Passive cooling

To be comfortable, buildings in all Australian climates require some form of cooling at some time of the year. There are many ways you can design or modify your home to achieve comfort through passive (non-mechanical) cooling, as well as hybrid approaches which utilise mechanical cooling systems.

The most appropriate passive cooling strategies for your home — including orientation, ventilation, windows, shading, insulation and thermal mass — are determined by climate, so first identify your climate zone by reading *Design for climate*. You can then apply the more detailed advice here and in *Passive solar heating*.

All Australian climates apart from tropical (Zone 1) require some form of heating in winter, and this affects advice relating to cooling. The balance between summer cooling and winter heating should be adjusted for climate through appropriate passive design. Tropical climate buildings, which require year round shading and are subject to very different passive cooling principles, are discussed separately below.

The advice in this article applies to most types of residential housing; however, additional useful tips can be found in *Buying a home off the plan*, *Buying an existing home*, *Renovations and additions* and *Buying and renovating an apartment*.

Verandas, underfloor ventilation and shady plantings keep this Darwin classic comfortable in the heat.

Heat waves can affect large regions at the same time, causing combined household demand for cooling energy to 'peak' for a few days or weeks each year due to increased use of air conditioning or heat pumps for cooling during these periods. However, with careful design for passive cooling we may delay or eliminate this peak demand.

What is passive cooling?

Passive cooling is the least expensive means of cooling a home in both financial and environmental terms. Some level of passive cooling is required in every Australian climate at some time of the year.

As cooling requirements are dictated by climate, distinctly different approaches to passive cooling are required for:

- hot humid climates (Zone 1) where no heating is required
- temperate and warm climates (Zones 2–6) where both heating and cooling are required
- cool and cold climates (Zones 7–8) where heating needs are more important.

Each climate is discussed separately below.

Cooling people

Factors affecting comfort for people (human thermal comfort) are outlined in *Design for climate* and include both physiological and psychological factors.

> *To be effective, passive cooling needs to cool both the building and the people in it.*

Evaporation of perspiration is the most effective physiological cooling process. It requires air movement and moderate to low humidity (less than 60%).

Radiant heat loss is also important, both physiologically and psychologically. It involves direct radiation to cooler surfaces.

Conduction contributes to both types of comfort and involves body contact with cooler surfaces. It is most effective when people are sedentary (e.g. sleeping on a water bed).

Cooling buildings

The efficiency of the building envelope can be maximised in a number of ways to minimise heat gain:

- shading windows, walls and roofs from direct solar radiation
- using lighter coloured roofs to reflect heat
- using insulation and buffer zones to minimise conducted and radiated heat gains
- making selective or limited use of thermal mass to avoid storing daytime heat gains.

To maximise heat loss, use the following natural sources of cooling:

- air movement
- cooling breezes
- evaporation
- earth coupling
- reflection of radiation.

Cooling sources

Sources of passive cooling are more varied and complex than passive heating, which comes from a single, predictable source — solar radiation.

Varying combinations of innovative envelope design, air movement, evaporative cooling, earth-coupled thermal mass, lifestyle choices and acclimatisation are required to provide adequate cooling comfort in most Australian climate zones. Additional mechanical cooling may be required in hot humid climates and in extreme conditions in many climates, especially as climate change leads to higher temperatures during the daytime and overnight.

Air movement

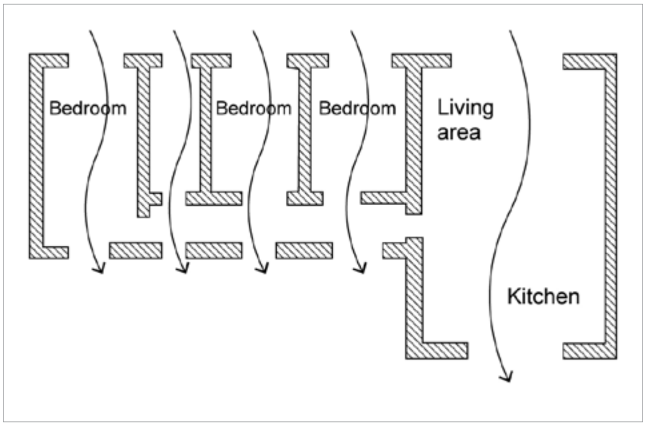
Air movement is the most important element of passive cooling. It cools people by increasing evaporation and requires both breeze capture and fans for back-up in still conditions.

It also cools buildings by carrying heat out of the building as warmed air and replacing it with cooler external air. Moving air also carries heat to mechanical cooling systems where it is removed by heat pumps and recirculated. This requires well-designed openings (windows, doors and vents) and unrestricted breeze paths.

In all climates, air movement is useful for cooling people, but it may be less effective during periods of high humidity. An air speed of 0.5m/s equates to a 3°C drop in temperature at a relative humidity of 50%. This is a one-off physiological cooling effect resulting from heat being drawn from the body to evaporate perspiration. Air movement exposes the skin to dryer air. Increased air speeds do not increase cooling at lower relative humidity but air speeds up to 1.0m/s can increase evaporative cooling in higher humidity. Air speeds above 1.0m/s usually cause discomfort.

Cool breezes

Where the climate provides cooling breezes, maximising their flow through a home when cooling is required is an essential component of passive design. Unlike cool night air, these breezes tend to occur in the late afternoon or early evening when cooling requirements usually peak.



Cool breezes work best in narrow or open plan layouts.

Cool breezes work best in narrow or open plan layouts and rely on air-pressure differentials caused by wind or breezes. They are less effective in:

- buildings with deep floor plans or individual small rooms
- long periods of high external temperature (ambient or conducted heat gains above 35–40 watts per square metre (W/m^2)
- locations with high noise, security risk or poor external air quality, where windows may need to be closed.

Coastal breezes are usually from an onshore direction (south-east and east to north-east in most east coast areas, and south-west in most west coast areas, e.g. the 'Fremantle Doctor').

In mountainous or hilly areas, cool breezes often flow down slopes and valleys in late evening and early morning, as heat radiating to clear night skies cools the land mass and creates cool air currents.

Thermal currents are common in flatter, inland areas, created by daily heating and cooling. They are often of short duration in early morning and evening but with good design can yield worthwhile cooling benefits.

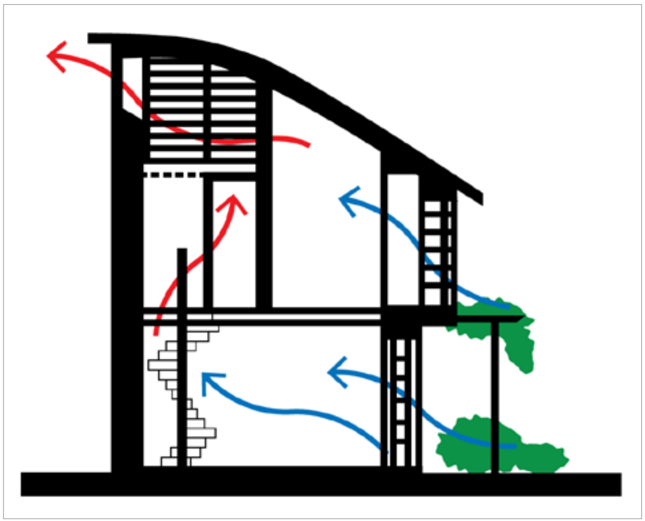
Cool night air

Cool night air is a reliable source of cooling in inland areas where cool breezes are limited and diurnal temperature ranges usually exceed 6–8°C. Hot air radiating from a building fabric's thermal mass is replaced with cooler night air drawn by internal–external temperature differentials rather than breezes. Full height, double hung windows are ideal for this purpose. Further cooling can be gained by including whole of house fans (see below).

Convective air movement

The rule of convection: warm air rises and cool air falls.

Stack ventilation, or convective air movement, relies on the increased buoyancy of warm air which rises to escape the building through high level outlets, drawing in lower level cool night air or cooler daytime air from shaded external areas (south) or evaporative cooling ponds and fountains.



Convection causes warm air to rise, drawing in cool air.

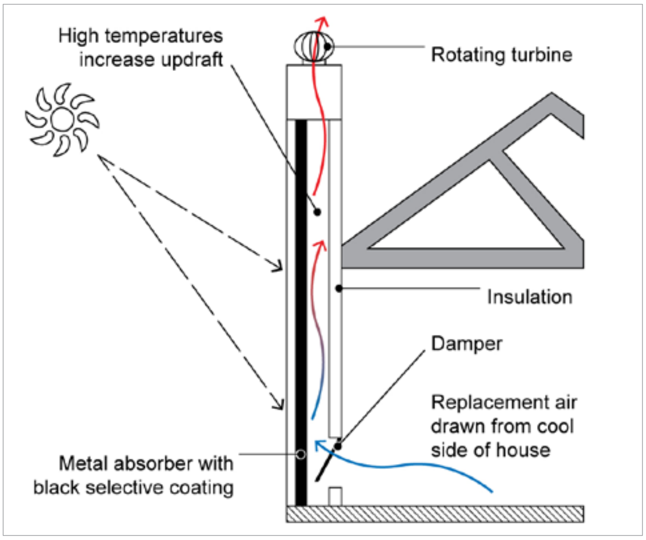
Convective air movement improves cross-ventilation and overcomes many of the limitations of unreliable cooling breezes. Even when there is no breeze, convection allows heat to leave a building via clerestory windows, roof ventilators and vented ridges, eaves, gables and ceilings.

Convection produces air movement capable of cooling a building but usually has insufficient air speed to cool people.

Solar chimneys

Solar chimneys enhance stack ventilation by providing additional height and well-designed air passages that increase the air pressure differential. Warmed by solar radiation, chimneys heat the rising air and increase the difference in temperature between incoming and out-flowing air.

The increase in natural convection from these measures enhances the draw of air through the building.



Source: Green Builder Solar Guidelines (Residential)

Solar chimneys enhance ventilation.

Evaporative cooling

As water evaporates it draws large amounts of heat from surrounding air. Evaporation is therefore an effective passive cooling method, although it works best when relative humidity is lower (70% or less during hottest periods) as the air has a greater capacity to take up water vapour.

Rates of evaporation are increased by air movement.

Pools, ponds and water features immediately outside windows or in courtyards can pre-cool air entering the house. Carefully located water features can create convective breezes. The surface area of water exposed to moving air is also important. Fountains, mist sprays and waterfalls can increase evaporation rates.

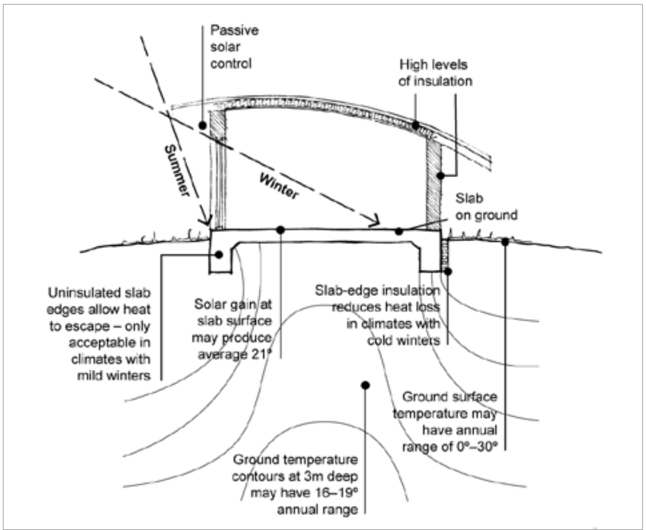
Photo: Sunpower Design

Ponds pre-cool air before it enters a house.

Mechanical evaporative coolers are common in drier climates and inland areas where relative humidity is low. They use less energy than refrigerated air conditioners and work better with doors and windows left open. Their water consumption can be considerable. (see *Heating and cooling*)

Earth coupling

Earth coupling of thermal mass protected from external temperature extremes (e.g. floor slabs) can substantially lower temperatures by absorbing heat as it enters the building or as it is generated by household activities.



Earth coupling utilises cooler ground temperatures.

Passively shaded areas around earth-coupled slabs keep surface ground temperatures lower during the day and allow night-time cooling. Poorly shaded surrounds can lead to earth temperatures exceeding internal comfort levels in many areas. In this event, an earth-coupled slab can become an energy liability.

Ground and soil temperatures vary throughout Australia. Earth-coupled construction (including slab-on-ground and earth covered or bermed) utilises stable ground temperatures at lower depths to absorb household heat gains.

Passive cooling design principles

To achieve thermal comfort in cooling applications, building envelopes are designed to minimise daytime heat gain, maximise 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.

- Maximise the indoor–outdoor relationship and provide outdoor living spaces that are screened, shaded and rain protected.

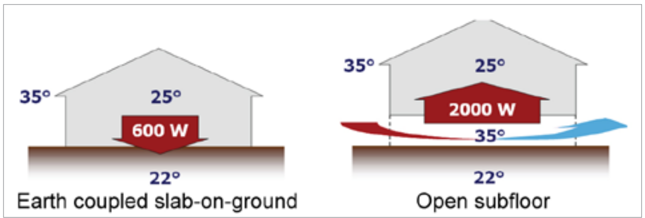
- Maximise convective ventilation with high level windows and ceiling or roof space vents.
- Zone living and sleeping areas appropriately for climate — vertically and horizontally.
- Locate bedrooms for sleeping comfort.
- Design ceilings and position furniture for optimum efficiency of fans, cool breezes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

Thermal mass

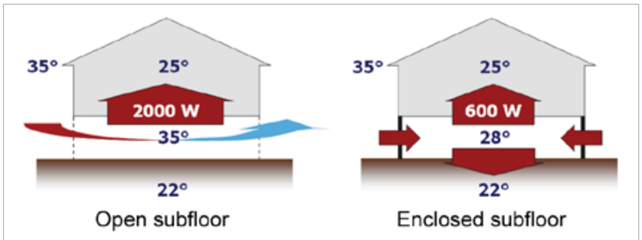
Thermal mass is the storage system for warmth and 'coolth' (the absence of warmth) in passive design.

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 favourable, 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.



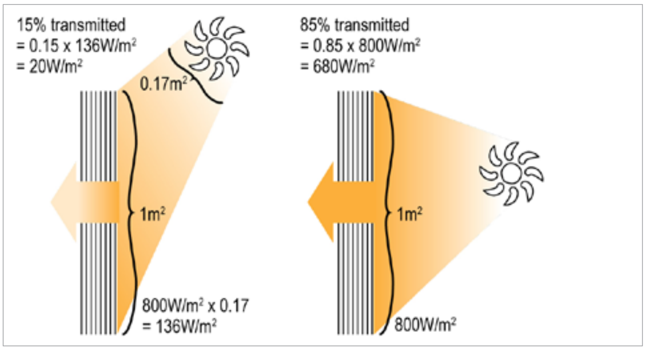
In regions where deep earth temperatures are lower, consider enclosing subfloor areas to allow earth coupling to reduce temperatures and therefore heat gains.



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)

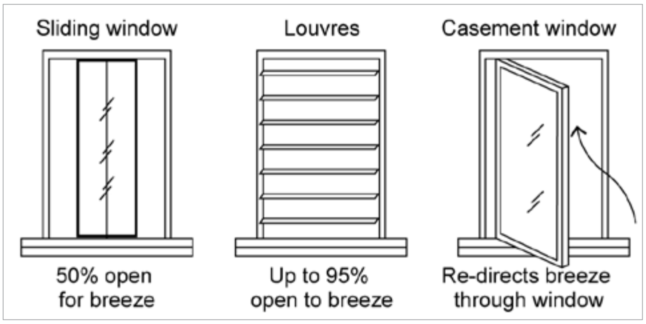
Relationship between sun angle and heat gain.

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.

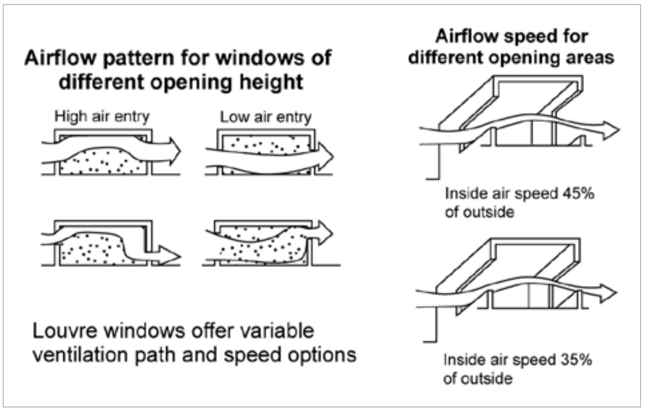
Use casement windows to catch and deflect breezes from varying angles.



Source: Dept of Environment and Resource Management, Qld

For breeze collection, window design is more important than orientation.

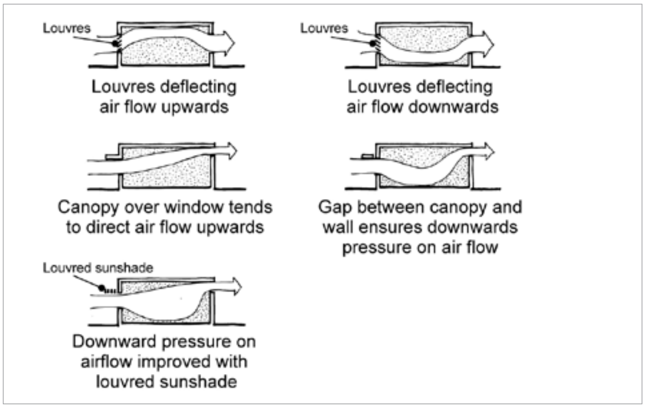
Wind doesn't blow through a building — it is sucked towards areas of lower air pressure. To draw the breeze through, use larger openings on the leeward (low pressure or downwind) side of the house and smaller openings on the breeze or windward (high pressure or upwind) side. Openings near the centre 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.



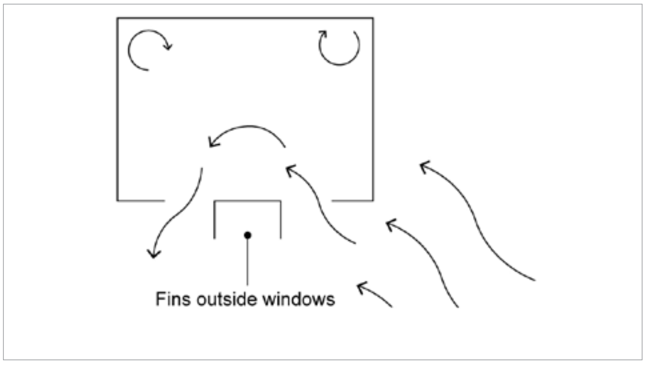
Source: Steve Szokolay

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.

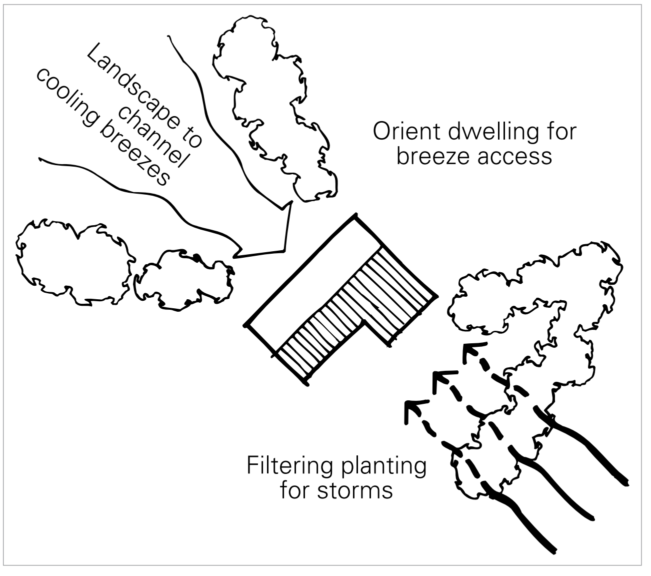
Position windows (vertically and horizonally) to direct airflow to the area where occupants spend most time (e.g. dining table, lounge or bed).

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.

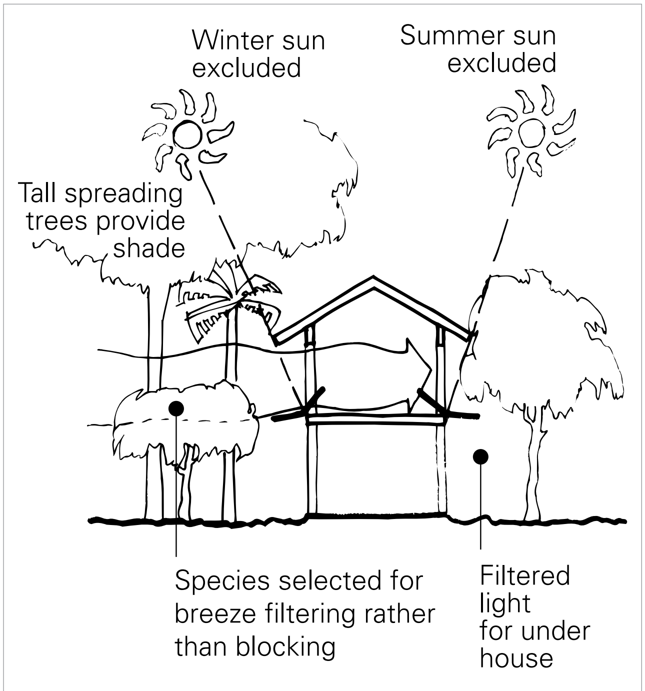


Use fins to direct airflow.

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.



Plant trees and shrubs to funnel breezes.

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.

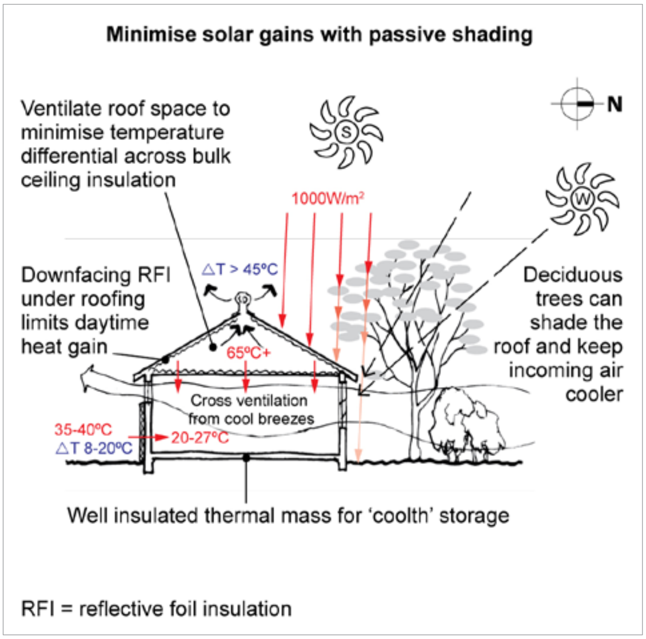
Insulation levels and installation details for each climate zone are provided in *Insulation* and *Insulation installation*. Pay careful attention to up and down insulation values and choose appropriately for purpose and location.

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 maximising 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

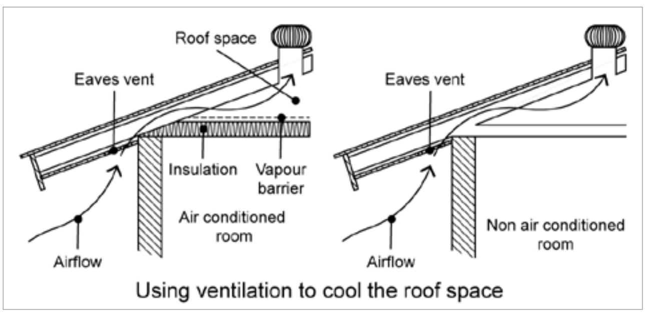
Well-ventilated roof spaces (and other non-habitable spaces) play a critical role in passive cooling by providing a buffer zone between internal and external spaces in the most difficult area to shade, the roof.



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

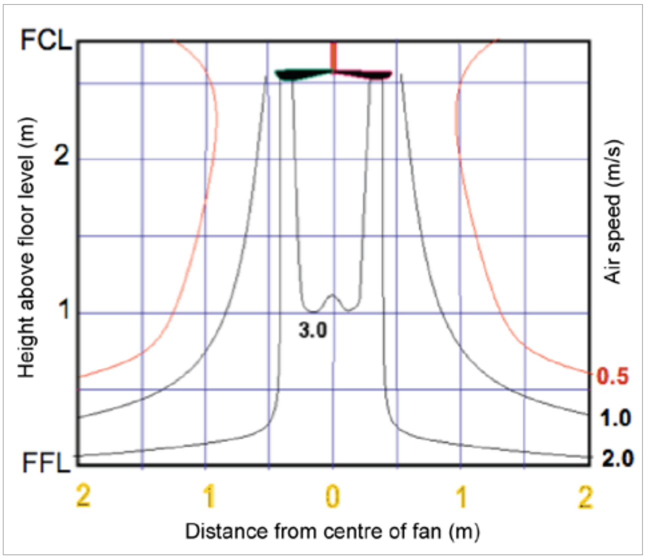
Hybrid cooling systems are whole house cooling solutions that employ a variety of cooling options (including air conditioning) in the most efficient and effective way. They take maximum advantage of passive cooling when available and make efficient use of mechanical cooling systems during extreme periods.

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.



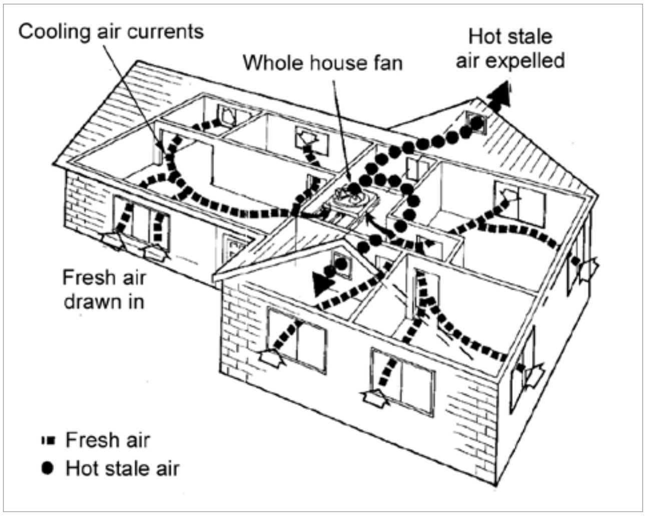
Source: Adapted from Ballinger 1992

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.

Air conditioning

Refrigerated air conditioning lowers both air temperature and humidity and provides thermal comfort during periods of high temperature and humidity. However, it is expensive to install, operate and maintain, and has a high economic and environmental cost because it consumes significant amounts of electricity unless high efficiency equipment is used in a very high performance building envelope. As it also requires the home to be sealed off from the outside environment, occupants are often unaware of improvements in the weather.

Air conditioning is commonly used to create comfortable sleeping conditions. The number of operating hours required to achieve thermal comfort can be substantially reduced or eliminated by careful design of new homes, as well as alterations and additions to existing homes.

Running a refrigerated air conditioner in a closed room for about an hour at bedtime often lowers humidity levels to the point where air movement from ceiling fans can provide sufficient evaporative cooling to achieve and maintain sleeping comfort. Some air conditioning units simply operate as fans when outdoor ambient temperature drops below the thermostat setting, so they can replace a ceiling fan.

Efficient air conditioning requires more than simply installing an efficient air conditioner.

Hybrid cooling solutions require a decision early in the design stages about whether air conditioning is to be used and how many rooms require it. Many inefficient air conditioning installations occur when they are added to a home designed for natural cooling as an afterthought to improve comfort.

Design of air conditioned spaces

There is usually no need to air condition all rooms. Decide which rooms will receive most benefit, depending on their use, and try to reduce the total volume of air conditioned air space (room size, ceiling height). Often one or two rooms are sufficient to provide comfort during periods of high humidity and high temperatures.

Design for night-time sleeping comfort by conditioning rooms commonly used in the early evening with bedrooms adjoining. A conditioned, masonry-wall television room in the centre of a free running (passively cooled) home with sleeping spaces adjoining it provides both direct and indirect cooling benefits. Efficient (low heat output) lighting and appliances are important in such an application.

A cool masonry wall in a bedroom gives both psychological and physiological comfort through combined radiant heat loss and reliable air movement from fans.

A well-ventilated tropical house.

Design conditioned rooms with high levels of insulation and lowest exposure to external temperature influences, usually found in the centre of the house. Adjoining living spaces should be well ventilated, free running (passively cooled), with fans to encourage acclimatisation, and provide a thermal buffer to conditioned spaces.

Address condensation in externally ventilated rooms surrounding conditioned rooms. Walls with high thermal mass have fewer dew-point problems than lightweight insulated walls and can store ‘coolth’.

When insulated walls surround an air conditioned space, a vapour barrier should be installed between the warm humid air and the insulation material to prevent the insulation being saturated by condensation. Choose materials and finishes that are resistant to damage from condensation for any linings placed over the vapour barrier: placing reflective foil insulation under a plasterboard wall lining, for example, causes the dew-point to form under the plasterboard. (see *Sealing your home*)

Avoid conditioning rooms that have high level indoor–outdoor traffic. Alternatively, use airlocks to minimise hot air infiltration or install an automatic switching device (such as a reed switch or other micro switch) to the doors leading to the air conditioned room that allows operation only when the door is closed.

Operation

Identify the months and times of day when mechanical cooling will be required and use control systems, sensors and timers to reduce total operating hours. Turn air conditioners off when you go out.

Set thermostats to the warmest setting that still achieves comfort. Experiment — you may find 26°C quite comfortable when you thought you needed 21°C.

Adapt your lifestyle where possible to take advantage of comfortable external conditions when they exist, to minimise operating periods for mechanical cooling systems.

Climate specific design principles

Climate specific design responses and passive cooling methods are different for:

- hot humid climates (Zone 1) where cooling only is required
- temperate and warm climates (Zones 2–6) where both heating and cooling are required
- cool and cold climates (Zones 7–8) where heating needs are predominant.

Hot humid climates requiring cooling only (Zone 1)

Due to the unique nature of hot humid climates, many state, territory and local governments in these regions have produced a range of excellent design resources and advice (*see 'References and additional reading' at the end of this article*).

> *Hot humid climates require a fundamentally different design approach.*

Hot humid climates require a fundamentally different design approach to those commonly recommended throughout *Your Home,* which focuses predominantly on climates requiring both summer cooling and winter heating.

The most significant difference is in the size and orientation of windows or openable panels and doors. In these climates, modest amounts of well-shaded glazing can and should be positioned on every façade to encourage air movement.

Windows or other openings should be located, sized and designed to optimise air movement, not solar access. As stated earlier, wind doesn't blow through a building — it is sucked towards areas of lower air pressure. Locate larger openings on the downwind, or leeward, side of the house and smaller openings on the breeze, or windward, side. This is advantageous in these cyclone prone regions since cyclones and cool breezes commonly come from an onshore direction. (see *Orientation*)

Other elevations should also include openings because breezes come from a variety of directions and can be redirected or diverted through good design and appropriate window styles, especially casement windows.

Another critical difference is that the designer needs to make an early decision about whether the home is to be 'free running' (i.e. passively cooled), conditioned (mechanically cooled) or hybrid (a combination of both).

Free running buildings should not be conditioned at a future date without substantial alteration: this includes reducing the size of openings, adding bulk insulation around the room(s) to be conditioned and condensation detailing.

Design responses to the challenges of hot humid climates

High humidity levels in these climates limit the body's ability to lose heat by evaporating perspiration. (see *Design for climate*)

Sleeping comfort is a significant issue, especially during periods of high humidity where night temperatures often remain above those required for human comfort. While acclimatisation helps, it is often inadequate during the 'build-up' and wet season — especially in cities with highly transient populations such as Darwin.

Design responses consider shading, air movement, insulation and construction methods.

Shading

- Permanently shade all walls and windows to exclude solar access and rain.
- Consider shading the whole building with a fly roof.
- Shade outdoor areas around the house with plantings and shade structures to lower the ground temperature and thence the temperature of incoming air.

Air movement

- Maximise exposure to (and funnelling of) cooling breezes onto the site and through the building, e.g. larger leeward openings, smaller windward openings.

- Use single room depths where possible with large openings that are well shaded to enhance cross-ventilation and heat removal.
- Design unobstructed cross-ventilation paths.
- Provide hot air ventilation at ceiling level for all rooms with shaded openable clerestory windows, 'whirlybirds' or ridge vents.
- Elevate the building to encourage airflow under floors.
- Use higher or raked ceilings to promote convective air movement.
- Design plantings to funnel cooling breezes and filter strong winds.
- Install ceiling fans to create air movement during still periods.
- Consider using whole of house fans with smart switching to draw cooler outside air into the house at night when there is no breeze.
- Choose windows with maximum opening areas (louvres or casement) that can be tightly sealed when closed; avoid fixed glass panels. Openable insulated panels and security screen doors can be used instead of some windows.
- Use lighter colours on roof and external walls.

Insulation

- Use insulation solutions that minimise heat gain during the day and maximise heat loss at night, i.e. use multiple layers of reflective foil to create a one way heat valve effect and avoid bulk insulation.

Construction

- Use low thermal mass construction generally.
- Consider the benefits of high mass construction in innovative, well-designed hybrid solutions.

Mixed climates requiring heating and cooling (Zones 2–6)

Well-designed Australian homes do not require air conditioning in most climates.

More than 50% of homes in warm temperate climates are mechanically cooled. This proportion is rapidly increasing — often because inadequate shading, insulation and ventilation, or poor orientation and room configuration for passive cooling and sun control, cause unnecessary overheating.

Warm humid climates (Zone 2)

Energy consumption for heating and cooling can account for up to 25% of total household energy use in this climate. In benign climates like the coastal areas of south-east Queensland and north-east NSW, achieving the high levels of passive thermal comfort required to reduce this by as much as 80% is a relatively simple and inexpensive task.

- Design and orientate to maximise the contribution of cooling breezes.
- Use earth-coupled concrete slab-on-ground.
- Provide high levels of cross-ventilation via unobstructed pathways.
- Use ceiling fans and convective ventilation to supplement them.
- Include a well-located and shaded outdoor living area.
- Use lighter colours for roof and external walls.
- Consider whole of house fans in this climate.
- Apply hybrid cooling principles where cooling is used.

Passive solar heating is required during winter months and varies from very little to significant. Integrate passive heating requirements with cool breeze capture by providing passive or active shading (eaves or awnings) to all windows.

Employ well-designed shading and insulation to limit heat gain and maximise summer heat loss in response to the specific microclimate. (see *Shading*)

Construction

- Use high mass construction in areas with significant diurnal (day–night) temperature ranges (usually inland) to provide significant amounts of free heating and cooling.
- Use low mass construction where diurnal temperature ranges are low (usually coastal) to increase the effectiveness of passive and active heating and cooling.
- Elevate structures to increase exposure to breezes in warmer northern regions.
- Eliminate earth coupling in southern and inland regions.
- Use bulk and/or reflective insulation to prevent heat loss and heat gain.
- Use glazing with a low to medium solar heat gain coefficient (SHGC) and U-value.

Hot dry climates with warm winter (Zone 3)

Use courtyard designs with evaporative cooling from ponds, water features and 'active' (mechanical) evaporative cooling systems. They are ideal for arid climates where low humidity promotes high evaporation rates.

- Use evaporative cooling if mechanical cooling is required.
- Use ceiling fans in all cases.
- Use high mass solutions with passive solar winter heating where winters are cooler and diurnal ranges are significant.
- Use low mass elevated solutions where winters are mild and diurnal ranges are lower.

Minimise east and west-facing glazing or provide adjustable external shading. High mass living areas are more comfortable during waking hours. Low mass sleeping areas cool quickly at night. High insulation prevents winter heat loss and summer heat gain.

- Consider high mass construction for rooms with passive winter heating and low mass for other rooms.
- Shade all windows in summer and east and west windows year round.
- Use well-sealed windows and doors with maximum opening area to optimise exposure to cooling breezes and exclude hot, dry and dusty winds.

Hot arid climates with cool winter (Zone 4)

Use high thermal mass construction to capitalise on high diurnal temperature ranges by storing both warmth and 'coolth'.

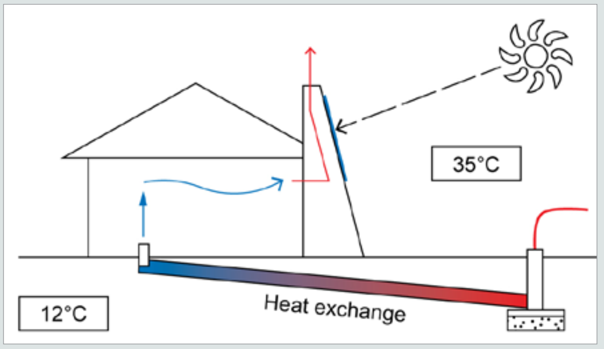
- Use compact forms to minimise surface area.
- Maximise building depth.
- Include closeable stack ventilation in stairwells and thermal separation between floors in two storey homes.
- Use shaded internal courtyards with evaporative cooling features in single storey homes.
- Use smaller window and door openings designed for night-time cooling and cool thermal currents where available.
- Use low U-value double glazing with high SHGC.
- Ensure that the majority of glazing is north facing and passive solar shaded.
- Avoid west windows.

Evaporative cooling and active solar heating systems reduce the need for large, solar exposed glass areas for heating (i.e. active rather than passive heating).

Traditional and innovative cooling methods for arid climates

Specialist passive and low energy cooling systems have evolved for hot dry climate areas in other parts of the world (e.g. Middle East, Arizona) which are also applicable to a large portion of the Australian continent.

They introduce moisture to building structures (such as roof ponds or water sprayed onto evaporative pads) and incorporate stacks or chimneys that use convection to exhaust rising hot air and draw cooler, low level air into the building. This air can be evaporatively cooled by being drawn over ponds, or through mist sprays or underground labyrinths. (These towers are dominant elements and are therefore an integral part of the fundamental architecture of the building.)



Modern version of an Iranian Badgir cooling system where earth exchange and evaporation pre-cool incoming air drawn by a solar chimney.

Temperate climates (Zones 5 and 6)

With good design, temperate climates require minimal heating or cooling. Good orientation, passive shading, insulation and design for cross-ventilation generally provide adequate cooling. Additional solutions from the range explained here can be used where site conditions create higher cooling loads.

- Design for compact form in cooler zones, extending the east–west axis in warmer zones (see *Orientation*).
- Prefer plans with moderate building depth — two rooms is ideal.
- Design for the impacts of climate change and consider highly efficient heat pump systems to cope with increases in extreme weather events.
- Use thermal mass levels appropriate to the amount of passive cooling available (cool breezes, consistent diurnal variations) and use thermal mass to delay peak cooling needs until after the peak demand period.

- Choose window opening styles and position windows to ensure good cross-ventilation.
- Orientate for passive solar heating and divert breezes.
- Employ larger northern and southern façades.
- Design for moderate openings with the majority to the north.
- Use minimal west-facing glazing (unless well shaded).
- Use moderate east-facing glazing and moderate south-facing glazing except where cross-ventilation paths are improved by larger openings.
- Use bulk and reflective foil insulation.
- Use low to medium U-value and SHGC glazing in milder areas and double glazing where ambient temperatures are higher.

Temperate climates call for good orientation, passive shading and cross-ventilation.

Cool and cold climates where heating dominates (Zones 7 and 8)

Zone 7 requires careful consideration of cooling needs because climate change modelling indicates that it is likely to be impacted by climate change more than most other zones.

This necessitates a shift from the current high thermal mass design practices to moderate or low mass designs with carefully calculated glass to mass ratios to avoid summer overheating. Higher mass solutions remain useful in higher altitude and colder regions where significant diurnal ranges are likely to continue to provide reliable cooling in all but extreme weather events.

- Winter heating remains the predominant need in all but the warmest regions in these zones.
- Passive solar orientation and shading is critical.
- On sites where passive heating or cooling access is limited, consider low mass, high insulation solutions with highly efficient reverse-cycle heat pumps.
- Give increased attention to the design of high level cross-ventilation for night cooling.
- Low U-value double glazing with high SHGC is highly desirable due to its effectiveness in both summer and winter.
- Use a well-designed combination of reflective foil and bulk insulation.
- Use modest areas of glazing with the majority facing north where solar access is available.
- Minimise west-facing glazing.
- Passive and/or active shading of all glazing is essential.

Adapting lifestyle

Applicable in all climates, especially hot humid and hot dry, ‘adapting lifestyle’ means adopting living, sleeping, cooking and activity patterns that respond to and work with the climate rather than using mechanical cooling to emulate an alternative climate.

High humid climates present the greatest challenge in achieving thermal comfort because high humidity levels reduce evaporation rates. (see *Design for climate*)

‘Adapting lifestyle’ means working with the climate rather than using mechanical cooling to emulate an alternative one.

Acclimatisation is a significant factor in achieving thermal comfort. Most people living in tropical climates choose to do so. They like the climate and know how to live comfortably within its extremes by adopting appropriate living patterns to maximise the outdoor lifestyle opportunities it offers.

Sleeping comfort at night during the hottest and most humid periods is a significant issue for many people living in tropical climates. Sleeping comfort generally should be a high priority when choosing, designing or building a home. Different members of a household have different thermal comfort thresholds. Children often adapt to seasonal changes more easily than adults do.

Understanding the sleeping comfort requirements of each member of the household can lead to better design, positioning or allocation of bedrooms — and increased thermal comfort for all with less dependence on mechanical cooling.

Live outside when time of day and seasonal conditions are suitable — particularly in the evenings. Radiation by the body to cool night skies is an effective cooling mechanism, especially in the early evening when daytime heat loads have not been allowed to escape from the interior of the house.

Cooking outside during hotter months reduces heat loads inside. This Australian lifestyle tradition developed to suit our climate is not often directly connected to thermal comfort. Locate barbeques outdoors, under cover in close proximity to the kitchen, with good access either by servery or screened door. Shaded barbecue and outdoor eating areas (insect screened where required) facilitate outdoor living and increased comfort.

Sleep-outs are an ideal way to achieve sleeping comfort and can provide low cost additional space for visitors who often arrive during the hotter Christmas period.

Vary active hours to make best use of comfortable temperature ranges at different times of the year. The siesta regime of most Central American countries is a practical lifestyle response to specific climatic conditions that are also experienced in high humid and hot dry regions of Australia.

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