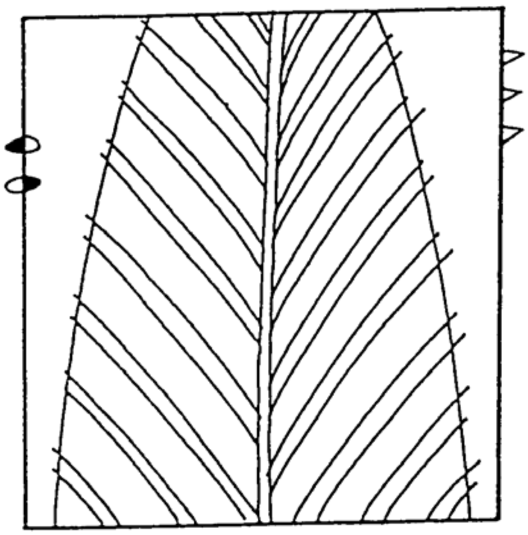
DESIGN FOR THE SUN



Waitakere City Council
Te Taiao o Waitakere

Contents

This chapter is part of the Waitakere City Council's Sustainable Home Guidelines. The complete set can be obtained through most libraries or from the Waitakere City Council, Private Bag 93109, Henderson, Waitakere City 0650, New Zealand, phone (09) 839 0400, email: info@waitakere.govt.nz.

The guidelines are also available on the council's web site: http://www.waitakere.govt.nz

Principles of passive solar design

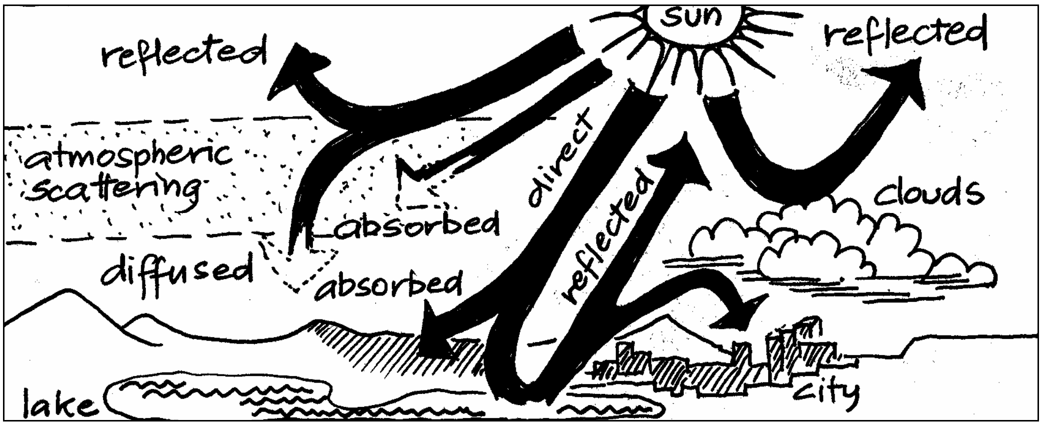
Designing for the sun is the most cost-effective and environmentally friendly way to heat and cool New Zealand houses. 'Passive solar design' refers to the use of the sun's energy directly for the heating and cooling of living spaces. The building itself uses the natural characteristics of materials and air to take advantage of the sun's energy.

Passive systems are simple, with few moving parts and minimal maintenance, though they do require some commonsense adaptation of the occupants' behaviour patterns. Passive solar design has been practised in various ways throughout the world for thousands of years. It reduces energy costs and offers superior comfort.

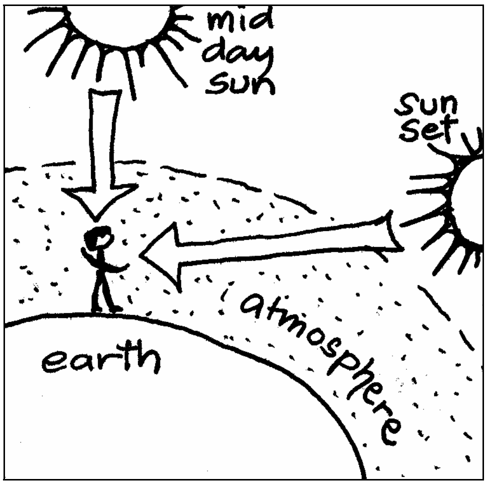
You can design a simple and cost-effective passive solar home from the options described in these guidelines. If you want to get serious about it you can do calculations to fine-tune the system or employ professional advice to maximise the benefits. The approach you choose should take account of the view, daylight and ventilation, but avoid glare, extreme UV exposure, and big internal temperature swings. For successful passive solar design it helps to understand the way the sun's energy interacts with the atmosphere and materials.

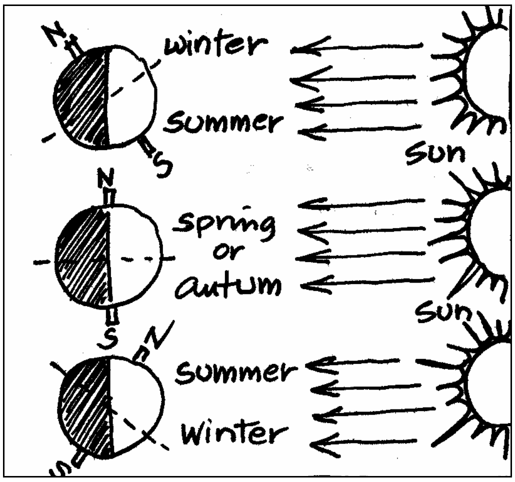
Solar radiation and the Earth's atmosphere

Some of the sun's radiation is reflected back into space or scattered and absorbed by the atmosphere, clouds, dust, water vapour, carbon dioxide and ozone. Nevertheless we still receive solar energy even on a cloudy day. The amount that arrives at your house depends on the season, the time of day, the weather, and local air pollution levels.



Solar energy is highest when the sun is overhead midday and summer. It is lowest when the sun angle is low e.g. sunset, or in winter, when it rises no more than 30 degrees above the horizon and the radiation has to pass through the atmosphere for a much greater distance.



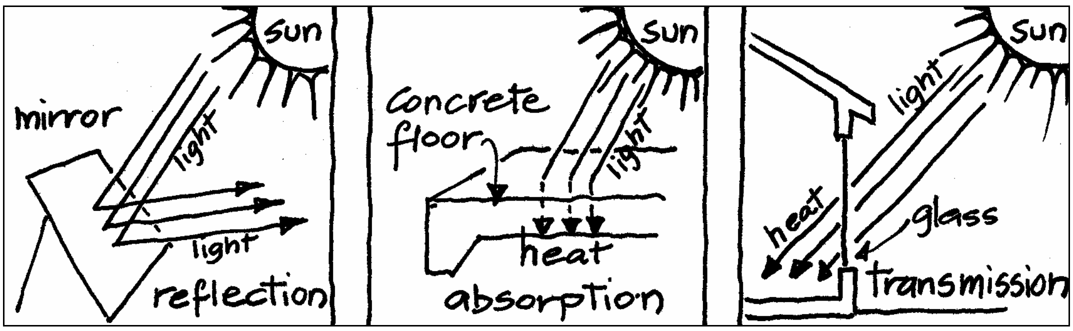


Solar radiation and materials

Reflection, absorption, transmission

Light colours **reflect** solar radiation while dark colours **absorb**. The exception to this is that some paints incorporate an infrared-reflecting additive which allows dark colours to stay cooler. Transparent surfaces **transmit** solar energy. The capacity of a surface to reflect, absorb or transmit solar energy depends on its density and composition.

Plain glass lets most of the sun's radiation pass straight through. When the radiation hits a dark surface behind, it is absorbed and converted into heat. The heat spreads to adjacent materials including the air, and is kept trapped inside by the glass, which is more opaque to the longer-wave heat than it is to the shorter-wave light energy. This is known as the greenhouse effect – on a larger scale a similar thing happens with the earth's atmosphere.



Heat transfer

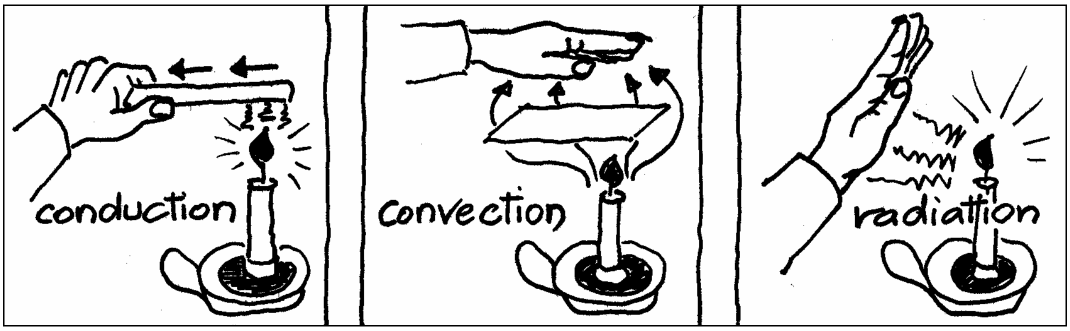
Conduction, convection, radiation

Heat tends to spread itself around to balance the temperature. The greater the temperature difference, the faster heat is transferred. The transfer occurs in one of three ways, each of which plays an important role in passive solar design.

Heat may be redistributed by **conduction**. This involves the vibrational energy being passed from molecule to molecule. Heat spreads from a warm place to a cool place.

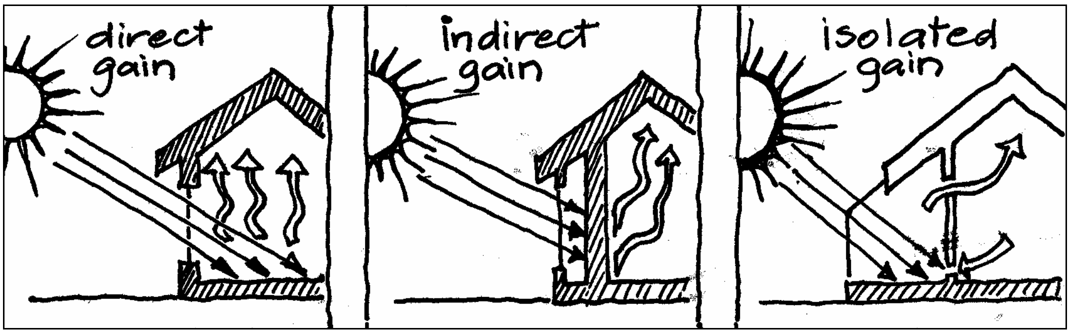
Transfer by the movement of a liquid or gas (e.g. air) is called **convection**. Cooler air will generally fall to displace less-dense warm air.

The transfer of heat by invisible infra-red waves is called **radiation**. All materials are constantly radiating thermal energy in all directions. Such radiation can keep you comfortably warm even when the air temperature is low.



Gaining heat from the sun

Direct, indirect and isolated solar gain

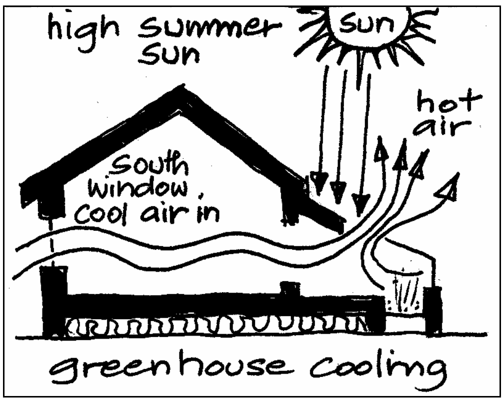


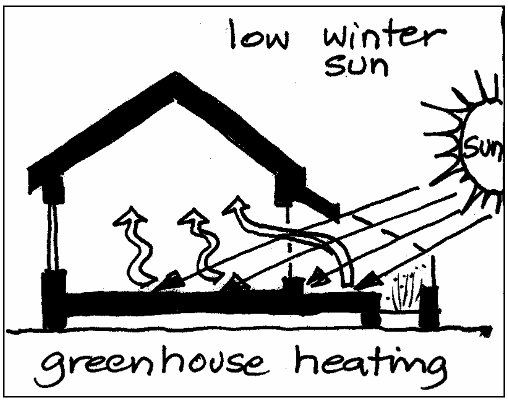
You can bring the sun's heat into your house in three different ways:

Direct heat is gained by exposing rooms to direct sunlight, which warms up surfaces where the heat can be stored. This method is the most appropriate for much of New Zealand where there are not extremes of very hot days and cold nights. It is also easy to build and maintain. You need living spaces with north-facing windows, in combination with thermal mass to store some of the heat and good insulation to keep it inside.

Indirect gain is useful in the unusual situation where you do not want to open up your living spaces to the north. The sun's radiation penetrates through insulating glass into a thermal mass, such as a concrete wall, which stores heat for re-radiation into the rooms behind it.

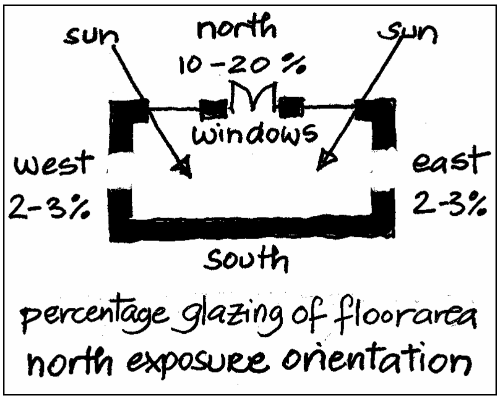
Isolated gain allows you to heat rooms at a distance from where you can collect and store the heat. The stored heat can be drawn through into the rooms by a variety of methods. A conservatory is an example of isolated gain. Conservatories have become popular in New Zealand because of the attractive living space they can offer in winter. With careful design they can also offer energy efficiencies. However, they are considerably more difficult to build and maintain than Direct Gain systems. To get the best results you should observe the guidelines on the following page.

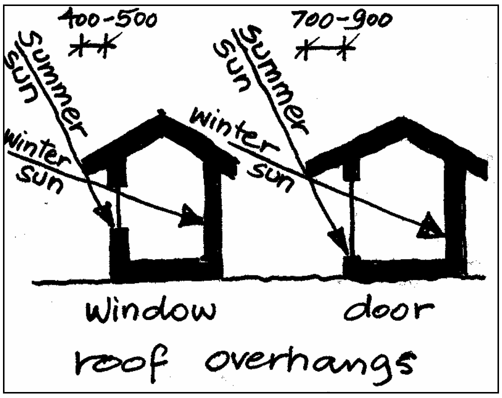




Solar gain checklist

- ❑ Ensure that north windows will allow direct sun onto thermal mass for six hours on a sunny winter's day.
- ❑ Given the right combination of insulation and thermal mass, the area of north-facing glazing should be about 10-20% of the house's floor area – you need to balance the rate of heat loss (dependent on insulation) with thermal mass and local climate.
- ❑ Windows on east or west walls would ideally be 2–5 % of total floor area. You may wish to increase exposure to the east for an early-morning warm-up.
- ❑ Glazing more than 30% of the total wall area is likely to result in excessive winter heat loss and summer overheating, depending on orientation and shading.
- ❑ Double glazing, judiciously used, will improve thermal performance in both winter and summer. There are many options for glazing types, and the Window Association of NZ can help you choose.
- ❑ On a south wall, windows should be the minimum necessary for adequate ventilation and light. The Building Code requires windows to be at least 10% of a room's floor area for daylighting, with at least 5% openable for ventilation. Consider the use of clerestory windows (above the roofline) to bring sun and light into south-facing rooms.
- ❑ For a complex house design, or on a south-facing slope, consider a mix of passive solar systems, using direct, indirect and isolated heat gain where each is appropriate.
- ❑ Eaves or other overhangs prevent overheating by the high summer sun through north-facing windows. In a 2.4m-high wall, the average window works well with a 400-500mm overhang, while glass doors require 700-900mm depending on wall height and orientation.
- ❑ Overhangs are not practical on west-facing walls, where the hot late-afternoon sun is very low in the sky. Here, external shading by trees or a pergola is more effective.
- ❑ Be very careful with the design of a conservatory. It is likely to overheat in summer unless you build in ventilation and shade, and on winter nights it could leak heat massively if it cannot be sealed off from the rest of the house. The value of a conservatory is in the quality of winter living space it offers. Ensure that it is thermally efficient, not a thermal drain.





Storing heat from the sun

Thermal mass

Some materials can store large amounts of heat energy. They have a high thermal mass. Examples are water, and concrete or earth floors (rather than timber). A dark surface (e.g. paint, tiles, slate) will help the absorption of heat into the thermal mass.

Buildings with little thermal mass rely on direct sunlight and warm air to achieve comfort. Air is a relatively inefficient heat store, so once the sun is gone and the air cools down, you may need back-up heating to maintain the same level of comfort. If your floor and walls are cold you need a higher air temperature to achieve the same comfort level. Boosting the air temperature in this way costs more and results in dry stale air.

It is healthier and more economical to allow a lower air temperature and achieve the same feeling of warmth from the heat radiated by warm building surfaces.

Solar heat storage checklist

- ❑ Choose or create site conditions suitable for a solid concrete floor for solar heat storage. The floor offers the best opportunity for thermal and economic performance.
- ❑ Too much thermal mass may slow down the morning's heating up, while too little mass does not store sufficient energy, so choose the correct size of thermal mass. It is possible to calculate your requirement exactly by balancing it with the solar gain and insulation of the house. Alternatively you can use the rules-of-thumb that follow.
- ❑ A concrete floor slab should be about 100mm thick, exposed to direct winter sunlight, dark in colour, and insulated, especially at the perimeter, where most heat loss occurs.
- ❑ A masonry wall (e.g. brick, concrete block) should be 100 to 150mm thick, and insulated on the outside.
- ❑ Avoid covering up thermal mass floors with carpet because it reduces the rate of heat absorption. In places where you will be sitting with your feet on the floor you can use rugs for comfort.
- ❑ Avoid air cavities in thermal mass (e.g. fill concrete block cavities).
- ❑ Avoid thermal mass walls in shady areas unless they are well insulated. They will lose too much heat to the outside, without giving the benefit of absorbing the sun's heat.
- ❑ Internal thermal mass walls are better than external thermal mass walls as they don't lose heat to the outside. However, external walls will usually get more sun and offer the most practical solution.
- ❑ A thermal wall of half height will offer some thermal storage while still allowing a view.
- ❑ You can make a thermal mass wall into a feature wall. Build it with ornamental stone, artistic earth, patterned bricks, etc.

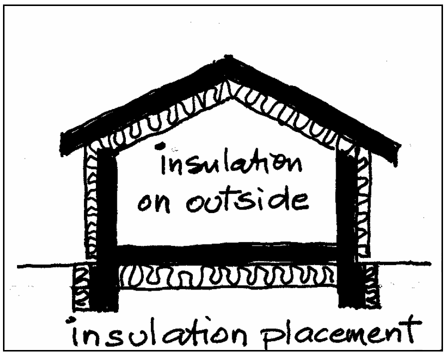
Keeping the heat inside

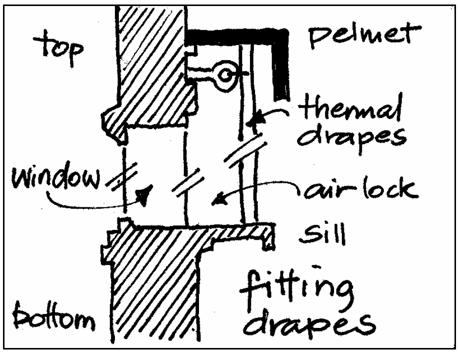
Insulation

You can protect against unwanted heat loss and gain by designing an envelope of insulation around your house. Insulation will slow down the heat loss in winter and keep the house cooler in summer. It is a key ingredient of energy-efficient design.

'R-value' is the measure of the insulating effectiveness of a material or structure: the higher the R-value, the more it resists the flow of heat through it. Generally the R-value of a part of a building (e.g. a wall or window) is lower than the R-value of the insulating material contained in it, because of thermal bridging.

'Thermal bridging' refers to the ways heat can leak through the thermal envelope, rather like holes in a bucket of water. In a timber-framed wall, thermal bridging occurs when the framing has a lower R-value than the insulating material in the cavities, or where there are gaps between the insulation and the framing. In a ceiling, thermal bridging can occur through holes cut for recessed downlights, through gaps in the insulation due to poor installation, or through the joists.





Insulation checklist

- ❑ Use at least R3.6 insulation for the ceiling, preferably covering the ceiling joists, and allow for an air gap of at least 25mm to the underside of the roof underlay for ventilation.
- ❑ Use at least R2.6 insulation for the walls, and fill all wall cavities with insulation, including the small cavities at the corners.
- ❑ For suspended timber floors, insulate with 150mm of joist-cavity insulation, lined underneath with tempered hardboard or fibre-cement board. Draped foil is a cost-effective alternative but it is susceptible to being torn by the wind, and it becomes dangerous if it touches exposed electrical cables. If the sub-floor ventilation is inadequate or the ground is damp, cover the whole ground with a polyethylene sheet taped to the piles and foundation wall.
- ❑ Insulate under a new concrete floor slab with 60mm of expanded polystyrene, 100 mm of loose compacted pumice, aerated concrete, or similar, protected by a damp-proof membrane. Remember that most heat loss occurs at the perimeter and around the footing.

- ❑ Design floor, wall and ceiling details for good thermal performance. Don't forget to insulate around the edges of a floor slab. Consider junction points as possible heat loss areas.
- ❑ In a particularly cold shady location insulate to a higher R-value.
- ❑ Careful installation, avoiding gaps, compression, and thermal bridging, is vital. A 4mm gap can result in a 40% loss of R-value.
- ❑ Using recessed downlights which require large insulation clearances will seriously compromise ceiling insulation. Either use pendant lighting or specify downlights classed as CA-type – insulation can be installed in contact with these (but not over them).
- ❑ Most heat loss occurs through windows. Double glazing reduces condensation, mould growth and noise, as well as heat loss. Wooden frames leak less heat than aluminium, and thermally-broken aluminium frames leak less heat than unbroken.
- ❑ Avoid too much window area and use drapes closely fitted at the pelmet, sill and jambs to restrict air flow around the edges.
- ❑ Apply additional night insulation where necessary – for example where a conservatory opens into a living area.
- ❑ You can calculate the heat loss through your building envelope and balance it with solar gains and the efficiency of your heating system (see BRANZ's ALF (*Annual Loss Factor Method)* available through www.branz.co.nz).

  The *Insulation* chapter of these guidelines provides more information.

Moving the heat around

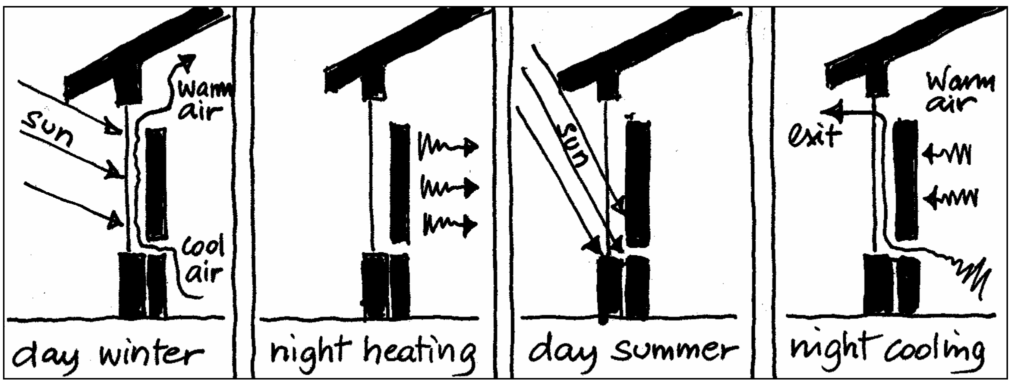
Air and surface temperatures, temperature stack effect and thermal chimney

Warm air in a house rises, creating a temperature stack effect, with layers of higher temperature at the top and colder temperature at the bottom.

A **thermal chimney**, the traditional equivalent of mechanical ventilation, applies these principles to your advantage. It draws cool air down from the south rooms of the house in summer, and in winter it draws warm air up from the rooms on the north side.

Temperature checklist

- ❑ Direct the sun's heat to the areas of the house where it is most needed. It is not necessary or economical to heat all rooms to the same temperature. Design for the sun to heat floors at lower levels of the house so that the air can rise naturally to higher living areas.
- ❑ Think through the way heated air will travel from the ground floor to a mezzanine or first floor; and also from the high wind pressure side of the house to the low-pressure side.
- ❑ Consider how you will control natural air circulation loops using vents, hatches, internal windows, doors, ducts or stairwells.
- ❑ With high ceilings use reversible ceiling fans to overcome the temperature stack effect by pushing warm air down in winter but drawing it up in summer.
- ❑ Avoid glass ceilings or skylights. They tend to overheat in summer and lose heat badly in winter. Vertical windows like clerestories offer better performance, because they let in more of the low-angled winter sun than the unwanted summer sun. If you do need a skylight or light tube, fit it with ventilation, shading and double glazing to improve its thermal performance. If the R-value of the skylight or light tube is significantly less than that of the roof it is part of, consider installing a close-fitting blind or shutter to reduce heat loss at night.
- ❑ If you need a back-up heating source, locate it near the centre of the house and direct its heat into rooms that have no direct access to the sun.
- ❑ A thermo-siphoning collector panel (see sketches below) applies the thermal chimney effect to generate heat-balancing convection and radiation in a window space. It is only applicable where you don't want light or a view.

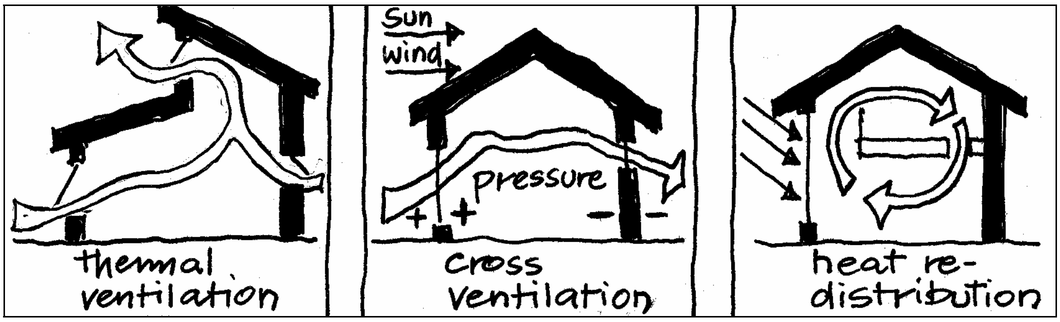


Refreshing the air

Ventilation

The healthy and efficient way to stay warm indoors is to receive radiant heat from a good thermal mass, sustained with effective insulation. Trying to maintain comfort just by holding warm air inside can be counter-productive. Warm air is not an efficient heat store, and if you seal it in too effectively it may become stuffy and polluted.

A successful passive solar design will allow sufficient controlled ventilation to maintain good air quality and humidity levels. You should minimise draughty cracks, but design for the air volume of the house to be exchanged naturally once an hour. The following rules of thumb should achieve this in normal conditions



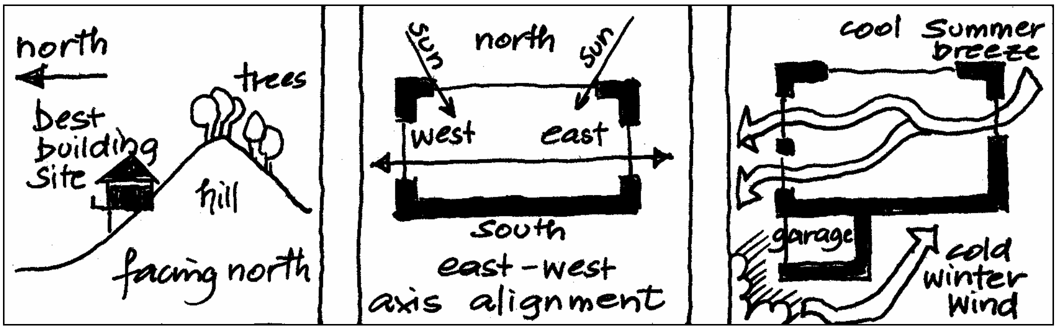
Ventilation checklist

- ❑ Opening windows and doors should make up at least 5% of external wall areas to provide for ventilation.
- ❑ Ventilation openings for internal walls need be only half the above percentages.
- ❑ For wind-effect (cross) ventilation, the breeze path should be less than 15 metres, there should be no more than one interior door or window in the path, and the inlet and outlet openings should each be at least 1 m^2 in area.
- ❑ For stack-effect ventilation, the outlet opening should be at least 3 metres higher than the inlet.
- ❑ To reduce condensation on windows, use double glazing or joinery with permanent or manually controlled ventilation built in.
- ❑ Moisture produced in kitchens and bathrooms needs to be vented to the outside to prevent a build up of moisture in the air. Use rangehoods and bathroom extractors, and dry clothes outside if possible. If you use a clothes dryer have it vented to outside. Don't use unvented gas heaters.
- ❑ Consider thermostatically controlled ventilation for living areas.
- ❑ If all else fails, consider the use of a heat-exchange ventilation system to warm incoming air. Simply transferring air from the ceiling cavity will not provide heat in the evening or on a cloudy day in winter, and will require filters that need to be serviced.

Laying out the house for the sun

Location, orientation, room layout

The orientation and location of the house are important. Passive solar design works best with the house orientated along an east-west axis so that more wall area is exposed to the sun. The ideal site would be a north-facing slope. You also need to plan the layout of rooms within the house so that they make the best use of the sun for their particular activities.



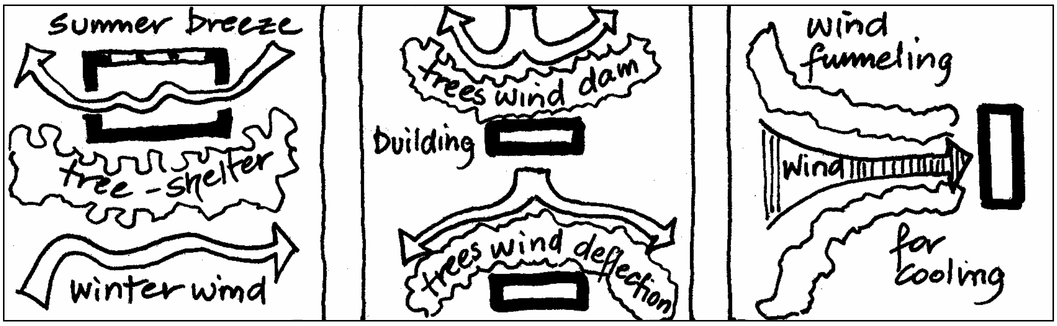
House layout checklist

- ❑ Check how much sun your building site gets. It is harder to design for the sun on south facing slopes, areas exposed to winter winds, and low areas where cold air settles.
- ❑ Work out the path of the sun and plot the shadow patterns of trees and other obstructions on the site. Remember that the sun's path in winter is much shorter and lower than its summer path. Midday sun in winter is about 30 degrees above the horizontal in Waitakere (see EECA's Energywise website).
- ❑ Think about the local microclimate, especially the direction, strength, and frequency of prevailing winds, as this will affect your heating performance. Winds may be buffered or funnelled by your local ridges and valleys. Wind strength is highest at a saddle in a ridge.
- ❑ Design the house on an east-west axis so that you have a long north wall to catch plenty of sun. The ratio of north to east should be at least 1:1.5.
- ❑ The north wall should have the most windows.
- ❑ The east side should also have plenty of windows for an early morning warm-up.
- ❑ On the west side you should reduce the window area or use pergolas or trees to avoid late afternoon overheating.
- ❑ Although people like to have sun in every room of the house, think about how you will use different rooms during the course of the day. You may place the kitchen/breakfast area at the east end to catch early morning sun; living areas and family rooms to the north; lounge/dining at the west for afternoon and evening light; and service rooms and garage to the south. Bedrooms need some winter sun to dry out the moisture generated at night.

Using shade and breezes

Site planning and landscaping

Passive solar design is most effective if the site is laid out and planted to provide shelter from the excesses of the climate. Pergolas, deciduous trees and vines can offer shade in summer but allow the sun's warmth in winter.



Site planning checklist

- ❑ Use existing natural elements, and take advantage of the varying characteristics of shrubs and trees, to modify the microclimate of your site.
- ❑ Plant deciduous trees to the north to give shade in summer and sun in winter.
- ❑ Consider the timing of the leaf season to coincide with the heating season, and also the density of branches and how that may affect sun and wind shelter.
- ❑ Select and locate plants carefully and consider the shadow that will be cast when the tree reaches its full height and canopy spread.
- ❑ Avoid a building shape where the north side is shaded by other walls between 9 and 3 in winter..
- ❑ Protect the house from cold south-westerly winds, but open it up to the cooling effect of the warmer north-easterlies. These are Auckland's prevailing winds, but check how local hills and vegetation may change the prevailing wind for your site.
- ❑ Cluster evergreens to the south of the house for year-round wind shelter. A garage, which doesn't need sun, may also offer wind protection from the south.
- ❑ A diffusing screen (like a hedge) will give better wind shelter than a solid one like a wall, which causes turbulence and gusting.
- ❑ Create outdoor areas that you can choose to be in for different wind directions. Aim for a choice of shade in summer and sun in winter.
- ❑ Think about glare and reflected heat from sealed outside surfaces like driveways. Can the sealed area be reduced? Would the surface cooling effect of a pond or moist vegetation help?
- ❑ If you have solar water heating or electricity generation, make sure they will always have full sun.
- ❑ Base your landscaping plan on good design principles and a respect for your local ecology (see *Native to the West,* Waitakere City Council, listed in references).

Living with passive solar design

Behaviour patterns

Passive solar design will work best if you understand it and make sure your patterns of behaviour take full advantage of what it offers. Once the sun has gone down, close doors and windows and draw the curtains. Once the surfaces and air in a conservatory begin to cool down, close the door to keep the heat in the living areas. Learn to control ventilation to move the heat throughout the house.

The installation of automatic controls such as light, temperature and moisture sensors can help, but there is a commonsense balance between healthy living connected to the natural elements and the comfort of sophisticated electronic technology. The human body is brilliantly designed to cope with a range of temperatures and there are always simple healthy solutions like putting on a warm jumper when feeling cold.

Further information

Advice at the Waitakere City Council:

Phone the call centre (09) 839 0400
Ask for: Eco Design Advisor
Building Consents
Duty Planner

In print

Your Home Technical Manual, Australian Government. Comprehensive printed resource, much of it relevant to New Zealand, particularly the 'Temperate' and 'Cool Temperate' sections.

PAS 4244:2003 *Insulation of lightweight-framed and solid-timber houses*, Standards New Zealand, publicly available specification.

BRANZ House Insulation Guide (3rd Edition). Available through BRANZ www.branz.co.nz. This reference provides New Zealand's most comprehensive guide to wall, window, ceiling and floor insulation.

Native to the West: A guide for planting and restoring the nature of Waitakere City. Waitakere City Council.

On the web

Smarterhomes, http://www.smarterhomes.org.nz is a mine of up-to-date and independent information. Designed for the general public, it's easy to use, has case studies, and includes features such as Homesmarts, a calculator you can use to find information relevant to your needs or simply to run a home-health check.

If there are questions you can't find answers to on Smarterhomes, www.level.org.nz goes into more depth and is aimed at the design and building industries, with drawings and links to Building Code compliance documents.

Annual Loss Factor Method – Aid to the Thermal Design of Buildings – ALF software (BRANZ – Building Research Association of New Zealand – www.branz.co.nz)

EECA Energywise website, www.energywise.org.nz

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