SUSTAINABILITY FACT SHEET

BRANZ

PASSIVE SOLAR DESIGN

Guidelines for Inclusion in New Zealand Homes

Introduction

The aim of this factsheet is to provide an overview of high performance passive solar design for new homes. The emphasis is on practical, compact and comfortable designs that are easy to build, use and maintain. The requirements and benchmarks suggested in this guide are well above the thermal insulation requirements of the New Zealand Building Code, which are a minimum and rarely result in high-performing passive solar homes.

New Zealand is fortunate in that it has, by international standards, a very mild climate coupled with a good number of sunshine hours. BRANZ and other research has shown that, for the majority of New Zealand, well integrated passive solar home design results in keeping homes at comfortable temperatures of between 18°C and 25°C, with minimal (or no) costs year round.

This factsheet is the result of a BRANZ search for robust technologies that can be applied to houses, which are less common yet provide significant environmental benefits. It supports two other factsheets – on grid-tied photovoltaics and Trombe walls. If you would like more information on the process applied or the technologies explored, see Supporting Information.

A glossary of terms is provided at the end of this factsheet.

What is passive solar design?

Passive solar buildings are designed to keep occupants at a comfortable temperature using the home's physical structure and site conditions alone, requiring little or no purchased energy for heating, cooling and ventilation. Although the specific design approach to passive homes may differ, its core elements – good solar management, high levels of insulation, well controlled ventilation and the careful use of massive (high mass) materials – are common to all. It is also about simplicity and robustness – typically, the designs have few moving parts, require minimal maintenance and have no mechanical systems.

This guide examines key design aspects for new houses in New Zealand, by outlining useful strategies for the principal components: the site and building placement, building layout, insulation, glazing, shading, thermal mass and ventilation. These inter-related components should be integrated, to ensure the house performs well all year round – not just during inclement weather but also during summertime peaks and shoulder seasons. The earlier these aspects are addressed, the simpler and cheaper it will be for them to be incorporated and the more opportunities there will be for them to benefit other design issues, such as weathertightness, access, security, indoor-outdoor flow, privacy, durability and aesthetics.

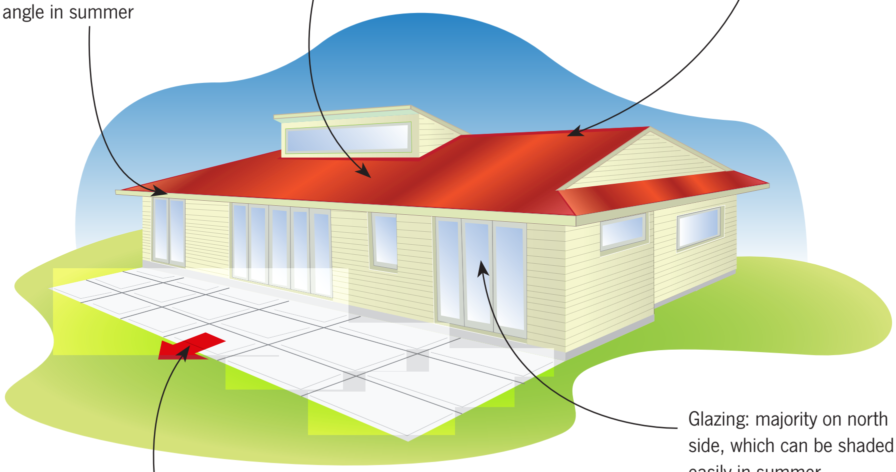


Figure 1: Key design concepts for a higher performing passive solar design

Building site and building placement

Key concepts: orientation; climate; use of 3D design tools for site analysis.

When planning a building, the orientation of the site will influence the design. A house should be located to both avoid shading from other structures and plants and, in turn, not shade the neighbours, wherever it is on the section. If the site has an east-west alignment, it should be wide enough to accommodate a north-facing outdoor area. If the site has a north-south alignment, then the house will probably not have sufficient exposure for northern sun.

It is critical that the site where the house is going to be placed has good solar access. If the site hasn't got solar access for at least 75% of daily sunshine hours in the area concerned, then this has implications for not only the thermal effectiveness of the house, but also occupant wellbeing, running costs, day-lighting, durability of the building components, and so on. Ideally, building sites should be chosen where sun access is guaranteed for the lifetime of the building, such as when the north side of the section is: bounded by a road; adjacent to a park, golf course, or river; or, just well sized with low foliage. Strategies for dealing with sites with a lower than 75% solar exposure are overviewed in the last section 'Sites with poor solar access'.

The design needs to consider the specific micro-climate. The micro-climate of the site itself results from substantial vegetation, landscaping, neighbouring influences and other causes. The better

this is understood, the better the house can be designed to take advantage of it or protect against it, as necessary.

SketchUp, a free and easy-to-use 3D design tool, can be used to optimise the placement of the planned house. This design tool provides accurate shading and sun-casting information for any day or time of the year, so the user can quickly determine the site specifics. This means that shading impacts from existing and future landscaping, topography and neighbouring buildings can easily be examined.

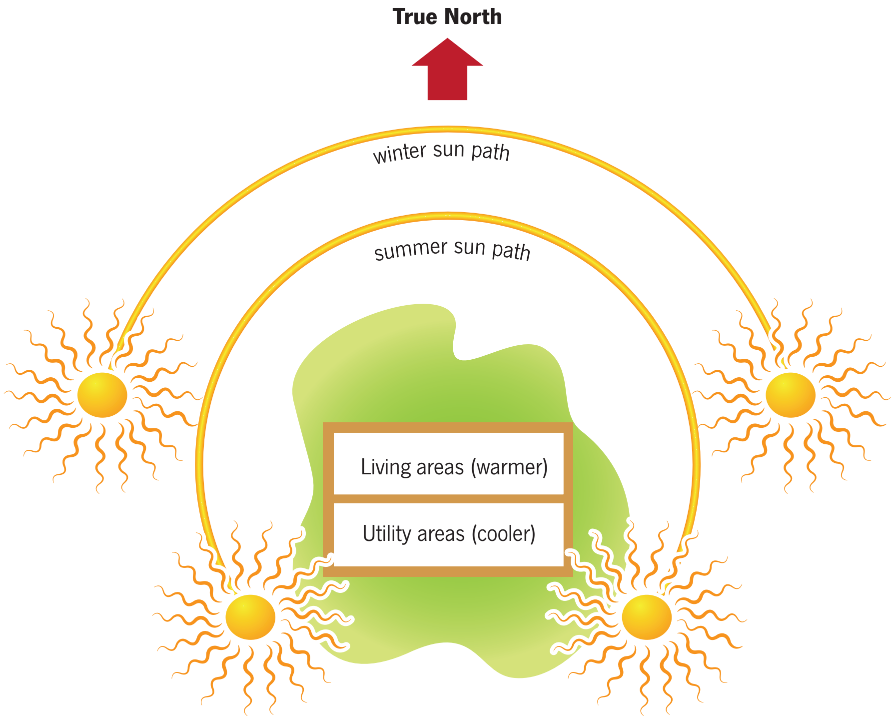
Ideally, all the areas that are used extensively within a home should face true north or within ±20 degrees of north for maximum solar gain and also to simplify the shading strategies. However, having a house with a long north wall is sometimes not physically practical and other site issues – such as views, privacy and noise – have to be factored in.

Building layout

Key concepts: building footprint; room placement; outdoor area placement.

Internally, as many living areas as possible should be north-facing. During winter, they should benefit from the low solar aspect, while in the warmer months they should be excluded from excessive solar gain by the use of outdoor shading devices.

Although the most efficient building footprint is the simple rectangular form with a ratio of about 1:1.4, where the longer axis of the house is oriented east-west, you can still achieve a highly effective design using variants of this. Ideally, the design should be kept simple, ensuring that the north-facing exposure is maximised and that the number of thermal weak points, in the form of corners, is minimised. The design should allow for reasonable cross-flow ventilation to occur across the width of the building, with few impediments.



Note that solar orientation has to be considered alongside other factors such as noise, views, privacy, and access.

Figure 2: Room placement for passive heating.

East-facing rooms are best suited for bedrooms, kitchens and breakfast areas, and for catching the early morning sun. These rooms have good morning light and will be cooler in the late afternoon. West-facing rooms are best suited for living areas, which the occupants can use in the early evening. These rooms are prone to overheat in the late afternoon for much of the year but have good afternoon daylight. South-facing rooms are best for those spaces where people spend less time – garages, laundries, transition areas, and toilets. These rooms need lower levels of daylight compared to other areas, and so are less suitable for general living spaces, depending on the time of year. Outdoor spaces, such as barbeque areas, patios, decks and terraces, are generally best suited to the north- or western-facing areas, but should be shaded in the summer months and exposed in the cooler months.

Insulation

Key concepts: thermal envelope; high importance in terms of good design; target R values.

Specifying high levels of insulation for the thermal envelope is a cornerstone of passive solar design. The thermal envelope is the physical division between the conditioned (heated and cooled) zones of the house and the unconditioned outside (see Figure 3). High levels of insulation are the key to keeping the house both warm in the winter and cool in the summer. Garages are almost always out of the thermal envelope – as garage doors are difficult to insulate well.

Thermal insulation must be carefully installed. Only by ensuring that the insulation is well fitted – i.e. snug fitting, continuous for the whole envelope, and uniform – will the installed insulation meet its rated performance. BRANZ has shown that the effectiveness of insulation reduces massively once gaps, folds, and compression are introduced. One of the best guides for installers of insulation is NZS 4246:2006 *Energy efficiency – Installing insulation in residential buildings* (see Supporting Information).

Although the levels of insulation required to comply with the Building Code have risen over the years, these are a minimum, and a well designed passive solar house will have higher insulation levels than those specified. To achieve zero, or near zero, space heating requirements, the following insulation targets (measured in construction R values) should be achieved, in conjunction with the other passive solar aspects. The lower R values are for the warmer regions.

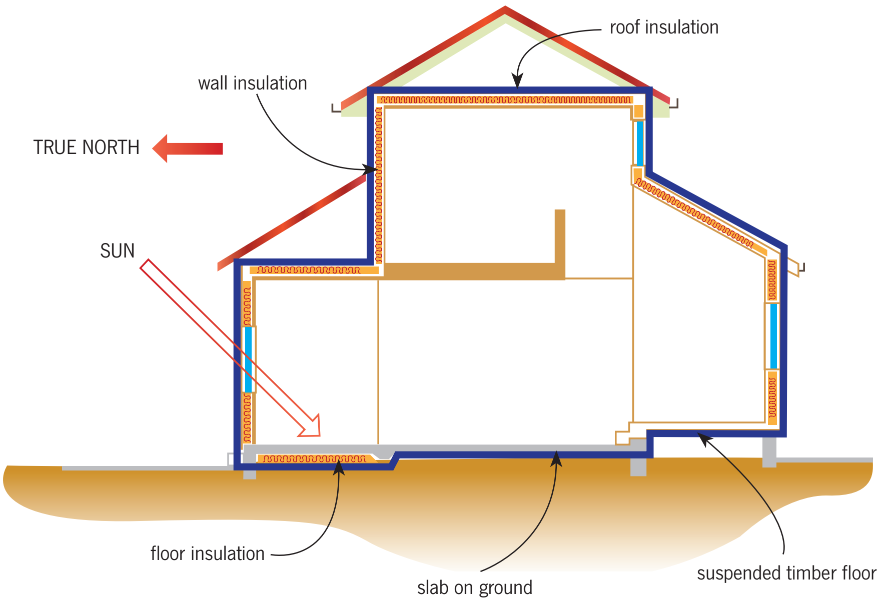


Figure 3: Cross section of house showing the 'thermal envelope' boundary line in blue.

ROOF: about R 4.6 to R 5.5 with the colder climates aiming for the higher options.

WALLS: about R 3.6 for low mass construction (for example, all timber) and R 3.0 for high mass construction (for example, concrete floors and walls)

FLOOR: either fully insulated concrete slab that has a continuous horizontal insulation under-pad (pod and raft style concrete floors don't have this) with perimeter insulation; OR timber floor of about R 3.0 (depending on construction and product). For pole houses, the insulation levels should be at least the same level as the walls.

WINDOWS: about R 0.4 (for example, thermally broken, aluminium frames with low-e glazing) to 0.53.

The specific construction R values for your particular design depend on your goals and require hourly thermal simulation, using a computer program such as AccuRate, EcoDesigner or SUNREL (see Supporting Information). These simulation programs provide detailed information on the likely comfort levels of each room year round, and show any requirements for space conditioning.

Glazing

Key concepts: shading by orientation strategies; effectiveness of different types; using a 3D model to help.

Glazing plays a multitude of roles in a home, but its placement, size and thermal properties are the critical factors for high-performing passive homes. Careful design will ensure that its thermal positives are maximised, and are balanced with its other properties, such as its connection to the outside, views, shading, daylight, etc. BRANZ Bulletin 471 *Insulating Glass Units* provides detailed information on some of these other properties (see Supporting Information).

The placement and sizing of glazing – whether in the form of windows or glazed doors – needs careful consideration and will be influenced by the amount of thermal mass contained within the internal building materials. (Typically, thermal mass in homes is provided by exposing the concrete floor.) Larger glazed areas – especially north facing – are more suited to homes with higher thermal mass. Glazing orientated north can be moderately large in proportion to wall size, as it is by far the most useful for collecting solar energy and is easy to shade just using fixed overhangs during the summer. If there is good solar access and the concrete floors are exposed, the north facing windows should be 10% to 15% of the home's total floor area; however, if the floors are timber, then the north-facing windows should be closer to 10%. If the solar access is poor, the north-facing windows should be less than 8% of the home's total floor area.

Glazing that faces east, west or south should be far smaller and is mainly there to meet daylight/view requirements. This glazing is usually a net heat loser in the winter-time – dependent on the climate and the heating schedule. East- and west-facing glazing can also cause problems with glare. The south- and west-facing windows should be less than 3% of the home's total floor area ideally and be there more for views, cooling cross-flow breezes and daylight. East-facing windows should be reasonably small – less than 5% of the homes total floor area. Skylights are good for getting natural light into deep plan shapes (i.e. where the exterior is far away from the furthest point) but suffer from high heat loss during cold nights and overheating during the summertime. Ideally, they should be kept as small as possible, and be double-glazed with an R value of 0.4 or greater.

In terms of thermal design, glazing can be simplified into two components: the framing material and the glass unit. The framing material's thermal conductivity affects the whole window's thermal performance; the smaller the frame the more significant that influence is. Good passive homes should have thermally broken aluminium frames as a minimum, to ensure condensation build-up and thermal losses are minimised. Higher performance timber and uPVC frames should also be considered if the budget allows.

Low-quality double glazing, comprising of an aluminium frame without a 'thermal break' between the internal and external parts of the frame, is being specified in almost all new homes in New Zealand. Its thermal performance can be greatly enhanced by substituting thermally broken frames and a low-e coating glazing, increasing its insulation value by 65% (old R = 0.26 to new R = 0.4). This upgrade significantly increases thermal comfort (as well as vastly reducing the risk of condensation forming on the framing) while reducing whole-house heating energy costs by between 20% and 24% typically. In addition, upgrading the windows in an average house from standard aluminium double glazing will only cost around $4,800 per average house-lot, based on late 2012 figures.

Shading

Key concepts: orientation-specific approaches for external shading; options for internal shading; 3D design tools.

If larger north, east- or west-facing glazed areas are required for views or daylight considerations, then good external shading should be used in conjunction with low solar heat gain coefficient (SHGC) glazing. This is to reduce the overheating from the sun as it rises or drops towards the horizon, throughout the year. East and west glazing is challenging to shade externally due to the lower sun aspect making overhangs and awnings largely ineffective. Internal blinds and louvres are very good for controlling glare, but not very useful for controlling solar heat gains. Movable external shading devices for glazed areas are usually more effective than fixed external shading devices, as they can be adjusted seasonally. Note that even the best advanced glazing films are no match for effective (external) summertime shading.

There are a variety of approaches to external shading of windows. Each approach should be designed to take account of the site-specific incident solar radiation paths at different times of the year (see Table 1). A light-coloured material that allows the air to permeate through – such as 90% shade cloth – is the most effective. No shading is necessary for the south, as the solar gains are not large enough.

Table 1: Preferred external shading type, by orientation.

Orientation	Summertime sun angle	Critical time of day	Best external shading type
Northern	High	Around noon	Fixed or adjustable above window, e.g. eaves; adjustable horizontal roller blinds; retractable awning blind; fixed horizontal louvres with correct blade angles; shade sails.
Eastern/ western	Low	Morning and evening	Fixed and moveable screens and shutters; externally mounted roller blinds and screens close to window; deep pergolas.

Although deciduous vegetation can be used for shading, it is usually not nearly as effective as specifically constructed shading. This is because deciduous trees: have fixed seasons, which may seldom match with the homeowner's shading needs; are inflexible, in terms of their positioning and coverage; and cannot cope with 'unseasonal' weather at all.

Shading upstairs windows is more of a challenge – the options include motorised external blinds (which are expensive), shutters, or controlled shaders. Another alternative is European-style external roller blinds, which are very effective.

Internal shading options, such as blinds, for controlling heat gains should only be considered as a last resort, as they are comparatively less effective. They should be very light in colour, and be able to create a very still air layer between the blind and the window, usually by having well sealed sides. This layer will act as insulation.

To see how various shading devices perform year round, a 3D computer model should be constructed of the house using SketchUp. Season changes can be easily be examined. Ideally, there should be no direct sunlight on internal floor or internal wall surfaces between 10am and 6pm in summertime. Not getting the shading right will mean that overheating is highly likely – so it's very important to adopt a robust shading strategy.

Internal shading devices, such as lined curtains and close-fitting blinds, can be beneficial in passive solar houses, but are more reliant on sensible operation. In winter-time, these internal shading devices have the potential to reduce heat loss by creating a layer of still air between the internal face of the glass and the shading device. In summertime, curtains can reduce overheating by reducing the solar radiation transmitted into the room, to some degree. Their dual roles are overviewed in detail in the Sustainable Energy Authority Info Factsheets from Sustainability Victoria (see Supporting Information).

If internal shading devices are used to reduce winter-time overheating, they should be:

- well fitted, either within the window framing or dropped from a pelmet to create a still airspace between the curtain/blind

- made of a material that has reasonable insulative properties (i.e. not just a light, single layer)
- used as soon as the window's daylight/views are not needed.

Provided these strategies are followed, the winter-time window heat loss can be reduced by up to 20%, compared to an unfitted double-glazed unit.

If internal shading devices are used to reduce summer-time heat loss, they should be:

- as opaque as possible, to minimise solar transmission
- lined curtains, close-fitting blinds, or internal shutters
- used while the window is open
- drawn as soon as there is direct sunlight coming through the window.

Provided these strategies are followed, the summer-time window heat gain can be reduced by between 15 and 35%, compared to an unfitted double-glazed unit.

Thermal mass

Key concepts: main properties and benefits; 'rules of thumb' usefulness; possible thermal modelling tools.

Heavyweight building materials are known as 'thermal mass'. The mass absorbs the sun's heat (even if not directly sunlit) during the day and releases it slowly as the ambient temperature falls at night time. When placed inside an insulated home they moderate the daily temperature swings, reducing the overheating and lowering under-heating. Common heavyweight building materials used in homes are concrete floors. Other materials, such as earth (and derivatives, such as adobe) and enclosed water, are possible. Although largely beneficial, mass construction has to be carefully managed as there is less opportunity to cool the house quickly if it overheats, or heat the house quickly if it gets too cold.

To ensure that a useful amount of mass is provided within the thermal envelope of the house, a sophisticated thermal design tool is needed to model the house. Two possible tools are SUNREL and HERS AccuRate, which will provide a very comprehensive room-by-room examination of hourly internal temperatures over the whole year. Details of these programs are provided in Supporting Information at the end of this guide.

Ideally the thermal mass within the home should have the following properties:

- receive direct sunlight on it in the colder seasons yet be completely shaded in the warmer seasons
- be a darker colour
- be appealing to look at, such as polished concrete or ceramic tile, to reduce risk of covering by occupants
- be proportionate volumetrically, so it is large enough to heat the adjacent spaces
- be contained within a well insulated envelope which can be easily ventilated.

In New Zealand, lightweight houses are those built mainly of timber, for the floors, walls and roof structure. These can almost always benefit from more mass to improve thermal performance, in all climate zones. How much more mass is dependent on: the physical characteristics of the house, the heating schedule and the site's climate. It is very difficult to give 'rules of thumb' for mass levels in houses. However, a polished, 100mm thick, perimeter-insulated concrete floor slab on the north side of the house, which receives direct sunlight, will provide a significant thermal benefit during the colder months in all climate situations. Additionally, if shaded in summer, it will absorb surplus heat and keep the house cool. It will also provide an extremely hardwearing and aesthetically pleasing surface for the owner to enjoy for many decades.

Ventilation

Key concepts: purposes; drivers; best ways of exploiting; limiting overheating using good summertime strategies.

Ventilation in homes has two primary purposes. It is needed to:

- remove pollutants, such as moisture, cooking smells and other odours, from the building's internal environment
- assist in cooling, as part of the passive measures of keeping internal temperatures comfortable.

Ventilation can be either controlled (through openings such as windows or purpose-built vents) or uncontrolled (through unintentional openings such as gaps around windows). Good passive design and construction addresses both types, to ensure that, as much as possible, ventilation is controllable, providing enough fresh air for the health of the occupants yet be able to be sealed off completely against cold weather. In modern houses, air leakage can account for 20% of the space heating energy loss, due to uncontrolled ventilation.

A good passive designed house will be 'built tight and ventilated right'. This means that uncontrolled ventilation through building elements – i.e. around window and door frames, construction joints and service ducts penetrating the thermal envelope – will be avoided. External doors will have seals on all four edges, and service penetrations should be sealed with gaskets or specialist tape. Only in wet areas – such as bathrooms and kitchens – where large quantities of moisture are generated, may it be necessary to rely on mechanical extract systems. Ideally, the overall house design should focus on keeping the shape simple – fewer corners, fewer construction joints and a simple roof profile.

Controlled passive ventilation is air movement driven by one of two processes: stack effect and wind effect. Stack effect is the naturally occurring air movement resulting from the greater buoyancy of warmer air compared to cooler air. The wind effect is generated by the wind-induced pressure differences on the leeward and windward sides of the house.

Stack-effect driven ventilation can best be exploited in the summer by:

- having a vertical ventilation pathway through the house, between the intake and exhaust openings, which is as unobstructed as possible
- ensuring that those intakes and exhausts can be adjusted in size, and completely closed off when necessary
- being able to secure the openings, so that they can be left open while the occupants are away during the day
- in multi-storey homes, ensuring that there is at least a 3 metre height difference between the intake and the exhaust

Wind-effect driven ventilation can be best exploited in the summer by:

- locating openings (whether doors or windows) to exploit summer winds to 'capture' prevailing sea, valley or regular breezes
- allowing for cross-flow ventilation through the shortest axis of the house which is unobstructed by structure as far as possible
- having multiple open pathways to the house and within the house.
- choosing windows with maximum opening areas (e.g. louvres or sliding) for efficiency
- having the exhaust opening larger than the intake opening
- being able to secure the lower windows, so that they can be left open while the occupants are away during the day.

As New Zealand's new homes become more airtight and over-glazed, the risk of summertime overheating in much of the country increases greatly. Overheating – usually defined as having extended periods of indoor temperatures above 25°C – leads to occupants who cannot function well, and can have severe health implications for the very young and old. The groups especially vulnerable to overheating include: infants, elderly or socially isolated people, urban dwellers, and those suffering obesity or chronic disease. This is due to a number of physiological, social and behavioural reasons. However, no one likes to be at an uncomfortable warm or cold temperature for extended periods of time, no matter what the situation.

Overheating is usually a room-specific problem, rather than a whole-house problem – that is, there are often parts of a house which never get overheated while others often do. 'At risk' rooms usually have several of these features: receive considerable direct solar radiation during the afternoon; have very limited provision for external shading of sunlight; are enclosed during the daytime with minimal ventilation; are able to be opened only on one side; and cannot take advantage of any cooling breezes.

Another function of ventilation is to reduce overheating, to: limit solar gains to all but the eastern side of the house; incorporate thermal mass; be highly insulated, use natural ventilation when it's colder outside than in; and make use of night time cooling when possible.

The number one solution to prevent overheating is to prevent sunlight from entering the house at the wrong time of the day during the warmer months. Other good summertime ventilation strategies include:

- reducing the radiant heat by painting the external cladding light colours or using the new heat-rejecting darker paints
- having small, high windows that can be left open all the time
- shading the ground around the building so that cooler breezes are better able to vent the inside
- including larger trees and shrubs in landscaping to create a cooler microclimate.

For more detailed information, see Sustainable Energy Authority's 'Info Factsheets' in Supporting Information, at the end of this document.

Smart active cooling

Key concepts: ceiling fans good backup; benefits over air-conditioning; importance of good specification.

BRANZ research has shown that comfortable indoor summer temperatures can be maintained in all New Zealand locations by combining cooling strategies, such as window shading and good ventilation, in well designed homes. However, maintaining comfortable indoor temperatures requires rational and consistent occupant behaviour, which does not always occur. The advent of climate change adds to the challenge, as it will significantly increase the amount of uncomfortably warm temperatures in the near future (see Table 2). As a result, even very well designed passive homes may need a small amount of active cooling, in the form of a fan or heat pump, in some rooms during the warmer months.

The most at-risk climates include those in Northland, Auckland, Waikato, East Coast, Nelson-Marlborough, Christchurch, and Central Otago, where there are fewer pressure-driven (i.e. wind) ventilation opportunities.

Although many NZ homes will rely on heat pumps for their cooling, ceiling fans can be a very effective alternative and offer several advantages. Compared to heat pumps, ceiling fans are far cheaper to purchase, install, use and maintain. However, their cooling potential is limited to 3°C, which is less than that of heat pumps.

Fans cool by increasing the skin's ability to evaporate perspiration. The faster the flow of air across, the quicker perspiration can occur and the cooler we feel. Consequently, fans should only be used in inhabited rooms as they don't have any impact on air temperature. In well designed NZ homes, the airflow rates provided by well placed ceiling fans should be able to provide the necessary cooling for the hottest days as long as the indoor humidity levels are not close to 100%.

In terms of their design, ceiling fans are now a far cry from their origins, running whisper quiet and being easy on the eye (see Figure 4). In addition, the latest ceiling fans require as little as 4 Watts to power them at their lowest setting and 18 Watts at the highest (approximately 1/100th of the energy used by heat pumps) – yet they provide sufficient air movement for cooling. Fans have another advantage over heat pumps – to work effectively, they don't require the home to be closed off from the outside environment or adjacent rooms. This option enables more open-plan living, which better reflects the way we typically use our homes in the warmer months.

The specification, placement and operation of ceiling fans are very important. Fan airflow energy efficiency is measured in cubic metres/hour/Watt – the higher the better. Look for fans with an airflow efficiency of at least 200m^3/hr/W. Fans should be located immediately above each activity area within a room – this might not be necessarily at the room's centre. Also, ensure that the fan head (i.e. the lowest point of the fan) is at least 2.2m above the floor for safety; ceiling heights may therefore be higher in a passive solar house. Lastly, since fans cool people rather than the air they can be easily linked to occupancy sensors to ensure they are only being used when the room is being occupied.

Table 2: Estimated number of days where maximum outdoor temperatures will exceed 25°C, by year.

Region	Now	2030	2070
Auckland	20	27–31	31–81
Wellington	3	4–7	5–21
Christchurch	26	29–36	32–24
Invercargil	2	2–3	3–11

Figure 4: An example of an energy efficient ceiling fan, the Haiku.

Sites with poor solar access

Where possible, select a site that provides good solar access. In practice, this might not be possible, such as where the north face of the site is narrow, or heavy shading is provided by neighbouring trees in high-density areas. Consequently, compensations have to be made in the form of building features and design strategies.

They can include one, or several, of the following features:

- ensuring that the house is well draught-proofed to minimise heat loss through unwanted air leakage
- keeping the total window area of the home to below 20% of the total floor area
- improving window performance, in the form of insulative drapes, to reduce conductive and convective losses
- raising sill heights and/or incorporating high clerestory windows to accommodate for shading at lower heights, and
- lowering the amount of thermal mass.

Once again, thermally modelling the house to determine the implications and therefore the effectiveness of strategies, both singularly and in combination, will ensure the best cost-comfort figure is reached.

Glossary of terms

R value (m^2°C/W)
A measure of a material's ability to restrict heat flow; the higher the figure the better it insulates. Measured in m^2°C/W.

construction R value (m^2°C/W)
the combination of the R values of the individual components, less the effect of any thermal bridging of the framing.

thermally broken window frame
Where there is a plastic insert between the inside and outside of a metal window frame, to reduce thermal conductance losses from the warmer inside to the colder outside.

watt (W)
A standard measure of power. Used to rate the electricity requirements (or demand) of appliances. A typical heat pump will draw at least 400W, depending on the settings and outdoor temperatures.

Supporting information

These references are specifically chosen to ensure that the designer and user can gain unbiased, independent and relevant information on passive solar design strategies.

1. Jaques, R. 2013. *Uncommon energy technologies in NZ homes.* Conference paper for 4th International ASA Conference, Hong Kong, November 2013.
2. For good passive cooling: www.yourhome.gov.au
3. For a free, easy-to-use visual design/shading tool: www.SketchUp.com
4. SolarView, the tool which examines how accessible your site is for the sun: www.niwa.co.nz; then word-search "solarview".
5. For practical sustainable strategies: www.renew.org.au *Renew magazine*.
6. Computer thermal modelling tools: SUNREL (www.nrel.gov/buildings/sunrel), ArchiCAD EcoDesigner (www.graphisoft.com) and HERS AccuRate, to provide a very detailed energy and comfort assessment. Thermal modelling providers include: www.snughome.co.nz, www.settlement.co.nz and www.righthouse.co.nz.
7. Dengel, A. & Swainson, M. Nov. 2012. *Overheating in new homes: A review of the evidence*. NHBC Foundation.
8. BRANZ Bulletins: #500 *Optimising energy-efficient design of houses*; #471 *Insulating glass units; #450 Solar-control glass selection and installation; #430 Passive ventilation; #540 Solar gain in housing.*
9. NZS 4246:2006 *Energy efficiency – Installing insulation in residential buildings*, provides clear and sound guidance to installers of insulation to ensure that the design thermal performance and thermal durability of the building element is achieved.
10. Sustainable Energy Authority, Victoria (now Sustainability Victoria), Australia, Info Factsheets:
    - *Thermal mass*: www.sustainability.vic.gov.au/resources/documents/thermal_mass.pdf
    - *Windows placement and sizing*: www.sustainability.vic.gov.au/resources/documents/Window_placement.pdf
    - *Window protection*: www.sustainability.vic.gov.au/resources/documents/Window_protection.pdf

This factsheet is part of a BRANZ series on the best performing, home energy-related technologies for the New Zealand situation.