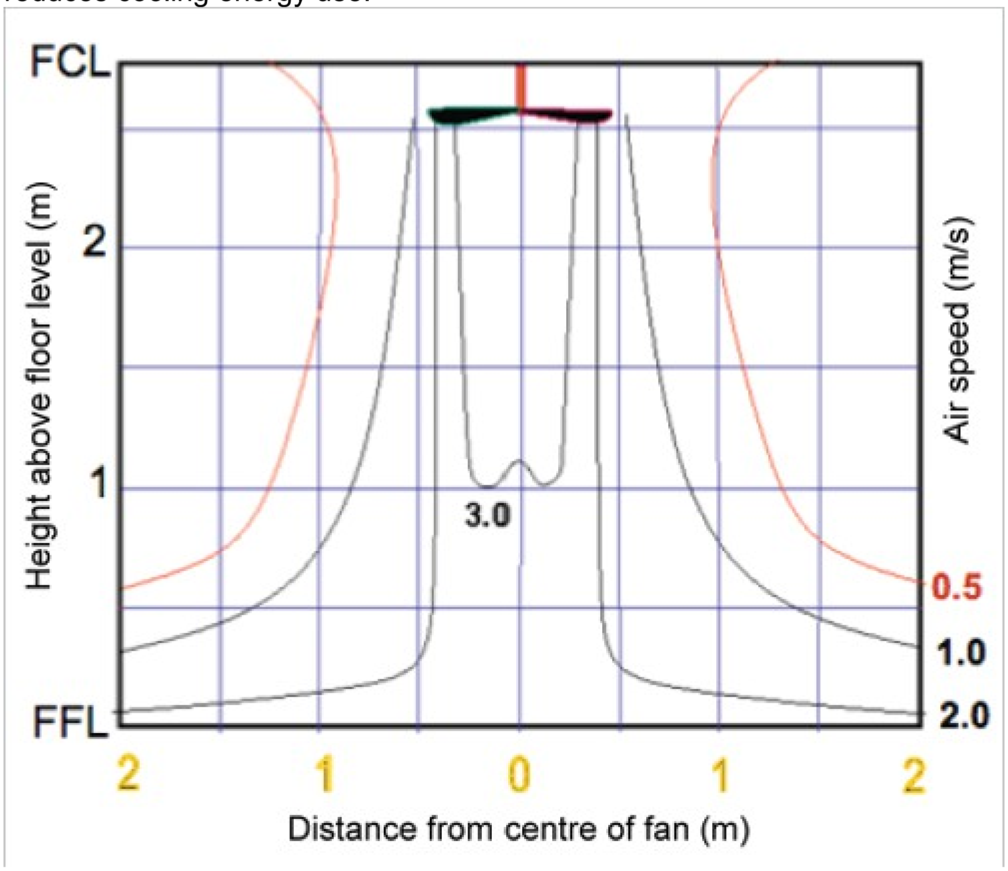


Source: COOLmob
Using ventilation to cool the roof space.

Hybrid cooling systems
Hybrid cooling systems are whole house cooling solutions that employ a variety of cooling options (including air conditioning) in the most efficient and effective way. They take maximum advantage of passive cooling when available and make efficient use of mechanical cooling systems during extreme periods.

Fans
Fans provide reliable air movement for cooling people and supplementing breezes during still periods. At 50% relative humidity, air movement of 0.5m/s creates maximum cooling effect; faster speeds can be unsettling. As noted above, air speeds up to 1.0m/s can be useful in higher relative humidity, but prolonged air speeds above 1.0m/s cause discomfort.

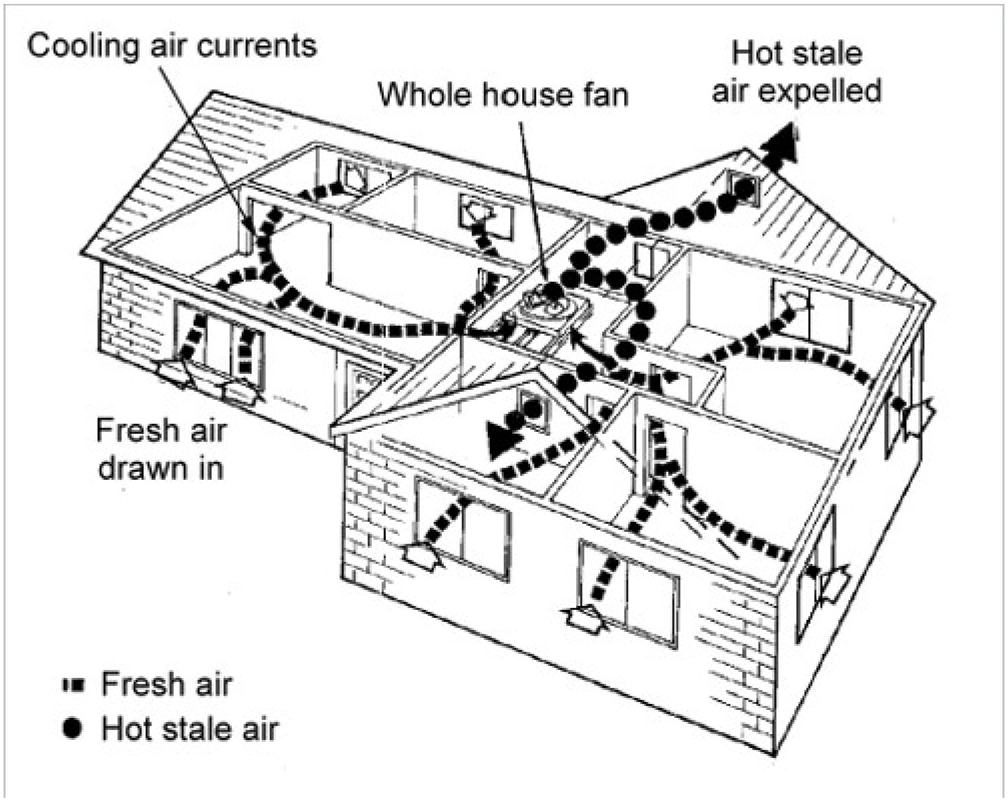
Standard ceiling fans can create a comfortable environment when temperature and relative humidity levels are within acceptable ranges. In a lightweight building in a warm temperate climate, the installation of fans in bedrooms and all living areas (including kitchens and undercover outdoor areas) significantly reduces cooling energy use.



Source: Adapted from Ballinger 1992

Air movement relative to fan position.
Fans should be located centrally in each space, one for each grouping of furniture. An extended lounge/dining area needs two fans. In bedrooms, locate the fan close to the centre of the bed. Because air speed decreases with distance from the fan, position fans over the places where people spend the most time (see Heating and cooling).

Whole of house fans
Whole of house or roof fans are ideal for cooling buildings, particularly where cross-ventilation design is inadequate. However, they do not create sufficient air speed to cool occupants.



Source: Breezepower

Whole of house fans should be positioned centrally, e.g. in the roof, stairwell or hallways.

Typically, a single fan unit is installed in a circulation space in the centre of the house (hallway or stairwell) to draw cooler outside air into the building through open windows in selected rooms, when conditions are suitable. It then exhausts the warm air through eaves, ceiling or gable vents via the roof space. This also cools the roof space and reduces any temperature differential across ceiling insulation. Control systems should prevent the fan operating when external air temperatures are higher than internal.

Drawing large volumes of humid air through the roof space can increase condensation. A dew-point forms when this humid air comes in contact with roof elements (e.g. reflective insulation) that have been cooled by radiation to night skies (see Insulation and Sealing your home for ways to mitigate this). Whole of house fans can be noisy at full speed but are generally operated in the early evening when cooling needs peak and households are most active. If run at a lower speed throughout the night, they can draw cool night air across beds that are near open windows, provided doors are left open for circulation. On still nights this can be more effective than air conditioning for night-time sleeping comfort.