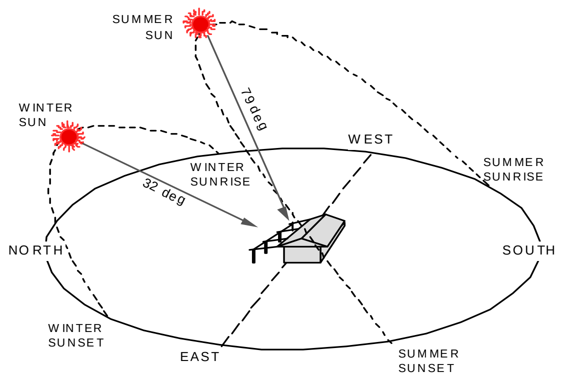
Low Energy Building Design

PART 1
BASIC PRINCIPLES OF PASSIVE SOLAR DESIGN

Australia receives an annual average radiation of about 600 watts per sq. metre on exposed horizontal surface. With careful design we can trap about **500 W/ sq.m**. and use it to heat a building. To visualize 500w think of the heat given off by a 1000w electric radiator.
We design the building as a large solar collector.
If we take advantage of the seasonal changes in the path of the sun we can build structures that capture the low altitude north winter sun while still keeping out the high altitude summer sun. [see diagram].



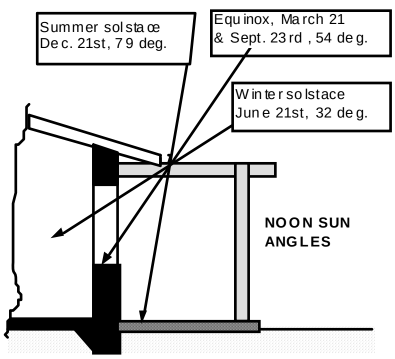
SEASONAL SUN PATHS

To collect and retain this free energy we design to the following principles-

1. Ideally orient the long axis of the house east- west. [within 15 degrees]. In Denmark the shadow of a vertical stick at 12.16 pm points to true north.

2. Maximise the **windows on the north wall** [about 13 to 20% of the floor area On the south coast] ie 13 to 20 sq m for a 100 sq m house! but only if there is adequate thermal mass. Reduce or omit windows on the east, west and south walls.
   Note: Add more north glass where there is a high thermal storage capacity. (large thermal mass) and less in low mass buildings.

3. Design the eave on the north wall to only admit sun during the coldest months.
   Ideally construct a pergola out from the north wall to support a deciduous vine which can offer shade during summer and autumn and can be cut back to allow the sun to penetrate the house during winter and spring. In Denmark an eave 500mm wide is generally adequate.



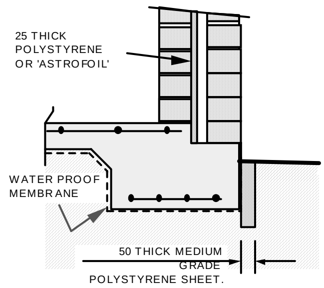
4. Introduce as much **mass (insulated from the exterior!)** into the building as possible ie. concrete floor, masonry walls. Masonry interior walls are particularly useful because they absorb and emit heat into the interior from both surfaces. Carpet, vinyl and cork tiles will to some extent mask the moderating influence that a concrete floor has on the temperature of a building.

   Use tiles or slate where possible. Some compromise is needed here as a building with large areas of exposed masonry will have the acoustics of a bathroom, ie too much echo, although it may work well thermally. Book shelves, curtains, soft furnishings will then become important.

5. Insulate as much as costs will allow.
   'U' value - The insulating value of a material is called its 'U' value.
   The U value is the number of watts that will pass through 1 sq. metre of a material, wall, floor or roof when the temperature difference of the air between both sides is 1 degree C.
   Therefore **the lower the 'U' value the better the insulation**.
   The U value is the inverse of the R value.
   For example R2 fibreglass batts allow 1/2 a watt per degree temperature difference per sq. metre so if it is 2 degrees outside and 20 degrees inside a house of 100 sq. metres the amount of heat being lost through the ceiling is 18 degrees x 1/2 x 100 = 900 watts/hour.

A 100sq m house with an uninsulated ceiling under a tiled roof has a U value of 2.47 and would be losing 4450 watts/hour when the inside is heated to 18 deg above the outside temperature!

Insulate heavy masonry elements from the exterior
eg. use reverse brick veneer, 'Thermalite' bricks or
insulated cavity brick – for cavity insulation use 30 thick 'Styrofoam' panels, 'Aircell' or sisalation which is cheaper but not quite as effective.
For areas prone to frosts place polystyrene at edge of footings [see diag.].
Reverse brick veneer is ideal thermally but durability, maintenance costs etc. have to be considered with external walls. Colorbond external cladding with brick internal walls is well worth considering.
Insulated cavity brick though is the best option. To make it more effective use a low density, brick on the outside eg 'Thermalite' blocks, Mt. Barker stone or highly cored clay fired brick, and a heavy high density brick for the inside leaf ie. 'solids', pressed earth blocks, mud bricks, rammed earth. And insulate cavity.



INSULATED SLAB EDGE

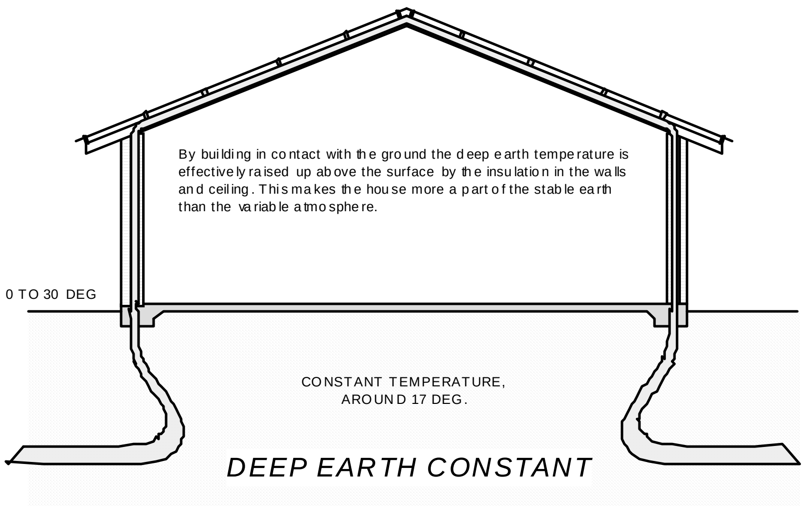
For frost prone areas

6. Use materials and building techniques that allow the finished building to be tight and free of drafts. ie. masonry walls can be sealed against the ceiling with mud, mortar or plaster much more easily than with timber.
Avoid building bush poles into timber walls unless they can be machined flat to provide a good seal!
Install seals to exterior doors and windows.

7. Design the structure to **contact the ground** as much as possible to take advantage of the planet earth which is a huge thermal store in itself.

The temperature of the earth 2 metres down is a constant at around 17 degrees. Therefore a concrete slab in contact with the ground will approach temperatures somewhere between the 'deep earth constant' and the air inside the building.

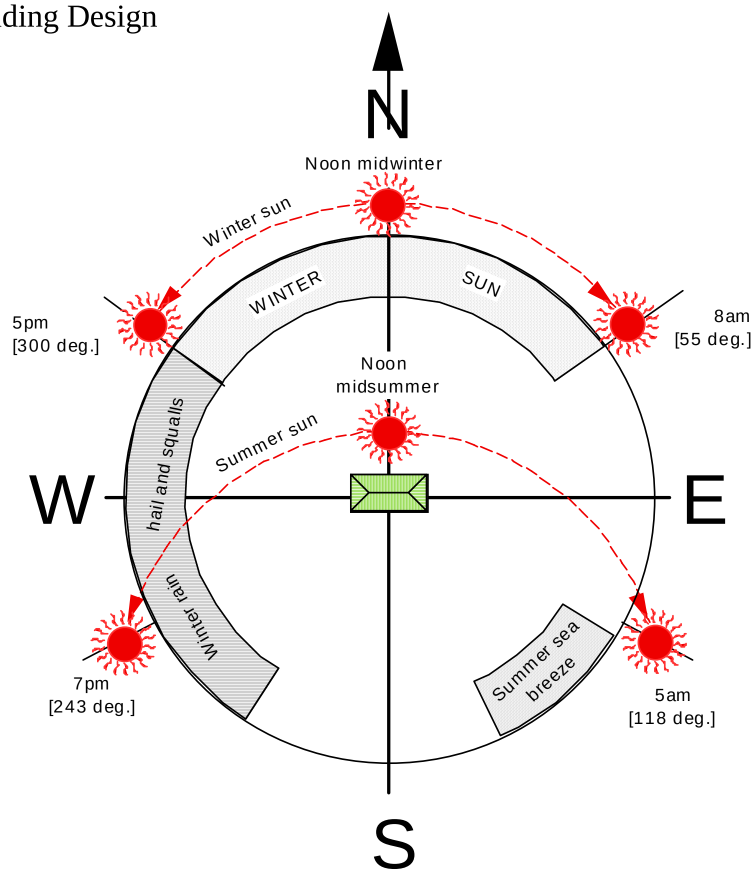
The perimeter of the slab can be insulated using polystyrene to protect it from excessive seasonal change in inland regions. Insulation to 300 below ground level is adequate in WA.



Earth berm. Bank up soil against a well waterproofed wall to increase contact with the ground. Insulate to 300 below G.L.

8. Be fully aware of the prevailing weather conditions all year round and design the house accordingly.

Diagram showing prevailing weather conditions for the Walpole to Albany stretch of coast.



LOW ENERGY BUILDING DESIGN

PART 2- 1nsulation, Windows, Solar access, Thermal storage.

INSULATION

HEAT is transferred in three ways
RADIATION- the emission of heat from a surface.
CONVECTION- movement of heat through the air.
CONDUCTION- movement of heat through a solid.

Insulation works by reflecting radiated heat (eg aluminium sisalation) or slowing down conduction and reducing convection (eg wool, fibreglass, polyester).

Other properties of materials that affect their insulation value are

Absorption- the ability of a surface to absorb thermal radiation. Generally the lighter the colour of a surface the lower the absorption.
Emittance- Is the measure of the ability of a surface to give off heat. The amount of heat emitted by a painted surface is unaffected by colour.
Note- Weathered dark colorbond with no sisalation underneath will allow 9-10 times more heat into a building in summer than zincalume, however with the installation of sisalation laid under the sheeting the performance of the colorbond roof is as good as the zincalume.

The measure of the ability of a body to give off heat.

The ratio of thermal radiation to the radiation absorbed by a black body

MATERIAL	EMISSIVITY	ABSORPTION
aluminium foil	0.05	0.1
white paint	0.9	0.2
red brick	0.9	0.55
dark concrete	0.9	0.9
black shellac	0.91	0.91+
new galv iron	0.2	0.65
old galv iron.,	0.3	0.8

INSULATING MATERIALS
Reflective insulation- reflects radiant heat thus needs an air space adjacent to the reflective surface. It is also a poor emitter of heat. eg. aluminium sisalation, AirCell, reflective window insulation.
Bulk insulation- resists transfer of heat by conduction and convection by trapping air in millions of small pockets - eg. fibreglass, cellulose fibre, polystyrene, lightweight brick, wool, eel grass, polyester.

DURABILITY OF INSULATION
Rodents- Contrary to manufacturers claims rodents love to make nests in fibreglass and are quite happy romping around in other types of insulation thus reducing its effective life. Therefore it is important to seal cavities and ceiling spaces. Special care must be taken to block between battens or purlins at gable ends and rafters above the wall plate. Reflective insulation such as Aircell is not as effective as bulk insulation initially but 10 years down the track will probably perform better than slumped, rodent damaged bulk insulation.

FITTING INSULATION
Correct fitting of insulation is critical. Blanket insulation must be lapped 150mm min. and sealed well at the ridge and the exterior wall plates. Insulation draped over battens must be allowed to expand, or 'fluff up', to its maximum thickness to achieve its designed 'R' value. Thus **38 thick battens are too thin** if fastened over a ceiling laid on exposed rafters because they compress the insulation and thus reducing its insulation value. A minimum of 90mm ceiling space is required for adequate insulation.

Sisalation should be fitted so an air space of at least 20mm is created on each side. When fastened to a timber frame under weatherboard or sheeting it must be dished to work at maximum efficiency. This will in effect create an extra cavity.

The 'U' value of a weatherboard wall is 1.02, when the sisalation is stretched and 0.63 when it is dished, 40% more efficient !! Some 'U' values are given below.

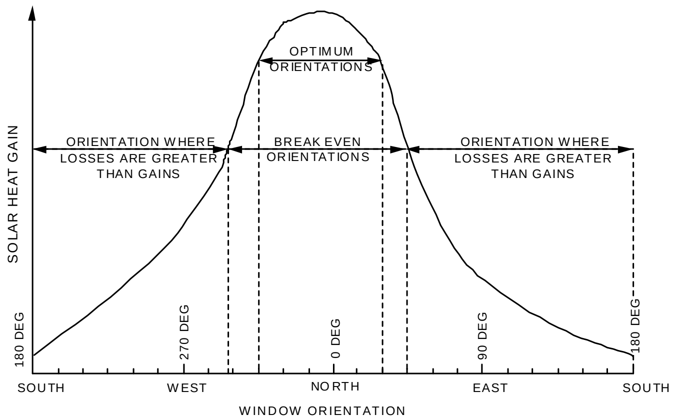
Construction type	‘U’ value watts/sq m K	Construction type	‘U’ value watts/sq m K
Framed walls		**Masonry walls**	
Timber & plasterboard	1.8	300 mm granite	3.8 the worst!
Timber,sisalation,plasterboard	1.0	300 mm mud brick	2.5 bad
Timber,dished sisalation,plasterboard	0.6	300 mm rammed earth	2.5 bad
Timber, 50mm bulk insulation, plasterboard	0.5	Double brick	1.7
Veneer walls		Double brick with Astrofoil	0.4 very good
Brick veneer	2.0	‘Thermalite’ brick, cavity, clay brick	0.8
Brick veneer with sisalation	0.7		
Brick veneer with 50mm bulk insulation	0.5		
Reverse brick veneer with sisalation	0.7		

The lower the U value the better

WINDOWS

Window orientation

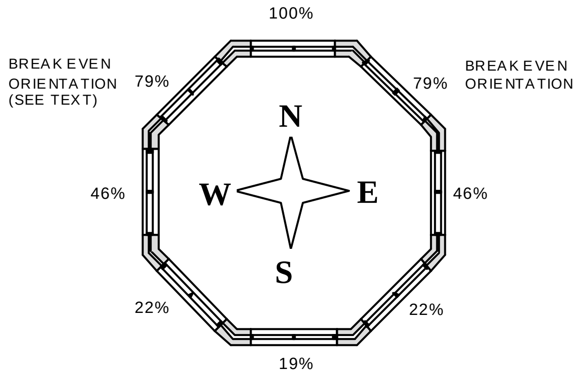
Windows are the weak point in a building. The ‘U’ value of 3-6mm glass is about 6. Therefore glass surfaces allow the passage of up to 12 times more heat than other surfaces in a structure. Glazing should therefore be kept to a minimum and carefully placed for maximum light.



VARIATION IN SOLAR GAIN FOR VARIOUS ORIENTATIONS

Even uninsulated windows when facing the right direction in winter will gain more heat from the sun during the day than they will lose at night. The optimum orientation of course is due north but they will still function as heat collectors when facing at an angle to north up to 50 degrees to the west and 45 degrees east. These are the 'break even' orientations (see graph).

However orientations that are greater than 15 degrees either side of north will allow too much sun penetration in summer unless external shading in the form of movable awnings, external shutters, or pergolas are added. This adds to the cost of the structure and means that residents have to consciously adjust shading devices seasonally.



STRUCTURE SHOWING % OF SOLAR INSOLATION IN RELATION TO A NORTH WALL IN MIDWINTER

WINDOW INSULATION

Fitting with thick curtains and pelmets will lower the 'U' value of windows to a value of 4.5 (only when the curtains are drawn of course}. Pelmets reduce the air circulation against the glass [convection].

Window treatment	Modifying value M	‘U’ value
Light drapes only	0.85	5.1
Light drapes+pelmet	0.7	4.2
Heavy drapes only	0.75	4.5
Heavy drapes+pelmet	0.45	3

The 'U' value can be multiplied by a 'modifying factor' depending on its treatment. If we add light drapes the modifying factor is 0.85 which can be multiplied by the 'U' value of the glass to give a value 6xO.85=5.1

Double glazing-the benefits of double glazing ('U' value 2.6, 20mm gap) probably doesn't warrant the extra expense except maybe in high windows where the temperature difference on each side can be quite large.

Glass bricks- have a 'U' value of 3. They are useful in places where the view is not important.

Frame material	Glass type	U value
aluminium	clear	6.6
aluminium	low e	5
aluminium	d/g clear	4.59
aluminium	d/g argon	3.63
uPVC or timber	clear	5.71
uPVC	d/g	3.58
uPVC	d/g argon	2.36

Aluminium versus timber windows-
Metals have a very high conductivity compared to timber thus aluminium forms a thermal bridge which increases the U value of a window by 10 to 11% (See conductivity table right).
In some situations a double glazed aluminium window has the same insulation properties as a timber framed window of the same area.
However aluminium windows can work reasonably well for a sunspace that can be closed off from the rest of the building during the evening. Also aluminium windows come with built in seals and require very little maintenance.

Material	Conductiviy W/m. degC
steel	47.5
aluminium	220
copper	350
Stone, brick, concrete	0.5 to 1.5
timber	0.1 to 0.15

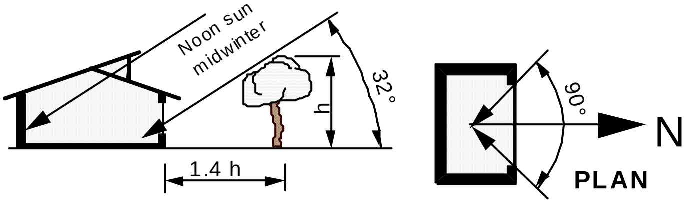
SPECIAL WINDOWS
High windows admit the most light for their size, ie clerestory windows and skylights. Any windows that provide a direct view of the sky will provide 3 times more natural light than windows viewing vegetation or other structures. However since the air is hottest near the ceiling the temperature differential is greater on each side of the glass thus the heat exchange slightly higher.
Personally I feel that this is more than compensated for if the clerestory faces north because then it is usually simple to focus sun onto an unobstructed masonry wall free of furniture and the high windows are unlikely to be shaded by trees growing to the north.

Skylights larger than about 0.5 sq. metres need some sort of shuttering to keep out the summer sun.

DIRECT & INDIRECT SOLAR GAIN
When sun is allowed to enter a building to heat its interior it is termed direct solar gain This has some disadvantages (ie. fades furnishings, can be glary, reflects off benches and desks etc.) so it has to be controlled with blinds. Blinds can be expensive and some people don't like opening and closing them at times during the day. To avoid this problem we can collect the sun's heat outside the house and duct it in. This is termed indirect solar gain. eg. attached glasshouse, Trombe wall, lean-to thermal store, Lawrence wall.
Laminated glass is ideal in clerestory windows as it filters out 100% of all damaging ultraviolet light.

SOLAR ACCESS AND SUBDIVISIONS
Solar access can be defined as ‘allowing the sun to penetrate a building or be used by a collector on the surface of that building between 9am and 3pm in midwinter'
Needless to say access to winter sun is crucial to the success of passive solar architecture but apparently no legislation exists at present. Few local councils have guidelines that recognise solar access as an amenity to be preserved.

In forested areas solar access is difficult. A 60m Karri will cast a shadow 100m long at noon in midwinter on level ground so careful siting of houses in rural areas around Denmark must be made if the occupants are going to enjoy the benefits of winter sun.



SOLAR ACCESS MIDWINTER

When subdivisions are planned solar access should be considered. The ideal shape for a block for maximum winter sun is to have the long axis running north-south. This gives the owners of the land control of their northern aspect. ie they can grow small trees to the north, trim large ones etc and not have to negotiate with neighbors who may not understand or appreciate the value of winter sun.

Denmark central business district is unfortunately badly oriented from an energy point of view. Holling Rd through to Offer St., by the school, are running at an angle of 30 degrees west of north. In buildings that line up with these roads it's difficult to position windows with a favourable orientation.

THERMAL STORAGE CAPACITY

When the thermal storage capacity of a building is being considered it is sometimes useful to take into account the thermal capacity of the building materials. The volumetric heat capacity or specific heat of some common materials is:

Material	Density Kg/cubic m	Thermal storage capacity Joules/cu m K
water	998	4175
steel	7850	3940
concrete	2320	2039
granite	2640	2154
Tiles/clay	1920	1768
wood	480	904
brickwork	1600	1339

Generally, in a building that receives winter sun the surface area of the thermal mass should be as large as possible.
A building that does not receive sun and is heated intermittently should not have heavy materials but be well insulated. This prevents large amounts of heat being soaked up by the thermal mass each time the heating is turned on.

SUMMER TIME PERFORMANCE OF SOLID MASONRY EXTERIOR WALLS

As has already been noted solid masonry exterior walls **do not keep buildings warm in winter.**
On the South Coast where we can depend on cool evenings they do however perform well in keeping buildings cool in summer. This is due to the delay between when the outdoor temperature reaches a maximum and the indoor surface temperature reaches a maximum.
This is called the **THERMAL LAG,** which for a 300 thick rammed earth wall is about 9 to 10 hours. Consequently at the hottest time of the day the walls are still cool from the previous evening and can therefore absorb excess heat from the interior thus moderating the inside temperature.

COMMENT ON PAINTING

Use materials that don't need paint. Oil weatherboards, they will eventually blacken but you won't be locked into the expensive, both financially and environmentally, 10 yearly paint job.
Jarrah will survive quite happily with no coating at all and will 'silver' like an old fence post. Western Red Cedar just needs a coat of Linseed oil occasionally.
Of course in urban environments this 'silvering' might cause problems with the local council and neighbours who might insist that you spend large amounts of time and money to pollute the neighborhood with paint products produced from mineral sand mining in order to maintain the 'visual amenity' of the area.

COMMON MISCONCEPTIONS

Solid exterior walls are energy efficient?

Note the low insulation values of Rammed earth, mud brick, granite etc in the table above.
These walls all lose more heat to the exterior than to the interior.
Insulated cavity and reverse brick veneer are best because the interior leaf exchanges heat with the interior of the building only.

A veranda of clear roof sheeting or glass over the north windows will not effect their winter solar gain?

Due to reflection, refraction and transmission losses due to the build up of dust etc on the 4 surfaces heat gain is reduced by at least 50%. I know because I've tried it!
Laserlight has the unfortunate tendency to stain on the top surface and can look pretty horrible after a couple of years of exposure. A pergola and deciduous vine is the most functional and aesthetically pleasing option.

Verandas all around will keep the house cool?

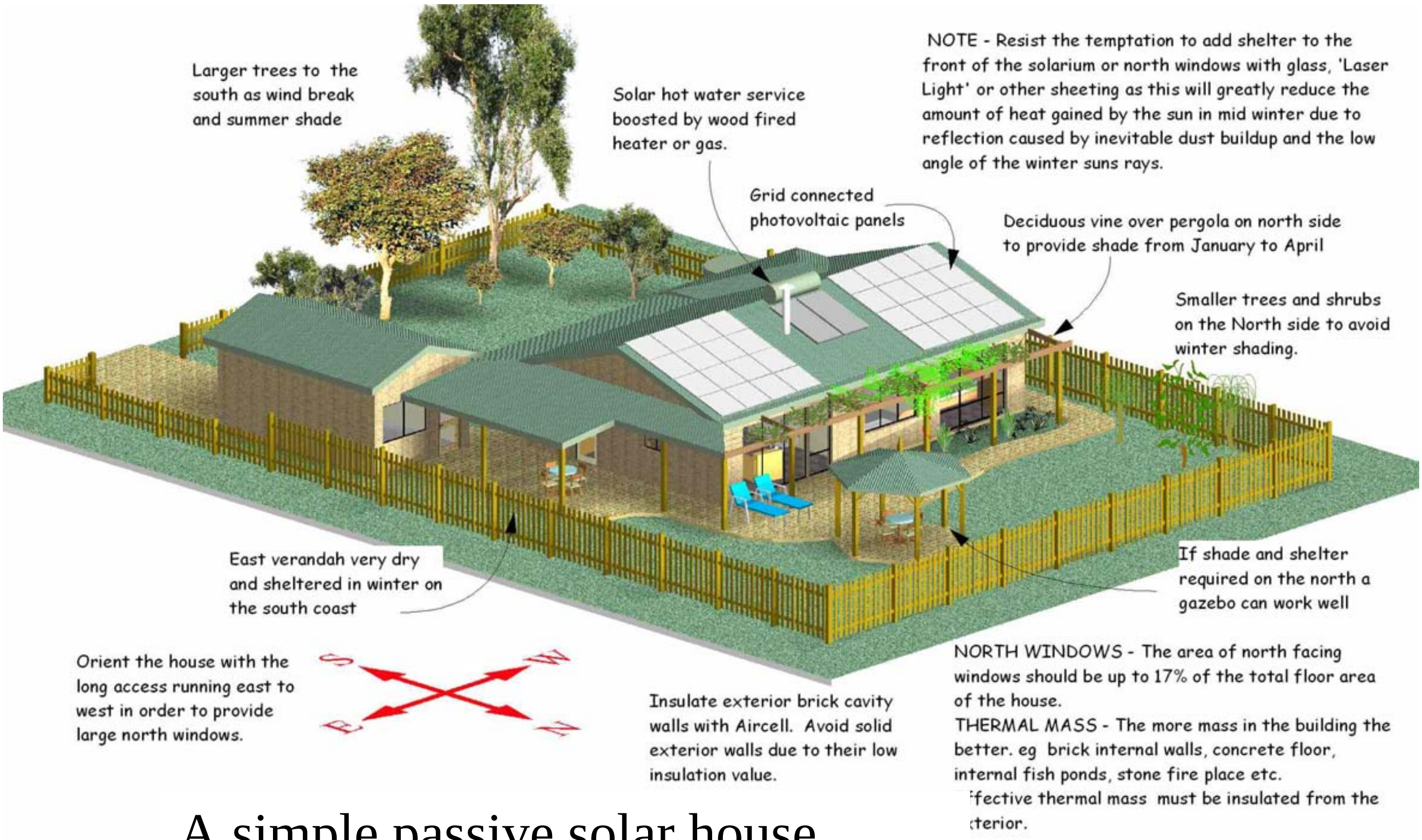
Early CSIRO studies clearly show that verandas can actually make the house hotter in summer because they restrict cool evening convection currents from forming against the outside walls and windows. A veranda will trap hot air against the external walls during hot still nights.

It is better to shade the walls with eaves on the north and south sides of the building and trees to the east and west.

Verandas link the house to the natural environment?

Design the house so that the living areas are linked to the environment through windows that have a view of the sky and look out onto close by ponds and gardens. A veranda will push this natural environment further from the main living areas where occupants invariably spend most of their time.

Some veranda area is of course essential but keep the area down as excess becomes a dumping ground and unnecessarily darkens the interior of the house, the lights on at 3 in the afternoon syndrome!



A simple passive solar house

Good web sites

www.greenhouse.gov.au/yourhome/technical

Sustainable Energy Development Office www1.sedo.energy.wa.gov.au