Passive solar heating

This fact sheet explains how the passive design principles discussed in other fact sheets can be applied to utilise free heating direct from the sun.

On average, 39 percent of energy consumed in Australian homes is for space heating and cooling. Using passive solar design dramatically reduces this figure.

WHAT IS PASSIVE SOLAR HEATING?

Passive solar heating is the least expensive way to heat your home. It is also:

Free when designed into a new home or addition.

Appropriate for all climates where winter heating is required (generally latitudes south of 27.5ºS).

Achievable when building or renovating on any site with solar access - often with little effort.

Achievable when buying a project home, with correct orientation and slight floor plan changes.

Achievable when choosing an existing house, villa or unit. Look for good orientation and shading.

Achievable using all types of Australian construction systems.

Put simply, design for passive solar heating is about keeping summer sun out and letting winter sun in.

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

> Northerly orientation of daytime living areas.

> Appropriate areas of glass on northern facades.

> Passive shading of glass.

> Thermal mass for storing heat.

> Insulation and draught sealing.

> Floor plan zoning based on heating needs.

> Advanced glazing solutions.

This will maximise winter heat gain, minimise winter heat loss and concentrate heating where it is most needed.

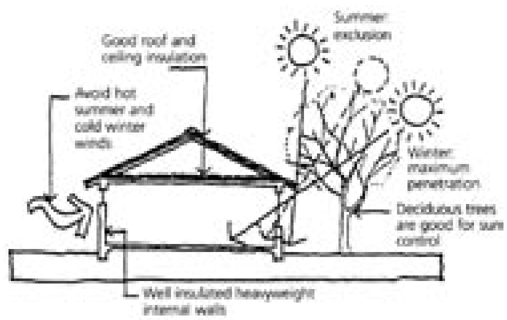
Passive solar houses look like other homes but cost less to run and are more comfortable to live in.

HOW PASSIVE SOLAR HEATING WORKS

Solar radiation is trapped by the greenhouse action of correctly oriented (north facing) windows exposed to full sun. Window frames and glazing type have a significant effect on the efficiency of this process. [See: Glazing Overview]

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

Passive shading allows maximum winter solar gain and prevents summer overheating. This is most simply achieved with northerly orientation of appropriate areas of glass and well designed eaves overhangs. [See: Shading]



Heat is re-radiated and distributed to where it is needed. Direct re-radiation is the most effective means. Design floor plans to ensure that the most important rooms (usually day-use living areas) face north for the best solar access. Heat is also conducted through building materials and distributed by air movement.

Heat loss is minimised with appropriate window treatments and well insulated walls, ceilings and exposed floors. Thermal mass must be insulated to be effective (including ground slab edges in cool and cold climates). [See: Insulation Overview; Thermal Mass]

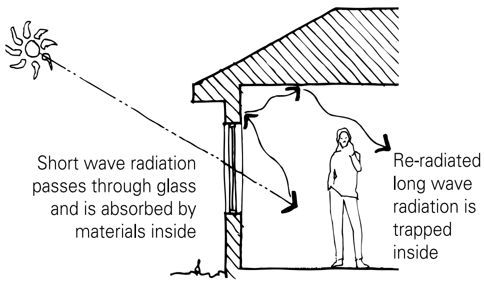
Air infiltration is minimised with airlocks, draught sealing, airtight construction detailing and quality windows and doors.

Appropriate house shape and room layout is important to minimise heat loss, which occurs mostly through the roof and then through external walls. In cool and cold climates, compact shapes that minimise roof and external wall area are more efficient. As the climate gets warmer more external wall area is appropriate.

PASSIVE SOLAR DESIGN PRINCIPLES

Greenhouse (glasshouse) principles

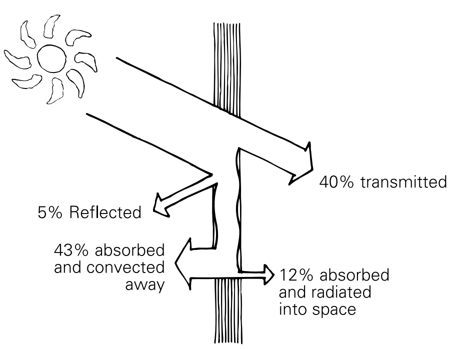
Passive design relies on greenhouse principles to trap solar radiation.



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

This diagram shows the percentage of solar heat gain through standard 3mm glazing. For comparison to advanced glazing materials. [See: Glazing]

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



Orientation for passive solar heating

For best passive heating performance, daytime living areas should face north. Ideal orientation is true north and can be extended to between 15º west and 20º east of solar north. [See: Orientation]

Where solar access is limited, as is often the case in urban areas, energy efficiency can still be achieved with careful design.

Homes on poorly oriented or narrow blocks with limited solar access can employ alternative passive solutions to increase comfort and reduce heating costs. [See Insulation Overview; Glazing; Shading; Thermal Mass]

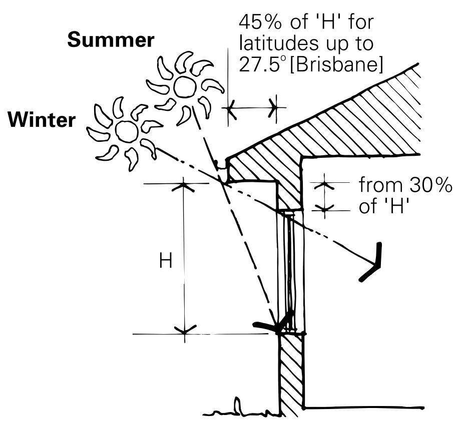
Passive solar shading

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

Fixed shading above openings excludes high angle summer sun but admits lower angle winter sun.

Use adjustable shading to regulate solar access on other elevations.

Correctly designed eaves are the simplest and least expensive shading method for northern elevations.



The 'rule of thumb' for calculating eaves width is given below. This rule applies to all latitudes south of and including 27.5º (Brisbane, Geraldton). For latitudes north of this the response varies with climate. [See: Shading]

Permanently shaded glass at the top of the window is a significant source of heat loss. To avoid this, the distance between the top of glazing and eaves underside should be 50% of overhang or 30% of window height. [See: Shading]

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

PLANNING AND DESIGN

Floor planning

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

Rooms requiring heat in winter

Rooms which don't require heating

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

Living areas and the kitchen are usually the most important locations for passive heating as they are used day and evening.

Bedrooms require less heating. It is easy to get warm and stay warm in bed. Children's bedrooms can be classified as living areas if considerable hours are spent there.

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

> To the west or south west, to act as a buffer to hot afternoon sun and the cold westerly winds common to many regions.

> To the east and south east, except where this is the direction of cooling breezes.

Detached garages to the east and west can protect north facing courtyards from low angle summer sun and direct cooling breezes into living spaces.

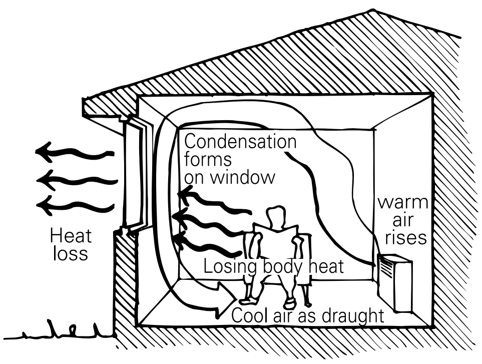
Compact floor plans minimise external wall and roof area, thereby minimising heat loss. Determine a balance between minimising heat loss and achieving adequate daylighting and ventilation.

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

Locating heaters

Internal thermal mass walls are ideal for locating heaters next to. Thermal lag will transfer heat to adjoining spaces over extended periods. [See: Heating & Cooling]

External wall locations can result in additional heat loss, as increasing the temperature differential between inside and out increases the rate of heat flow through the wall. Heaters should not be located under windows.



Adverse effects of draughts

Heaters create draughts when operating, see above. Try to locate heaters where they can draw cooled air back via passageways rather than through sitting areas.

Locating thermal mass

As a first priority, locate thermal mass where it is exposed to direct solar radiation or radiant heat sources. Thermal mass will also absorb reflected radiant heat.

Additionally, thermal mass should be located predominantly in the northern half of the house where it will absorb most passive solar heat.

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

Use thermal mass dividing walls between north facing living rooms and south facing bedrooms. Thermal lag will distribute some of the heat to bedrooms.

Air movement within the house will heat or cool thermal mass. Locate mass away from cold draught sources (eg. entries) and expose it to convective warm air movement within the house (eg. hallways to bedrooms). Consider the balance between heating and cooling requirements. [See: Thermal Mass]

Air movement and comfort

Air movement creates a cooling effect by increasing the evaporation of perspiration. Draughts increase the perception of feeling cold. [See: Passive Design Introduction]

Avoid convection draughts by designing floor plans and furnishing layouts so that cooled return air paths from windows and external walls to heaters or thermal mass sources are along traffic areas (hallways, stairs, non-sitting areas).

Create draught free nooks for sitting, dining and sleeping.

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

DESIGN FOR CONVECTIVE AIR MOVEMENT

Convection currents are created when heat rises to the ceiling and air cooled by windows and external walls is drawn back along the floor to the heat source.

Convective air movement can be used to great benefit with careful design or can be a major source of thermal discomfort with poor design.

Analyse warm air flows by visualising a helium filled balloon riding the thermal currents. Where would it go? Where would it be trapped?

Analyse cool air flows by visualising where water would run if you left an upstairs tap on.

Single storey homes

Minimise convective air movement in winter with insulation of walls, glazing and ceilings. Some convection will still occur and is a major means of passive heat distribution in any home.

Controlled convection can be used to warm rooms not directly exposed to heat sources. It can also reduce unwanted heat loss from rooms that do not require heating.

Opening or closing doors will control the return air flow but impact on privacy. Use vents that can be opened or sealed.

Highlight louvres or transom panels over doors promote and control movement of the warmest air at ceiling level whilst retaining privacy.

Floor to ceiling doors are effective in facilitating air movement.

Multi-storey homes

Place the majority of thermal mass and the main heating sources at lower levels.

Use high insulation levels and lower (or no) thermal mass at upper levels.

Ensure upper levels can be closed off to stop heat rising in winter and overheating in summer.

Use stairs to direct cool air draughts back to heat sources, located away from sitting areas.

Avoid open balcony rails. They allow cool air to fall like a waterfall into spaces below.

Use ceiling fans to push warm air back to lower levels.

Minimise window areas at upper levels and double glaze. Use close fitting drapes with snug pelmet boxes.

Maximise the openable area of upper level windows for summer ventilation. Avoid fixed glazing.

Locate bedrooms upstairs in cold climates so they are warmed by rising air.

PREVENTING HEAT LOSS

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

The building fabric must retain energy collected during the day for up to 16 hours each day and considerably longer in cloudy weather. To achieve this, careful attention must be paid to each of the following factors.

Insulation

High insulation levels are essential in passive solar houses. Insulate to at least the minimum levels recommended in the Australian Standards. [See: Insulation Overview]

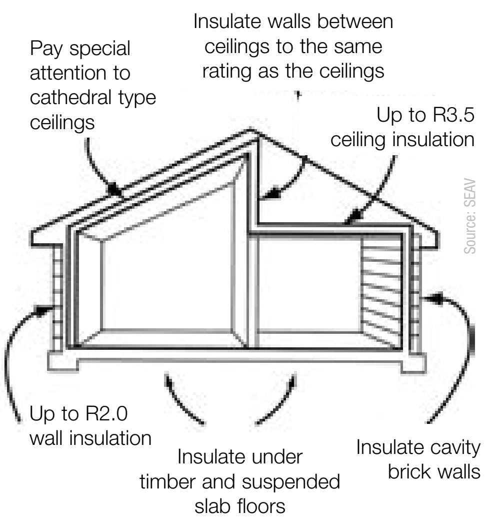
Ceilings and roof spaces account for 25 to 35 percent of winter heat loss and must be well insulated. To prevent heat loss, locate most of the insulation next to the ceiling as this is where the greatest temperature control is required.

Floors account for 10 to 20 percent of winter heat loss. In cool climates insulate the underside of suspended timber floors and suspended concrete slabs. Insulate the edges of ground slabs but do not insulate under ground slabs unless groundwater is present. [See: Insulation Installation]

Walls account for 15 to 25 percent of winter heat loss. Insulation levels in walls are often limited by cavity or frame width. In cold climates, alternative wall construction systems that allow higher insulation levels are recommended.

In high mass walls (double brick, rammed earth, straw bale and reverse brick veneer) thermal lag slows heat flow on a day/night basis. Insulation is still required in most instances (straw bale walls are an exception as they have a high insulation value) [See: Thermal Mass]

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



Draught sealing

Air leakage accounts for 15 to 25 percent of winter heat loss in buildings. The diagram below shows typical sources of air leakage:

Use airtight construction detailing, particularly at wall/ceiling and wall/floor junctions.

Control ventilation so it occurs when and where you want it.

Choose well made windows and doors with airtight seals.

Improve the performance of existing windows and doors by using draught-proofing strips. Use between the door and frame, at the door base and between the openable sash of the window and the frame.

Seal gaps between the window/door frame and the wall prior to fitting architraves.

Avoid using downlights that penetrate ceiling insulation.

Duct exhaust fans and install non-return baffles.

Avoid open fires and fit dampers to chimneys and flues.

Do not use permanently ventilated skylights.

Use tight fitting floor boards and insulate the underside of timber floors in cooler climates.

Seal off air vents, use windows and doors for ventilation as required. This may not be advisable for homes with unflued gas heaters that require a level of fixed ventilation.

Windows and glazing

In terms of energy efficiency, glazing is a very important element of the building envelope. In insulated buildings it is the element through which most heat is lost and gained. Glazing transfers both radiant and conducted heat.

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

Daytime heat gain must be balanced against night time heat loss when selecting glazing areas.

Window frames can conduct heat. Use timber or thermally separated metal window frames in cooler climates.

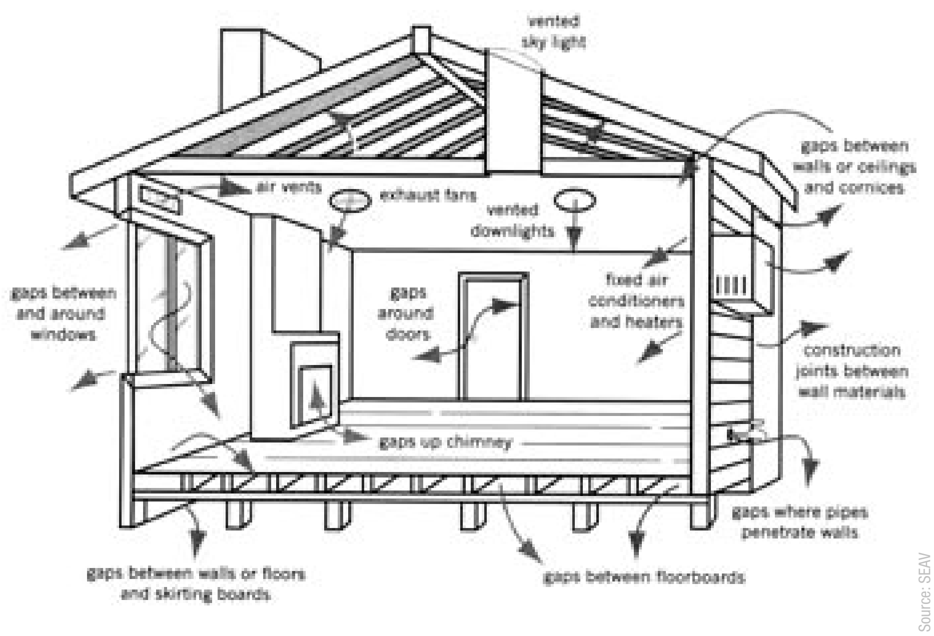
Views are an important consideration and often the cause of over-glazing or inappropriate orientation and shading. Careful planning is required to capitalise on views without decreasing energy efficiency.

Shading and advanced glazing options are critical in achieving this. There are many ways to reduce heat loss through glazing. [See: Glazing Introduction; How to Use WERS]

Air locks

Air locks at all regularly used external openings (including wood storage areas) are essential in cool and cold climates. They prevent heat loss and draughts.

For efficient use of space, airlocks can be double purpose rooms. Laundries, mud rooms and attached garages are excellent functional airlocks. Main entry airlocks can include storage spaces for coats, hats, boots and a small bench.



Allow sufficient space between doors so that closing the outer door before opening the inner door (or vice versa) can be done with ease of movement. Inadequate space often leads to inner doors being left open.

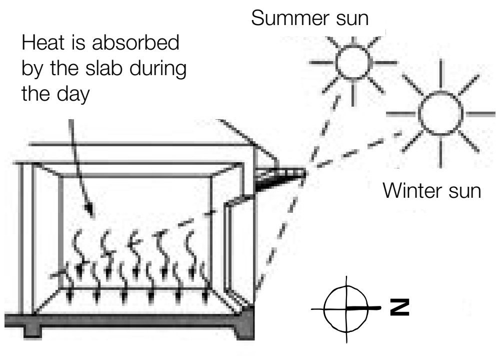
Avoid sliding doors in airlocks. They are invariably left open, are difficult to seal and can't be closed with a hip when both hands are full.

Always design door swings from airlocks so that they will blow closed if left open in strong winds, or consider using door closers on external doors.

THERMAL MASS AND THERMAL LAG

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

When used correctly, thermal mass can significantly increase comfort and reduce energy consumption. Thermal mass is essential for some climates or design solutions but can be a liability if used incorrectly.



Adequate levels of exposed (ie. not covered with insulative materials such as carpet) internal thermal mass in combination with other passive design elements will ensure that temperatures remain comfortable all night (and successive sunless days). This is due to a property known as thermal lag.

Thermal lag is a term describing the amount of time taken for a material to absorb and then re-release heat, or for heat to be conducted through the material.

Thermal Lag times are influenced by:

> Temperature differentials between each face.

> Exposure to air movement and air speed.

> Texture and coatings of surfaces.

> Thickness of material.

> Conductivity of material.

Rates of heat flow through materials are proportional to the temperature differential between each face.

External walls have significantly greater temperature differential than internal walls. The more extreme the climate, the greater the temperature difference.

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

In cool temperate and hot climates (or where the time lag is less than 10-12 hours), external thermal mass walls require external insulation to slow the rate of heat transfer and moderate temperature differentials. In these climates, thermal mass moderates internal temperature variations to create comfort and reduce the need for heating and cooling energy.

The following table indicates the relative thermal lag of some common building materials.

MATERIAL	THICKNESS mm	TIME LAG hours
Concrete	250	6.9
Double Brick	220	6.2
AAC	200	7.0
Adobe	250	9.2
Rammed Earth	250	10.3
Compressed Earth Blocks	250	10.5
Sandy Loam	1000	30 days

Source: Baggs, S.A. et al. 1991, Australian Earth-Covered Buildings, NSW University Press, Kensington.

Low mass solutions with high insulation levels work well in milder climates with low diurnal ranges.

Glass to mass and floor ratios

Optimum (solar exposed) glass to floor area ratios vary between climates and designs. This is due to varying diurnal ranges and the balance required between heating and cooling.

Location and exposure of thermal mass to direct and reflected radiation is also an important factor.

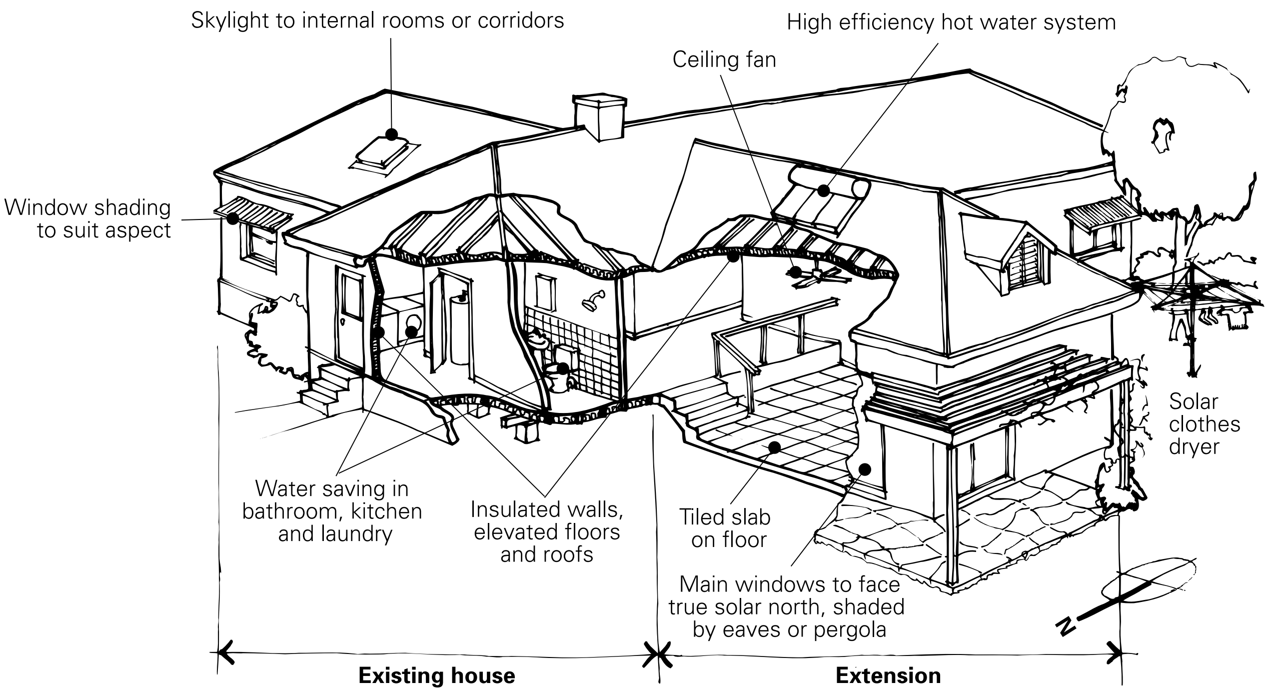
The useful thickness of thermal mass is the depth of material that can absorb and re-release heat during a day/night cycle. For most common building materials this is 100 to 150mm.

An exception is when thermal mass is used to even out seasonal temperature variations occurring in earth covered buildings. Summer temperatures warm the building in winter and winter temperatures cool it in summer. In these applications, lag times of 180 days are required in combination with the stabilising effect of the earth's core temperature.

A "rule of thumb" for best performance is: the exposed internal area of thermal mass in a room should be around 6 times the area of north facing glass with solar access.

In mixed climates where heating and cooling needs are equally important (for example Sydney, Adelaide, Perth) the amount of thermal mass used should be proportional to diurnal range. Higher diurnal ranges (inland) require more mass, lower diurnal ranges (coastal) require less.

In heating climates with minor cooling requirements (such as Canberra and Melbourne) larger glass areas with solar access can be beneficial providing that heat loss through glazing is adequately minimised and passive shading optimised. This requires double glazing and close fitting heavy drapes with snug pelmets.



Maximise externally insulated, internally exposed thermal mass. Edge insulation is desirable for earth coupled slabs, especially in colder areas. Earth coupling should be avoided where ground water action or temperatures can draw heat from slabs.

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

In predominantly cooling climates (for example Cairns, Darwin) solar exposed glass areas should be eliminated and thermal mass minimised. Some exceptions apply for advanced design solutions. [See: Passive Cooling]

Detailed analysis of glass to mass and floor area is complex and can be confusing. Detailed coverage appears in other publications. Refer to the additional key references at the end of this sheet.

PASSIVE HEATING IN RENOVATIONS

General principles

Many opportunities exist for improving or including passive solar design features when renovating an existing home. They include:

Design extensions to allow passive solar access and to facilitate movement of passive heat gains to other parts of the house.

Include thermal mass in areas with solar access. (Use slab on ground, reverse brick veneer or other insulated mass walls). [See: Thermal Mass]

Increase existing insulation levels and insulate any previously uninsulated ceilings and walls (and floors in cool climates). Access to roof spaces and walls is often easier during a renovation. [See: Insulation Overview, Insulation Installation]

Use high performance windows and glazing for all new windows and doors. Replace poorly performing windows where possible – glazing is normally the biggest area of heat loss in any building.

Double glaze windows to reduce winter heat loss. Double glazing does not prevent radiant heat from entering a home, but slows down conducted and convective heat losses. Expose the glazing to winter sun, but maintain summer shading. [See: Shading, Glazing Overview]

Seal existing windows and external doors, replace warped or poorly fitted doors. There is a wide range of seals available through hardware retailers which can be fitted to doors and windows at any time, but renovations are an ideal opportunity.

Create air locks at entrances in cool climates. In southern Australia, unwelcome winter winds come from the west and south. If entrances face these directions, it is important to provide a buffer to prevent freezing winds blowing straight into the house whenever someone opens the door.

Add doors and walls to group areas with similar heating needs into zones.

Consider a solar conservatory to maximise solar gains in cool climates. Ensure it can be sealed off from the rest of the house at night.

Install curtains with pelmet boxes where practical. Windows are generally the area of greatest heat loss. Solid topped pelmets with heavy double lined drapes which touch the walls at either side of the window and also touch the floor are a very effective way of reducing that heat loss to a trickle.

Improve natural ventilation with operable roof vents and maximum window opening areas. Even in cool climates some degree of ventilation is necessary. Some window designs provide better ventilation than others – casements and louvres are generally the best - but louvres need to be well sealed. [See: Passive Cooling]

Increase natural daylighting with new appropriately shaded skylights and windows. The following rules of thumb are a useful guide:

North — Maximise windows, especially to living areas, provide shading to the correct angle

East — Minimise windows where possible, provide deep overhangs, external blinds or pergolas

West — Eliminate windows where possible, provide the ability for complete shading by deep pergolas or other operable devices

South — Minimise large windows, provide some weather protection

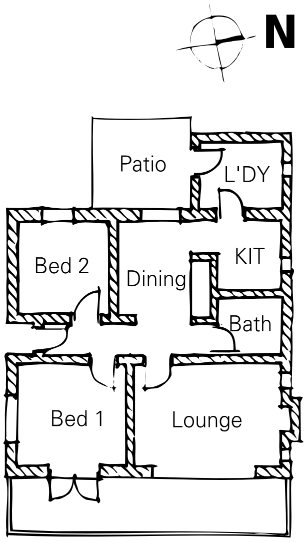
Views or other demands may necessitate large windows on east, south or west facades. If this is the case, creative design of shading and glazing should be used to minimise unwanted heat loss and gain.
[See: Shading, Glazing Overview]

Some quick renovation tips

1. Turn the house around:

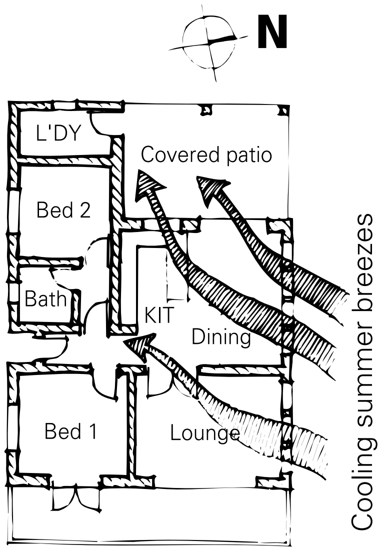
The ideal time to rethink the way a house works is when planning a renovation.

Reorienting as much of the living space as possible to the north side of the house achieves major improvements in the winter comfort of a house in cooler climates.



Original floor plan

North facing bedrooms can become living rooms, while south facing living areas can become bedrooms. Very often this can be done without increasing the scale of the renovations, thus providing great benefit at effectively no cost.



New floor plan

2. Turn the bricks around to add thermal mass:

It is often a simple matter to add thermal mass to timber framed structures, by adding an internal skin of brickwork.

Most houses are brick veneer – they have a light timber wall frame clad in a non-load bearing brick skin, or veneer. The bricks are effectively doing the same job as weatherboards.

The bricks have high thermal mass, but the outside of a wall is not the ideal place to locate thermal mass.

Reverse Brick Veneer (RBV) is a building system which places thermal mass (the brick skin) on the inside of the wall frame. The highly insulated wall frame protects the thermal mass from external temperature extremes.

The thermal mass in RBV is in contact with the house interior and helps to regulate indoor temperatures, for the benefit of the occupants.

This system is best used in conjunction with north oriented living areas, so the solar gain from the winter sun can add useful heat to these walls. [See: Alteration – Northern Sydney]

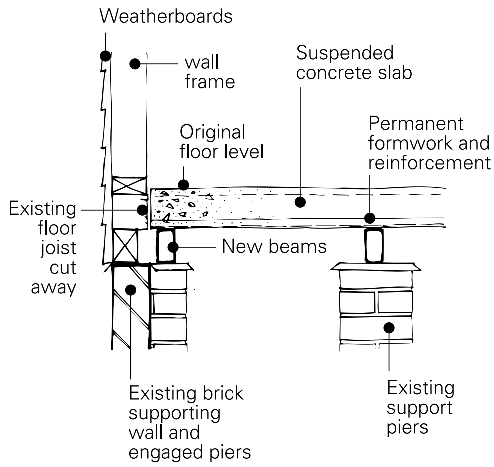
3. Add a concrete floor for more thermal mass:

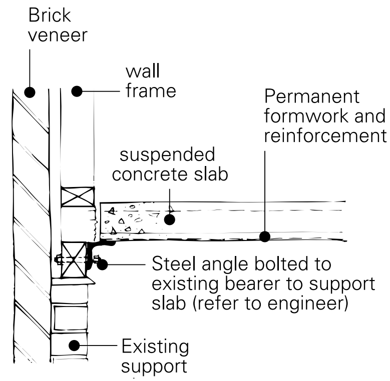
Many houses have raised timber floors, which have no thermal mass. This floor type is quite appropriate in many situations, such as sloping sites and in pole frame construction. But there are often easy opportunities to add useful thermal mass to floors when renovating.

This technique should be used where solar access is already available, or made available by 'turning the house around' as described above.

Most timber floors are of the conventional 'bearers and joist' construction, where the bearers are supported on brick piers or stumps, and these in turn support close spaced floor joists, on which the timber flooring sits. The bearers and joists can be cut, leaving a series of solid blocks supporting the wall frame above.

A suspended concrete slab can be put in place of this original structure, supported on the original piers or stumps, using steel lintels or beams as bearers. As with most structural changes and concrete slabs, an engineer will usually be required to certify the details.
[See: Alteration – Northern Sydney]

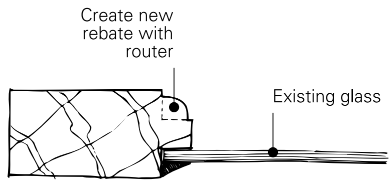




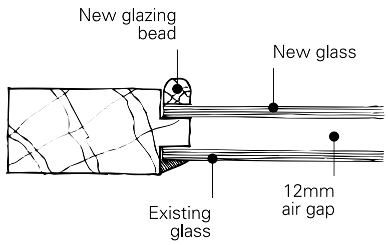
4. Double glaze existing windows:

If the windows do not need replacing for other reasons, they can be double glazed in-situ quite effectively and economically by adding a second pane of suitable glass to the existing window sash or frame.

Double glaze existing window sash



Existing sash/frame section



Modified sash/frame section

The previous diagram shows one method of double glazing older timber frames, but the principle can be applied to aluminium frames as well.

It is important to remove humidity from the air gap, which can be done by adding a small quantity of dessicant when the new glazing is fitted, or fitting the glazing during a period of very low humidity (20% or less). [See: Glazing Overview]

5. 'Zone' areas with similar heating needs:

Most houses built since the 1980s are 'open plan', with no walls or divisions between living areas. The idea first started when kitchens were opened up to adjacent eating areas, which was useful.

As houses have become bigger, with multiple living areas, 'open plan design' has allowed very large areas to lose thermal control and acoustic separation.

In most climates in Australia a very 'open plan' layout is not advisable. It is only ideal in warm humid climates, where it facilitates a high degree of cross-ventilation

Adding walls and doors to group areas with similar heating needs into separate zones allows spaces to be heated separately, reducing energy bills.

For example, more commonly used areas like living rooms can be heated separately without the heat dissipating to other areas of the house. This saves the expense of having to heat the whole house.

'Zoning' the floor plan in such a way also allows different family members and their friends to enjoy their often loud activities without disturbing the whole house.

ADDITIONAL KEY REFERENCES

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