Australian
Solar Energy Society
Tasmanian Branch

PASSIVE SOLAR DESIGN FOR COOL TEMPERATE CLIMATES

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Solar energy is a free energy source that we can use in various forms such as heat, light and electricity. Australia has an abundance of it. As yet it is neither charged for nor taxed by governments, multinationals or utilities. However as solar energy is cyclical and often required when the sun is not shining it costs money to harness it. Solar design comprises a collector, a storage system and a distribution system. Passive solar design is a way of doing this without using a mechanism.

Architectural features have a large influence on heating needs. Our comfort can either benefit or suffer from the decisions made about siting, layout, windows, materials and construction methods. A well designed passive solar house would reduce the need for supplementary heating (usually by gas or electricity) by about 80%. It is theoretically possible to heat a house using only solar and internal heat gains, thus making heaters quite unnecessary. Passive solar design of housing is the key to providing a sustainable lifestyle for the occupants.

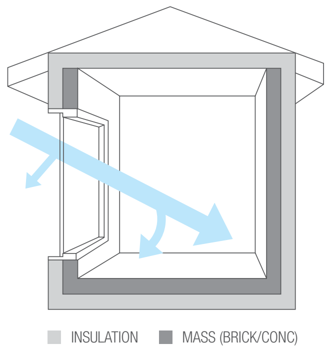

Fig. 2 Direct gain system

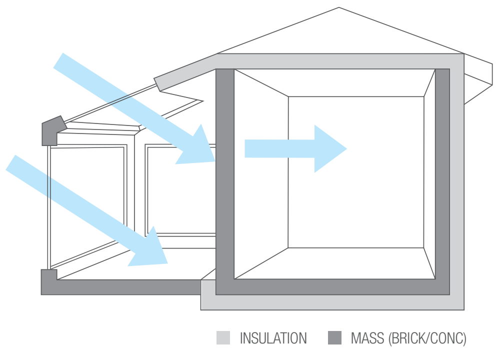

Fig. 3 Sunspace

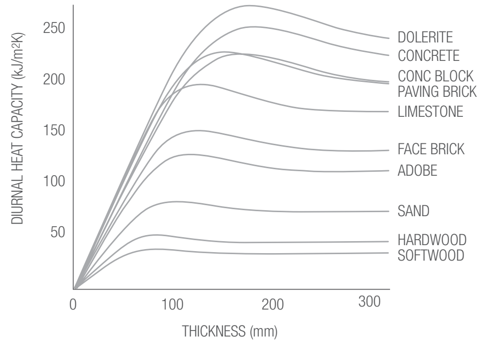

Fig. 5 Heat storage effectiveness of various materials

Source: Mazria, Baker, Wessling Sunworld Vol 2. No. 2 1978

CLIMATE AND COMFORT

Nowhere in the world do natural conditions provide a satisfactory physiological environment for humans. Natural conditions must be modified by wearing clothes and building shelters against wind, rain, snow and climate extremes. Comfort for a healthy active adult requires a temperature between 18-27ºC. Hobart, with a cool temperate climate (Zone 7 in Building Code of Australia), has over the last 10 years averaged:

- 321 days – 88% of year, with mean daily temperature below 18ºC (365 – 100%)
- 221 days – 67% of year, with maximum temperature below 18ºC (236 – 65%)
- 36 days – 11% of year with maximum temperature above 24ºC (29 – 8%)

The figures in brackets are for the 90 years between 1900 and 1990. Whilst a 10 year spread may not be statistically significant, it is hoped that the figures are indicative of the climate change now taking place. The increase in daily temperature means more attention needs to be given to shading in summer. However the seven to eight month heating season combined with a high proportion of sunny weather means Tasmania remains an ideal place for solar heating with either active or passive systems.

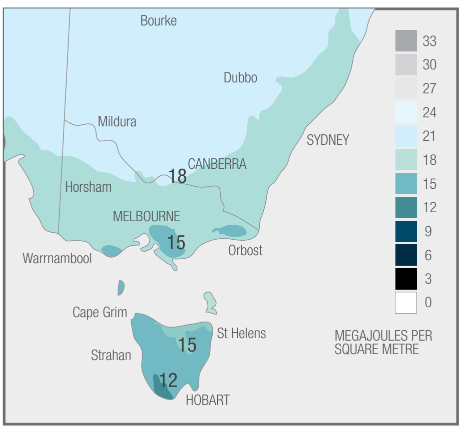

Fig. 1 Annual average daily solar exposure

Source: Australian Bureau of Meteorology

- Active Systems use a mechanism to convert the energy to a useful form, eg. a fan or compressor. This increases energy use.
- Passive Systems use convection, conduction and radiation for all heat flows (Figs 2, 3).

SOLAR SPACE HEATING

Passive solar heating uses the building and the climate to heat the building. It is not a component that can be bolted on to a building. Only a building that has been carefully designed and built can give you good results. Without attention to detail its operation and performance is usually mediocre.

The collector

The collector needs to be transparent to short wave infra red radiation, opaque to long wave re-radiation (for the greenhouse effect) and shaded in summer to prevent overheating. A high performance double glazed window facing north with an overhanging eaves is ideal. The double glazed unit would comprise clear glass on the outside, a sealed air cavity 12mm-20mm wide (refer Fig 4) and clear low-emissivity glass on the inside.

The store

The store is provided by thermal mass inside the building. Thermal mass is any material capable of storing heat. Those most commonly used in building are high density materials such as concrete, bricks, blocks and stone (refer Fig 5), or high specific heat materials such as water. It is important to distinguish between insulation and thermal mass. Insulation is measured by an R-value (thickness /conductivity), which is a measure of resistance to heat flow, and thermal mass by capacitance or C-value (density x specific heat x thickness), which is a measure of the amount of heat it can store. Dense materials are poor insulators and good capacitors. The amount of heat absorbed depends on the colour, texture and temperature of the surface while its' thickness determines the time lag required for heat to flow through. Rough dark walls and floors can absorb more heat than their smooth light counterparts and could result in a 1 star difference in performance. Insulation between the thermal mass and outside is essential to prevent heat loss by cold bridging.

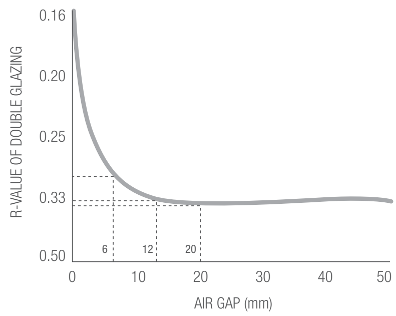

Fig. 4 Effect on R-value of conduction across cavity Source: Building Research Establishment BRD No. 140 1972

Distribution

Distribution is by direct radiation or indirectly by convection through a fluid such as air or water. Room air is the usual fluid for indirect gain and distribution is relatively automatic, the room temperature becoming warmer by convection and re-radiation from the warm wall surfaces. Other rooms can also be warmed by natural convection, usually achieved with air flow along passages and through open doorways.

Insulation

Insulation is essential for realising the full benefits of solar heating. It is required by the building regulations, but remember that minimum standards will keep rising despite opposition from self interest groups, so whatever is standard today is sub-standard tomorrow. Insulation is always your "best value for money". The more insulation you have

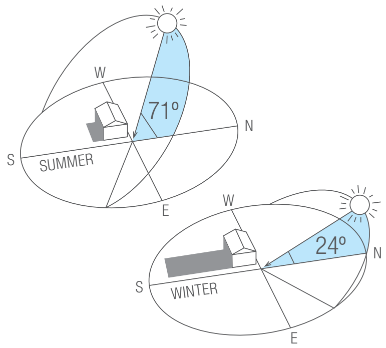

Fig. 7 Seasonal variation of the suns' trajectory Lat 42½º S

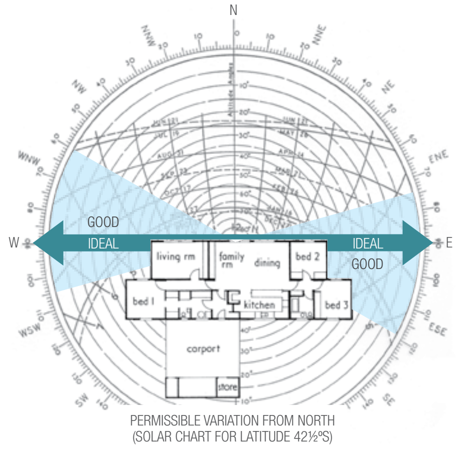

Fig. 8 Orientation

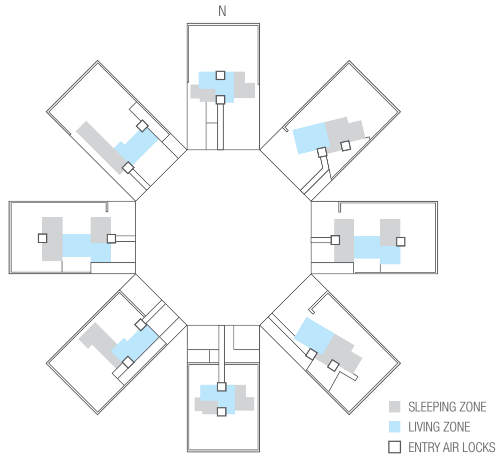

Fig. 9 Various designs for different orientations

Fig. 6 Recessed sunspace beyond, separated by dividing wall

the less fuel/energy you'll need for heating. Always try to equalise losses through the five sources of heat loss. 1 Roof/ceiling. 2 Windows. 3 Walls. 4 Floors. 5 Drafts. Most building materials, being either too thin or poor insulators, have low R-values, so specialist materials are used for insulating. Bulk insulation reduces conduction heat losses, reflective insulation reduces radiation heat loss, and draft seals reduce convection heat losses.

Sunshine

Sunshine is admitted to the space to be heated through windows. The energy is absorbed by walls or floors or other storages during the day and then released directly from the surfaces of those storages during the evening. As this also results in warmer walls, a higher average temperature and a much lower temperature swing, comfort is greatly improved.

Sometimes the zone to be heated is separate from the collector, in which case heating is usually through a contiguous wall such as a "Storage or Trombe" wall. Sunspaces and Conservatories (Fig 3) can be attached or recessed (Fig 6), but because of their large glass to mass ratios they experience large temperature swings both day and night and need to be closed off from other areas of a house when suffering from extremes.

Their appeal is in maximising the amount of collector, providing very pleasant indoor spaces on cold but sunny days and as a buffer space to the outside.

Errors

Mistakes commonly made in designing passive solar heating systems are:

1. Not enough insulation is provided and cold bridges in construction sabotage the value of insulation.
2. Windows do not face north and/or receive unobstructed winter sun because features such as wide verandahs or tinted glass cut out solar radiation.
3. Windows are not shaded in summer.
4. Mass is not sized in relation to glass and incident solar radiation.
5. Where views require large windows away from north, insulation values are not increased to compensate.

BUILDING LAYOUT

The following group of issues related to building layout are essential if passive solar heating is to work efficiently. As the major source of energy is the sun these issues are related to gaining the maximum possible exposure to the sun from mid March to late November. To an observer on earth the sun's path across the sky corresponds closely with the seasonal needs for heating and cooling. In winter the sun rises in the NE, travels in a low altitude trajectory and sets in the NW. At the equinox it rises due east and sets due west and in summer it rises in the SE and travels in a high altitude trajectory and sets in the SW (Fig 7).

Solar Access

Some sites are easier to work with than others but the key is to integrate the site and house design. Generally the sun should reach the collectors between 9.00am and 3.00pm in winter which requires a 90º cone of solar access. This is easier to achieve on the north slope of hills and in areas that are not shaded by large trees, thick bushes, tall buildings, cliffs or cuttings. Road patterns are usually set according to yield and engineering requirements, so the different block orientations require different plans and street setbacks. Whilst a long east-west configuration is convenient it is by no means mandatory and there are many different designs that all produce effective passive solar buildings (Fig 9).

Orientation

True north allows maximum sun entry in winter and easiest shading in summer. A 20º deviation from north gives up to 5% reduction in performance, and a 30º deviation gives approximately 10% reduction. This allows some scope for divergence. Based on a preference of morning sun for an early warm up and a dislike of overheating from the late afternoon sun "north" in this note means within the limits of 30º E of N and 15º W of N (Fig 8).

Windows

Window position is critical and a northern exposure is definitely required. A well designed passive solar house has 80% of its' windows facing north. This doesn't mean that large windows can't be placed elsewhere, particularly if there is a view. But the increased heat loss (or summer overheating) must be compensated as the insulation value of a single glazed window is slight.

Double glazing halves the heat loss over a single glazed window and in Tasmania's climate, really should be the norm. Windows can also be insulated with curtains if they prevent air flow. Most don't, regardless of the good intentions of their owners. Fitting an additional window, usually on the inside, is another way of insulating windows, particularly to preserve a building's architectural style.

Frames influence the performance of a window. Wood and plastic frames insulate while metal frames act as a heat sink. Metal frames with a thermal break between the inside and the outside can improve their R-value by 20%.

Fig. 10 Solar collectors at the Sustainable House Macquarie Street (a) north facing double glazed low-e windows for space heating (b) flat plate collectors for hot water, and (c) photovoltaic collectors for electricity.

Fig. 11 Aurora energy bills at the Sustainable House Macquarie Street have been continuously in credit since 14 November 2008

Zoning

Spaces in a house must be placed to suit the way its owners want to live. Commonly there will be four zones each requiring different comfort levels.

- Living zone (eg. lounge, sitting, family, dining, courtyard)
- Sleeping zone (eg. bedrooms)
- Service zone (eg. bathrooms, kitchen, laundry, storerooms)
- Circulation zone (eg. entry, corridor)

As the sun moves the character and climate within a house changes markedly over the course of the day. Sunshine brightens rooms on the eastern side in the morning, provides continuous heat to northern rooms during active hours and a late afternoon cosiness to rooms on the north west.

Wind Protection

Wind protection is almost as advantageous as good orientation. Strong winds increase heat losses by increasing transfer rates and air leakage. Shelter from the wind needs to be provided by windbreaks, hedges, fences, screens, shrubs and porches as well as air locks at all outside doors. In this regard a house using the living and sleeping wings to shield the winter winds also provides a very useful and sunny courtyard. Wind accelerates convection through the house as the inside and outside air masses try to equalise. A house contains about half a tonne of air which is replaced between two to ten times an hour, depending how leaky it is. The new air must be heated to maintain the indoor comfort level. By paying careful attention to sealing gaps and fitting sheathing, door seals and flue dampers as the house is being built it is possible to reduce this infiltration rate to one air change per hour. A healthy indoor environment is still maintained, heat losses are reduced and large heaters become unnecessary.

Thermal Comfort

As the phrase suggests is the feeling of comfort experienced by a person when they are in balance with their surroundings, neither too hot nor too cold. In a poorly insulated house, wall, floor and window temperatures are much colder than the warmed air. This is often experienced as a feeling of cold feet and/or stuffiness which is to be avoided. Too high a heat gradient and the body loses heat by radiation to the colder surfaces and is bathed in cold convective currents from windows. Turning up the temperature is futile.

When walls floors and windows are well insulated their surface temperatures are much closer to the room air temperature which could probably be set at 18º or 19ºC without any loss of comfort.

SOLAR ELECTRICITY

Solar electricity is another passive solar system, collecting light from the sun and converting it to electricity. Using the grid as a store overcomes the problem of providing electricity at night when the sun is not shining. An inverter changes the direct current (DC) from the panels to alternating current (AC) making it compatible with house wiring. Orient the panels to the north, tilted (35º in Hobart) in order to maximise the amount generated over 12 months (Fig 10). The power is supplied to the house with the surplus exported directly to the grid and additional needs imported from the grid. If there is a surplus of export over import the supply authority will credit you for that surplus. (Fig. 11) Solar electricity produces no carbon dioxide, is quiet, clean and above all sustainable.

Investment

A solar power system is an investment – a reasonable investment – returning somewhere between 5-9% p.a. It costs a lot less than consumer goods (a car, a fitted kitchen, a home theatre) which never pay themselves back. Payback, commences from the moment of connection to the grid and decreases with each electricity (or gas) tariff price rise. Value is added to your home and realised whenever you sell.

Sizing and Energy Conservation

The system you install depends on the amount of power you use, the subsidies on offer and your budget. Aim for a minimum 2kW system. Solar panels are modular so you can start small and increase over time. If you do this then size the inverter for the capacity of the eventual system. Buy the most efficient panels available as change is taking place rapidly It makes sense to make your home and lifestyle energy efficient before purchasing solar panels, so that you purchase fewer panels. Insulate and solarize your home; eliminate water heating by installing a solar water heater; install efficient appliances; increase your use of microwave cooking; convert your lighting to low wattage bulbs; eliminate stand-by loads. With a solar panel worth about $1,400 in 2008 it makes sense to spend $30 on a new light bulb or $1,000 on more efficient appliances.

Further Information

This pamphlet, one of the Solar Design Series for cool temperate climates, is produced by the Tasmanian branch of the Australian Solar Energy Society who may be contacted at www.auses.org.au It is supported with a Hobart City Council, Dr Edward Hall Environment Grant.

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