Passive cooling

This fact sheet examines ways to design and modify homes to achieve summer comfort through passive cooling.

Four key approaches for achieving thermal comfort in cooling applications are examined:

> Envelope design.

> Natural cooling sources.

> Hybrid cooling systems.

> Adapting lifestyle.

WHAT IS PASSIVE COOLING?

Passive cooling:

> Is the least expensive means of cooling a home.

> Has the lowest environmental impact.

> Is appropriate for all Australian climates.

Passive cooling maximises the efficiency of the building envelope by minimising heat gain from the external environment and facilitating heat loss to the following natural sources of cooling:

> Air movement.

> Cooling breezes.

> Evaporation.

> Earth coupling.

(A detailed description of these sources can be found later in this fact sheet).

Passive cooling also maximises the ability of the occupants to lose heat to natural sources of cooling.

Cooling requirements in houses are generated predominantly by climate. Household activities have a lesser impact but are still important – especially during periods of "extreme" weather conditions.

Heat enters and leaves a home through the roof, walls, windows and floor. Internal walls, doors and room arrangements affect heat distribution within a home. These elements are collectively referred to as the building envelope.

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

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

Passive design should include passive heating provision for winter in all climates except hot humid (tropical). The degree of winter heating can be adjusted for climate with appropriate passive solar shading. [See: Passive Solar Heating; Shading]

ENVELOPE DESIGN

All Australian climates require some degree of cooling.

General design principles

Reduce or eliminate external heat gains during the day with sound envelope design.

Design to allow lower night time temperatures and air movement to cool the building and its occupants.

The main elements of design for passive cooling are:

> Orientation for exposure to cooling breezes.

> Increase natural ventilation by reducing barriers to air paths through the building.

> Provision of fans to provide ventilation and air movement in the absence of breezes.

> Floor plan zoning to maximise comfort for daytime activities and sleeping comfort.

> Appropriate windows and glazing to minimise unwanted heat gains and maximise ventilation.

> Effective shading (including planting).

> Adequate levels of appropriate insulation.

> High thermal mass construction in regions with significant diurnal ranges.

> Low thermal mass construction in regions with low diurnal range.

> Use of light coloured roofs and walls to reflect more solar radiation and reduce heat gain.

See individual fact sheets for detailed information on each of the above elements, particularly the use of thermal mass in best practice design solutions in climates with modest diurnal range.

Floor plan and building form

Maximise the indoor/outdoor relationship and provide appropriate screened, shaded, rain protected outdoor living spaces.

Maximise convective ventilation with high level windows, ceiling and roof space vents.

Zone living and sleeping areas appropriately for climate – vertically and horizontally.

Locate bedrooms for sleeping comfort.

Design ceilings and furnishing positions for optimum efficiency of fans, cool breezes and convective ventilation.

Locate mechanically cooled rooms in thermally protected areas.

Varied responses are required for each climate zone and even within each zone depending on local conditions and the microclimate of a given site. General solutions exist for the main cooling climate categories:

> Tropical (hot humid).

> Hot Arid.

> Sub-tropical (warm humid).

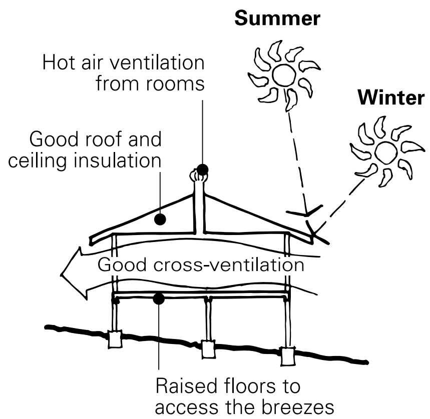
CLIMATE SPECIFIC DESIGN PRINCIPLES

Hot humid (tropical) climates

In these climates (eg. Cairns, Darwin):

> High humidity levels limit the body's ability to loose heat by evaporation of perspiration.

> Sleeping comfort is a significant issue – especially during periods of high humidity.



Design eaves and shading to permanently exclude solar access to rooms. [See: Shading]

Consider shading the whole building with a fly roof. [See: Shading]

Maximise shaded external wall areas and exposure to (and funneling of) cooling breezes through the building.

Use single room depths where possible with maximum shaded openings to enhance cross ventilation and heat removal.

Design unobstructed cross ventilation paths.

Provide hot air ventilation at ceiling level for all rooms with spinnaways, shaded opening clerestorey windows or ridge vents.

Shade outdoor areas around the house with planting and shade structures to lower ground temperatures.

Use insulation solutions that minimise heat gain during the day and maximise heat loss at night. Advanced reflective insulation systems and reflective air spaces can be effective. [See: Insulation Installation]

Choose windows with maximum opening areas (louvres or casement) and avoid fixed glass panels.

Include ceiling fans to create air movement during still periods.

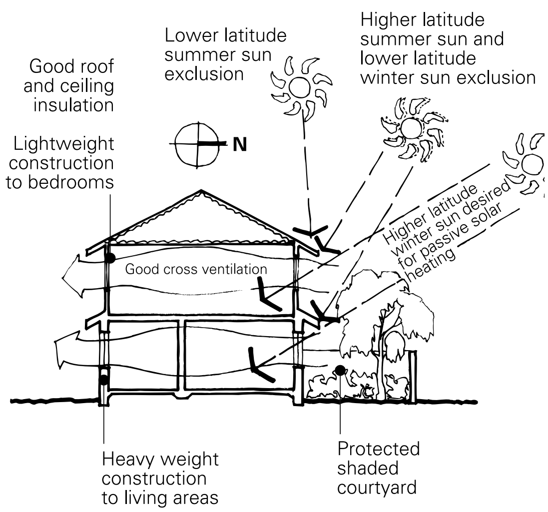
Consider using "whole of house" fans with smart switching to draw cooler outside air into the house at night when there is no breeze.

Use low thermal mass construction generally. (Note: high mass construction can be beneficial in innovative, well considered design solutions).

Use planting design to funnel cooling breezes and filter strong winds. (Appropriate in all cooling climates).

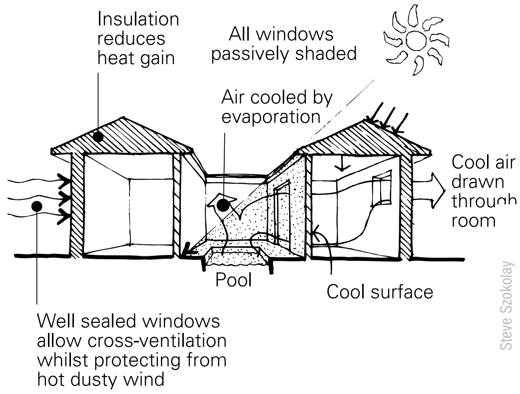
Hot arid climates (mild and cold winter)

Hot arid climates occur in a wide range of latitudes and geographic locations.
This creates a variety of diurnal ranges and winter heating requirements with hot to very hot, dry summers.



2 storey solution for hot arid climate with low diurnal range

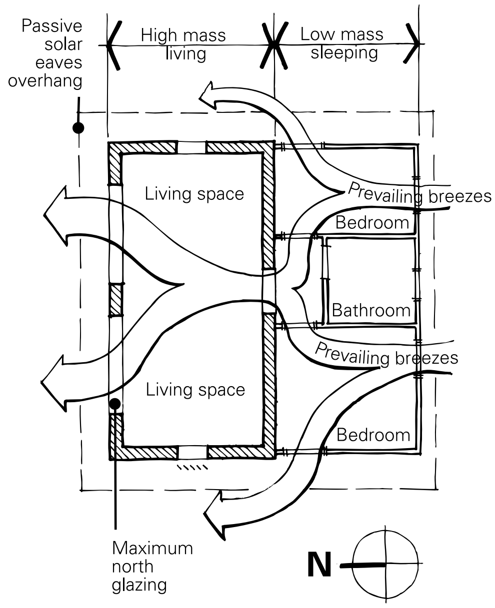
Evaporative cooling from ponds, water features and "active" (See below) or mechanical cooling systems is ideal for arid climates where low humidity promotes high evaporation rates.



Courtyard design with evaporative cooling pond

Use high mass solutions with passive solar winter heating where winters are cool or cold and diurnal ranges are significant.

Use low mass elevated solutions where winters are mild and diurnal ranges are lower.



Minimise east & west 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.

Consider high mass construction for rooms with passive winter heating and low mass for other rooms.

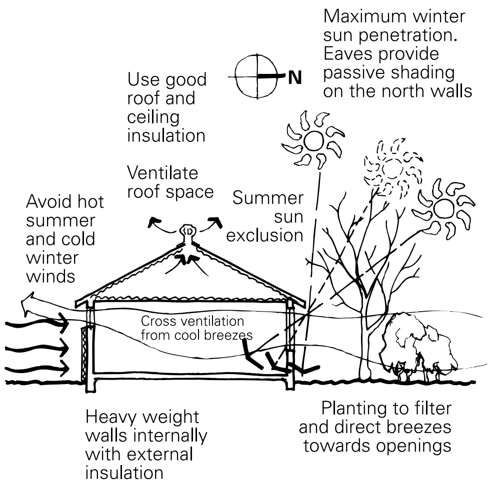
Shade all windows in summer and east and west windows year round.

Well sealed windows and doors with maximum opening area allow maximum exposure to cooling breezes and exclude hot, dry and dusty winds.

Sub-tropical climates

In benign climates like coastal areas of south east Queensland, energy consumption for heating and cooling accounts for around 6 percent of total household energy use. Achieving thermal comfort in these climates is a relatively simple task.

Passive solar heating is required during winter months. Adjust eave overhangs to suit the particular micro-climate. [See: Shading]



High mass solution for sub-tropical climate with high diurnal range

Use high mass construction in areas with significant diurnal range (usually inland).

Use low mass construction where diurnal ranges are low (usually coastal). [See: Thermal Mass]

Orient to maximise exposure to cooling breezes and use ceiling fans and convective ventilation to supplement them.

Elevated structures can increase exposure to breezes.

Include evaporative cooling and water features.

Use insulation to prevent heat loss and heat gain.

Temperate and cool temperate climates

Temperate and cool temperate climates require less cooling. Good orientation, passive shading, insulation and design for cross ventilation generally provide adequate cooling. Additional solutions from the range explained in this fact sheet can be used where site conditions create higher cooling loads.

NATURAL COOLING SOURCES

In combination with sound envelope design for cooling climates and appropriate lifestyle, air movement, evaporative cooling and earth coupled thermal mass can provide adequate thermal comfort in all Australian climate zones.

AIR MOVEMENT

Air movement is the most important element of passive cooling. It increases cooling by increasing evaporation rates.

Generally, cross ventilation is most effective for air exchange (building cooling) and fans for air movement (people cooling).

Air movement provides useful cooling in all climates but is less effective in tropical climates during periods of high humidity.

An air speed of 0.5 m/sec equates to a 3 degree drop in temperature at relative humidity of 50 percent.

This is a "one off" physiological cooling effect that occurs when still air is moved at 0.5 m/s.

In higher humidity, greater airspeeds are required to achieve the same cooling benefits.

Cooling breezes

Maximising the flow of cooling breezes through a home is an essential component of passive design.

Coastal breezes are usually from an onshore direction (southeast, east to northeast in most east coast areas and southwest in most west coast areas, eg. the Fremantle Doctor).

In mountainous or hilly areas, cool breezes often flow down valleys in late evening and early morning as night cooling creates cool air currents.

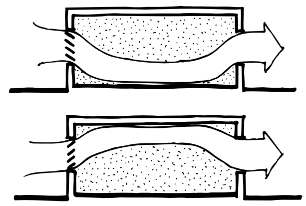
Thermal currents are common in flatter, inland areas, created by diurnal heating and cooling. They are often of short duration in early morning and evening but can yield worthwhile cooling benefits with good design.

Design to maximise beneficial cooling breezes by providing multiple flow paths and minimising potential barriers (single depth rooms are recommended).

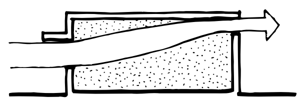
Use windows designed to deflect breezes from varying angles.

Locate windows on walls with best exposure to common cooling breezes and design for effective cross flow of air through the building.

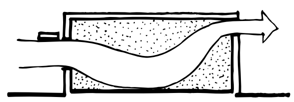
Consider directing airflow at levels suitable for the activity proposed for the room.



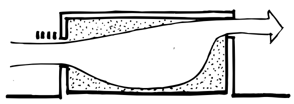
Louvres can direct airflow upward or downward.



A canopy over a window tends to direct air upward.



A gap between canopy and wall ensures a downward pressure.



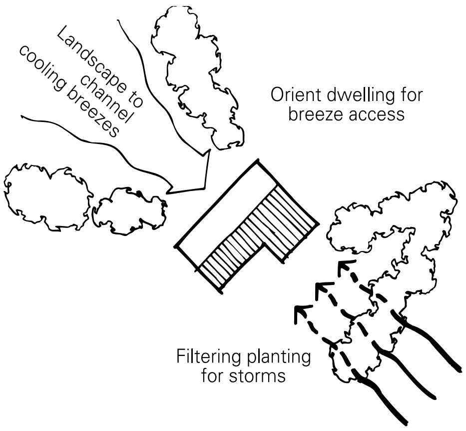
Steve Szokolay

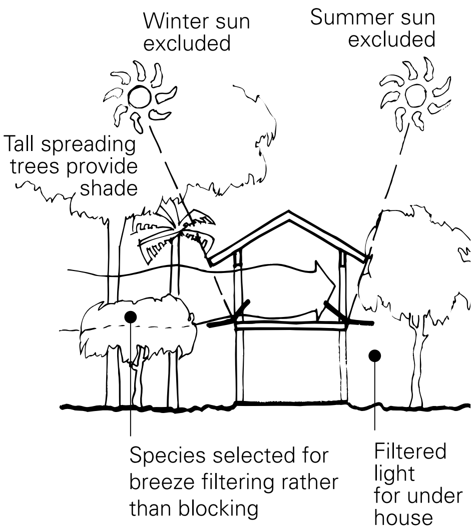
Downward pressure is improved further in the case of a louvered sunshade.

Use window styles with 100 percent opening area such as louvre and casement.

Understand your regional climate and how various features (topographic and man made) influence the microclimate of your site.

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



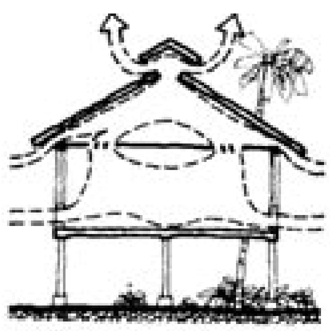


Convective air movement

Convective air movement relies on hot air rising and exiting at the highest point, drawing in cool air from shaded external areas over ponds or cool earth.

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

Clerestory windows, spinnaway roof ventilators, and vented ridges, eaves and ceilings will allow heat to exit the building in nil breeze situations through convection.



Fans

In all cooling climates, exposure to cooling breezes should be maximised. However, during still periods mechanical fans are required to supplement breezes.

The maximum useful air speed for comfort is approximately 7.5 metres per second. Higher air speeds do not create more cooling and can be unsettling.

Standard ceiling fans create adequate air speeds to achieve comfort when dry bulb temperature and relative humidity are within acceptable levels.

In a lightweight Brisbane house, fans to all living and bedroom areas will more than halve cooling requirements. They can typically turn a 3 star house into a 5 star house.

Whole of roof fans can be beneficial in cooling applications, particularly where cross ventilation design is inadequate. They do not create sufficient air speed to cool occupants.

Air intakes are usually located in the centre of the house (hallway) and are used to draw cooler outside air into the building through multiple rooms when conditions are suitable. They exhaust the air through eave or gable vents via the roof space. This cools the roof space.

Control systems for whole of roof fans should prevent operation when external air temperatures are higher than internal.

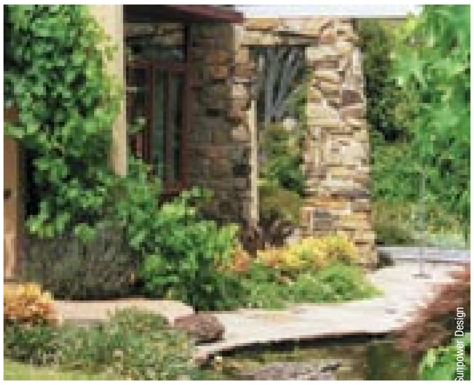
Condensation can be increased by drawing large volumes of humid air through the roof space. A dew point occurs when this humid air comes in contact with roof elements (eg. reflective insulation) which has been cooled by radiation to night skies. [See: Heating & Cooling]

EVAPORATIVE COOLING

Large amounts of heat are consumed by water as it evaporates. This is called the latent heat of evaporation. This heat is partially drawn from surrounding air, causing cooling.

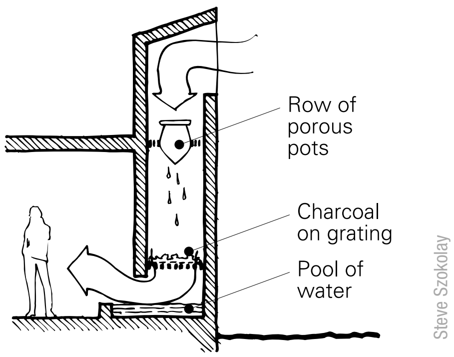
Evaporation is an effective passive cooling method. It works best when relative humidity is lower (70 percent or less during hottest periods) and the air has a greater capacity to take up water vapor.

Rates of evaporation are increased by air movement.



The surface area of water exposed to moving air is also important. Fountains, mist sprays and waterfalls can increase evaporation rates.

Passive evaporative cooling design solutions include the use of pools, ponds and water features immediately outside windows or in courtyards to pre-cool air entering the house. Carefully located water features can create convective breezes.

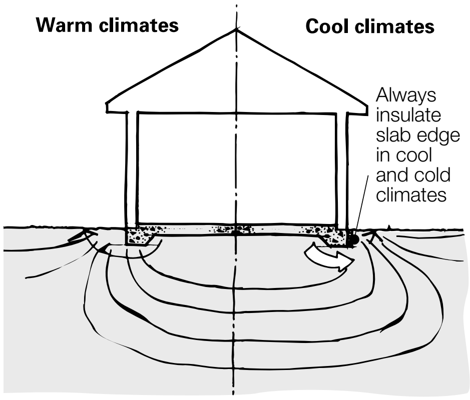


Active evaporative cooling systems like the above wind scoop, originating in ancient Persia, can be useful to catch cooling breezes and direct them into the house via an evaporative cooling system.

Mechanical evaporative coolers are common in low humidity climates. They use less energy than refrigerated air conditioners and work better with doors and windows left open. Water consumption can be considerable. [See: Heating & Cooling]

EARTH COUPLING

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



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, and earth coupled slab can become an energy liability.

Ground and soil temperatures vary throughout Australia. An excellent map showing ground temperatures at various depths can be found in Baggs 1991.

Earth covered/earth bermed construction utilises stable ground temperatures at lower depths to absorb household heat gains.

HYBRID COOLING SYSTEMS

These are appropriate for tropical climates with high summer humidity or where mechanical cooling (especially refrigerated air-conditioning) is used to overcome problems of extreme climate, existing house/ site constraints or poor design.

Hybrid cooling systems are whole house cooling solutions employing 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.

Refrigerated air-conditioning can provide thermal comfort during periods of high temperature and humidity by lowering air 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. It also requires the home to be closed off from the outside environment and this can interfere with acclimatisation.

Air-conditioning is often used to achieve comfortable sleeping conditions by lowering temperatures and humidity. The number of operating hours required for air-conditioning to achieve thermal comfort can be substantially reduced (or eliminated) by careful design of new homes, alterations and additions.

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

Well designed Australian homes do not require air-conditioning (either refrigerated or evaporative). Most of those that do are concentrated in the hot humid and hot arid climate zones.

A relatively small proportion of Queensland homes are mechanically cooled. This proportion is increasing – often because inadequate shading, insulation and ventilation, or poor orientation for passive cooling and sun control, cause unnecessary overheating.

Decide early in the design stages whether air-conditioning is to be used. Many inefficient air-conditioning installations occur when they are added as an afterthought to improve comfort.

Passive design principles are beneficial in maximising the efficiency of naturally and mechanically cooled homes.

A very different approach is required for design and construction of air-conditioned rooms to maximise efficiency.

Design of air conditioned spaces

Envelope design

Minimise external air infiltration.

Use higher insulation levels – particularly bulk insulation in walls, ceiling and floors. [See: Insulation Overview]

Reduce glass areas. [See: Glazing]

Reduce total volume of air space (room size/ceiling height).

Planning and layout

Minimise heat loads with good orientation, insulation and shading of the whole building.

Locate unit in the coolest zone in the house to minimise running costs.

Carefully choose rooms to be air-conditioned according to use. Do not air-condition all rooms.

Avoid air-conditioning rooms that have high level indoor – outdoor traffic or, use air-locks to minimise hot air infiltration.

Locate sleeping spaces so that convective air-movement and conduction through walls shared with air-conditioned spaces will provide indirect cooling benefits.

Decide which rooms will receive most benefit depending on use. Often one or two rooms will be sufficient to provide comfort during periods of high humidity and temperatures.

Design these rooms with high levels of insulation and lowest exposure to external temperature influences (usually in the centre of the house).

Ensure that rooms not requiring mechanical cooling have maximum passive cooling as described above and use them as a thermal buffer to cooled spaces.

Use fans and cross ventilation to improve comfort in non-air-conditioned spaces.

Other considerations

Address condensation in externally ventilated rooms surrounding air-conditioned rooms.

When insulated walls surround an air-conditioned space, a vapor barrier should be installed between the warm humid air and the insulation material to prevent saturation of the insulation by condensation.

Dewpoints form where humid air comes into contact with a cooled surface.

Any linings placed over the vapor barrier should be resistant to damage from condensation by choosing appropriate materials and finishes.

Eg. Placing reflective foil insulation under a plasterboard wall lining will cause the dewpoint to form under the plasterboard. A wet area lining such as compressed fibre cement with a waterproof finish is a better solution.

Identify the months and times of day mechanical cooling will be required.

Use advanced control systems, sensors and timers to reduce total operating hours.

Use low mass construction in mechanically cooled spaces to facilitate quick response and reduce running time.

Use split systems with low energy heat exchangers such as air to water or air to earth. [See: Heating and Cooling]

Set thermostats to warmest setting that still achieves comfort.

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

De-humidifiers use less energy than refrigerated air conditioners and can overcome evaporative cooling inefficiency in high humidity. They require sealing of rooms but have lower requirement for bulk insulation allowing use of "one way valve" reflective insulation principles. [See: Insulation overview]

In a closed room, running an air conditioner for about an hour will lower humidity levels to the point where air movement from fans can provide sufficient evaporative cooling to achieve thermal comfort.

ADAPTING LIFESTYLE

Applicable in all climates, especially hot humid and hot arid.

Adapting lifestyle involves adopting living, sleeping, cooking and activity patterns to adapt to and work with the climate rather than using mechanical cooling to emulate an alternative climate.

Hot humid climates present the greatest challenge in achieving thermal comfort because high humidity levels reduce evaporation rates. [See: Design for Climate]

Acclimatising is a significant factor in achieving thermal comfort. The majority of 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 thermal comfort issue for many people living in tropical climates. Unlike cooler climates, sleeping comfort is a high priority when choosing, designing or building a home.

Different members of a household will 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, resulting in increased thermal comfort for all and 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 – particularly 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 will reduce heat loads inside the house. This is an Australian lifestyle tradition developed to suit our climate but it 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, insect screened barbecue and outdoor eating areas 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 year. The siesta regime of most Central American countries is a practical lifestyle response to specific climatic conditions that are also experienced in hot humid and hot arid regions of Australia.

PASSIVE COOLING IN RENOVATIONS

Renovations provide the ideal opportunity to improve a home's potential for passive cooling.

All Australian houses can use passive cooling to great advantage. In many climates passive cooling is critical to comfort. [See: Design for Climate]

The principles and ideas outlined in the preceding pages of this fact sheet can be combined to achieve passive cooling in a renovation.

When renovating, ensure you make things better, never worse. Design renovations and extensions that improve rather than compromise performance.

Orientation and layout

Consider changing the orientation of the home so that the major openings face the breeze, and openings on the opposite side of the house draw the breeze through and out. [See: Orientation]

Design a layout that allows cool breezes to pass right through the house, aligning windows with and internal doors in a way that does not block weaker breezes.

Open plan interiors are best for encouraging natural ventilation in hot humid climates. Solid-bladed louvres can be provided in internal walls to let breezes pass right through the building.

Improved natural ventilation can be achieved without altering the existing footprint, just by changing the use of existing rooms and moving and/ or increasing the size of windows and doors.

Consider combining the laundry with the kitchen or bathroom (compact European style) and incorporate the old laundry space as extra open space for living areas, allowing better breeze penetration through the house.

Kitchens which back onto hallways or other living areas can have their back walls lowered (or large openings created in them) to allow air to flow over the top and through the whole house.

When adding new rooms, locate them so they do not block breeze paths. In hot humid climates the ideal house plan is long and narrow (single room depth), with large openings on either side. To preserve this form, locate additions at the ends of the building where possible.

Windows and doors

Use windows with a large opening area, and doors that open fully to allow the free passage of breezes. If the existing windows and doors do not work like this, consider changing some of them.

Casement sashes (side hinged) are good on the windward side of the house, and louvers or hoppers (short awnings) on the leeward side. Tall awning windows are not good ventilators, as the effective opening area is quite small. In tropical areas, where wet weather accompanies breezes, louvres are the best choice for external windows.

In climates where winters are cold, windows and doors must be well-sealed to prevent heat loss when closed. Double glazed widows can be made to open wide so that they work well in winter and summer. Low-e coatings can limit heat gain in hot conditions, but must be used carefully in regions with cold winters so as not to limit winter heat gains. [See: Glazing Overview, Glazing- Hot Humid]

Shading & landscape

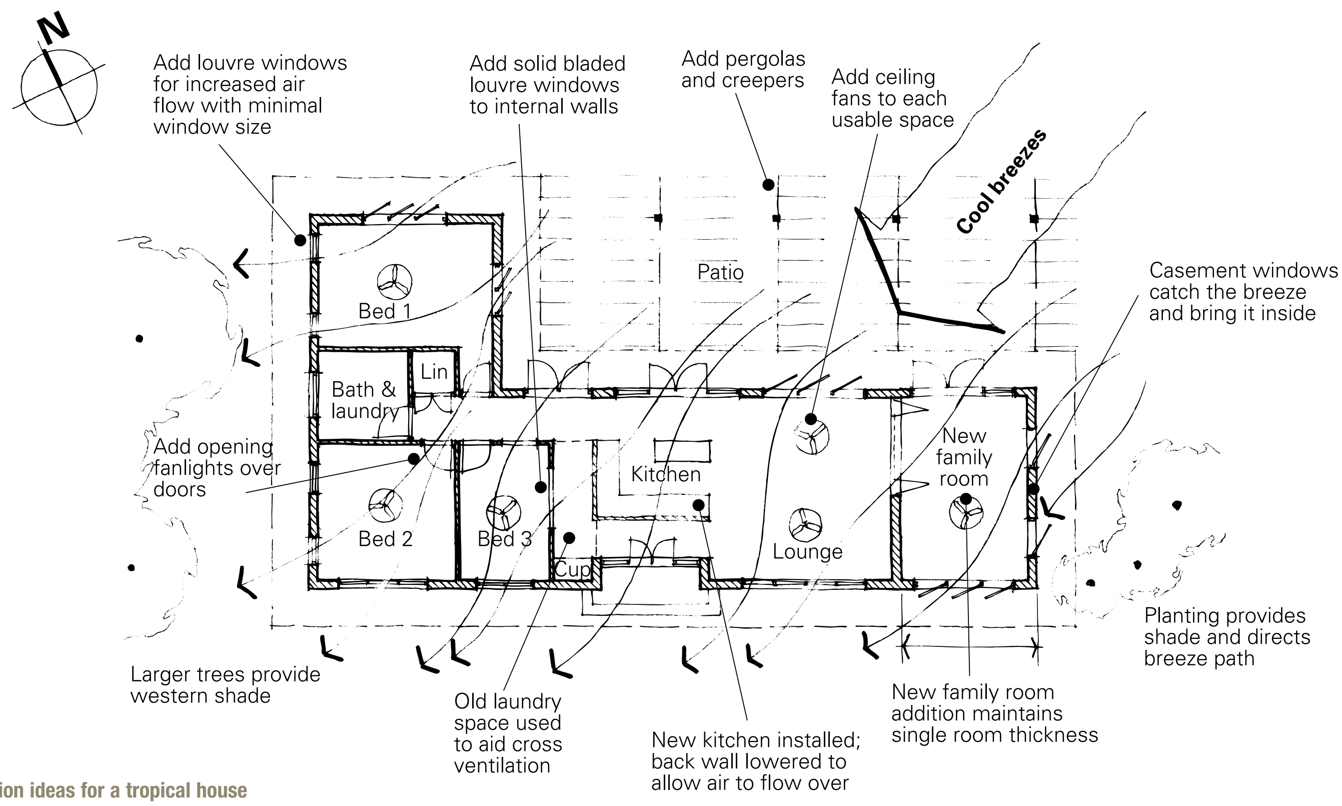
Renovations provide the ideal opportunity to improve shading. If adding a new roof, ensure the north facing eave overhang is appropriately sized. [See: Shading]

Alternatively, add a pergola, shade frame or suitably sized shade projections above north facing windows. North of the tropic of Capricorn, south facing openings will need shading too.

Shade structures added to the external face of the window (louvres, shutters, etc.) or deep pergolas are suitable for east and west facing walls. Deciduous vines such as decorative grape can be pruned in autumn to allow filtered winter sun through, while quickly growing in spring to cover the whole pergola.

Use planting to shade the house.
In climates where winter sun is desirable, plant tall or deciduous trees to the north. Lower trees or shrubs are suitable for shading east and west facades. Ensure plantings do not obscure breezes, but channel them toward the openings. [See: Sustainable Landscape, Shading]

Where shading cannot be provided, such as when too close to the boundary or prevented by body corporate rules, use 'smart glass' or apply a reflective film to reduce heat gain. Note that these techniques will reduce natural light levels and winter heat gain.



Renovation ideas for a tropical house

Active ventilation

Assist the breeze by installing ceiling fans where necessary. Ceiling fans are an energy efficient way of cooling building occupants. Locate fans centrally in each space, one for each grouping of furniture. An extended lounge/ dining area will need two fans. In bedrooms, locate the fan near to the centre of the bed. [See: Heating & Cooling]

Insulation & reflectivity

Add insulation to existing roofs, which are a major source of radiant heat gain. Reflective insulation provides the most effective resistance to radiant heat. Multiple layers of foil batts can be easily installed between roof rafters during renovations.

Add insulation to existing walls wherever possible. When internal linings are removed it is easy to install insulation to timber framed walls. It is also possible to insulate existing cavity brick walls, however this is more complex and specialist consultants may be required. [See: Insulation Overview, Insulation Installation]

An ideal time to change the colour scheme of a building is during renovation. Light-coloured surfaces reflect heat, while dark surfaces absorb heat. However, many local councils prohibit light coloured external surfaces, especially roofs, to prevent built form from overpowering the surrounding landscape.

The best compromise is to use lighter neutral colours on external walls and mid-range roof colours. Avoid black or dark grey for roofs. Blandness can be avoided by using contrasting or complimentary trims.

Thermal mass

In climate zones with a medium to high diurnal range, thermal mass can improve the passive performance of the building. In hot humid and warm humid climates, low mass construction is more appropriate. [See: Design for Climate]

Thermal mass for passive cooling works best when located in the core of the building, where its ability to regulate internal temperatures is greatest. High mass walls are better located internally than on the perimeter.

In renovations, a concrete slab or masonry wall can provide extra thermal mass. The thermal mass needs access to winter sun and cooling summer breezes.

Many timber framed buildings (including brick veneer) can have thermal mass added effectively and economically using 'reverse brick veneer' construction. The 'brick' can be any high mass material, including rammed earth or core filled concrete block. [See: Thermal Mass, Alteration-Clarke]

Low mass construction is generally the most appropriate solution for warm humid climates. It must be combined with good insulation and cross ventilation.

When used to construct permanently inhabited rooms, low mass walls must be well insulated. In colder climates, it may be necessary to add wall thickness to achieve adequate insulation levels. Minimum structural timber sizes may not provide enough thickness for the appropriate insulation.

ADDITIONAL KEY REFERENCES

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