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BULLETIN

DESIGNING TO AVOID HOUSES OVERHEATING

December 2022

- Many new homes can be uncomfortably hot in summer, partly the result of increasing airtightness, design trends for larger windows and a changing climate.
- Calculations show that internal overheating periods in houses may double or more as average global temperatures continue to rise.
- This bulletin gives an overview of passive design options for reducing overheating. It does not consider active (mechanical) ventilation systems.

1 INTRODUCTION

1.0.1 New Zealand is getting warmer – 7 of the past 9 years have been among the warmest in the last century.

1.0.2 The Ministry for the Environment forecasts rising average temperatures for coming decades. The best estimate is an increase of about 1°C by 2040 and 2°C by 2090. Given different scenarios for changes in greenhouse gas emissions and other uncertainties, however, the increases could be as much as 2°C by 2040 and 5°C by 2090. Higher outdoor temperatures may exacerbate overheating issues. (Since internal air temperatures are also influenced by solar heat gain, insulation levels and airtightness, there is not necessarily a one-to-one relationship between exterior and interior temperatures – 1°C rise in ambient temperature can result in more than 1°C rise in internal temperature.)

1.0.3 As the overall climate is getting warmer, the number of days per year when the maximum temperature exceeds 25°C is also forecast to increase. By 2050, the number of hot days in many locations could double from the number today. For Auckland, this could mean an extra month of hot weather each year.

1.0.4 The increase in outdoor temperature is happening in parallel with changes in house construction that increase the risk of internal temperatures rising above 25°C. New homes are becoming:

- more airtight, with better insulation and double glazing
- less likely to always have wide eaves for summer shading
- more extensively glazed compared to older homes.

1.0.5 Overheating has been identified as a growing problem by a number of different BRANZ research projects in the last three decades. The Household Energy End-use Project (HEEP), which ended in 2005, monitored temperatures in 397 houses and found that, in summer, houses were becoming uncomfortably warm. A separate examination of heat pump use in the late 2000s found indications that heat pumps initially bought to heat houses in winter were also being used to cool in summer. Another project (see 2.0.2) modelled free-running temperatures in new builds (with no added heating or cooling) and found many were uncomfortably hot in summer.

1.0.6 The potential for zones within a house to overheat should be assessed early in the design process and the options to reduce the risk discussed with clients. A number of the thermal modelling tools available, often used to ensure a house will be warm, can also be used to assess the risks of zone overheating. Designers and clients can look at the thermal performance and comfort of a design over the course of a year. Small changes, such as increasing insulation levels, exposing mass where the sun shines, changing the orientation of windows and/or reducing their size can have big impacts on the performance of a design at little or no extra cost. Modelling software is readily available for most CAD packages.

1.0.7 Designers have many strategies they can use to moderate indoor temperatures, including house orientation, encouraging passive cross-flow ventilation through interior layout and the design, placement and sizing of windows and doors, use of exterior shade devices and specification of glazing and glazing systems that reduce solar heat gain. (The principles of passive solar design for cooling, properly applied, also work in with winter comfort. Designing to prevent overheating must also consider the ability for the sun to get in during winter to warm the house.)

1.0.8 This bulletin gives an overview of passive cooling options for preventing and reducing summer and shoulder-season overheating in New Zealand houses. It does not consider active/mechanical ventilation systems. (These are considered separately in Bulletin 581 *Residential mechanical ventilation systems*.)

1.0.9 Designing a house so it does not overheat not only makes it much more comfortable for the occupants, but it also requires less purchased energy and the associated carbon costs for cooling.

2 PRESENT AND FUTURE OVERHEATING

2.0.1 BRANZ research conducted with a sample of New Zealand houses built during the 1990s found internal temperatures above 25°C – uncomfortably hot in New Zealand terms – for 40% of the period 4pm to 6pm during summer. (Maximum summer temperatures in houses are typically reached late in the afternoon – around 5pm in northern areas to around 6.40pm in the south.)

2.0.2 Another BRANZ study simulated free-running indoor temperatures (with no heating or cooling) for 70 Christchurch house designs consented in 2016. It found that the average house overheated by 412 degree-hours per year. (Degree-hours are obtained by counting and multiplying the number of hours that the internal temperature is above 25°C in a typical year.) Some houses overheated for more than 800 degree-hours per year. A calculation was then done using the design of the Beacon Pathway NOW Home, a home built in 2008 for around the average cost of a new house but very carefully designed to reduce the need for active heating or cooling. The modelling showed that the NOW Home design overheated for just 151 degree-hours. The conclusion was that, while new houses have excessive periods of overheating, this could be reduced considerably and cost-effectively with better design and specification.

2.0.3 The research then took forecasts for long-term increased temperatures and modelled five houses in three locations (Auckland, Hamilton and Christchurch) to find the average estimated overheating period per day in the main living area (Table 1). The overheating increases are considerable for all three centres in 2030 when compared to the current situation and massive in 2080 for Auckland and Hamilton especially.

2.0.4 The evidence is clear that year-round thermal performance needs to be considered carefully in the design of new houses.

Table 1. Average estimated overheating period per day in the main living area for five houses.

Location	Current	2030	2080
Auckland	1 hour 22 minutes	2 hours 12 minutes	4 hours 50 minutes
Hamilton	1 hour 59 minutes	2 hours 37 minutes	5 hours 9 minutes
Christchurch	2 hours 4 minutes	2 hours 23 minutes	3 hours 20 minutes

Source: Jaques, R. (2015). *Measuring our sustainability progress: Benchmarking New Zealand's new detached residential housing stock.* BRANZ Study Report 342. Judgeford, New Zealand: BRANZ Ltd. This is Table 18 in that document.

3 CAUSES OF OVERHEATING

3.0.1 These construction features can lead to overheating:

- Too large an area of unshaded glazing to north, west and east walls. Excessive glazing on west-facing walls is especially problematic because the sunlight comes in at a low angle and late in the day when the house has already heated up. This is difficult to control with shading.
- Lack of effective natural ventilation – in particular, no provision for cross-ventilation. A lack of secure ventilation is also an issue for households where no one is home during the day to keep windows open. Even with secure ventilation, security stays can restrict the size of the opening and thus the amount of ventilation possible.
- Insufficient insulation.
- Lack of thermal mass leading to wider extremes of indoor temperature.

3.0.2 Overheating is not just the result of too much visible light entering windows, since invisible infrared radiation typically makes a greater contribution to overheating.

4 SOLUTIONS FOR OVERHEATING

4.0.1 Designers have a number of options to consider when dealing with the risk of overheating, including:

- eaves and exterior shading devices
- layout and cross-flow or purge ventilation
- stack ventilation (openings at different levels to promote air movement across a space/house)
- windows and glazing options
- insulation and thermal mass.

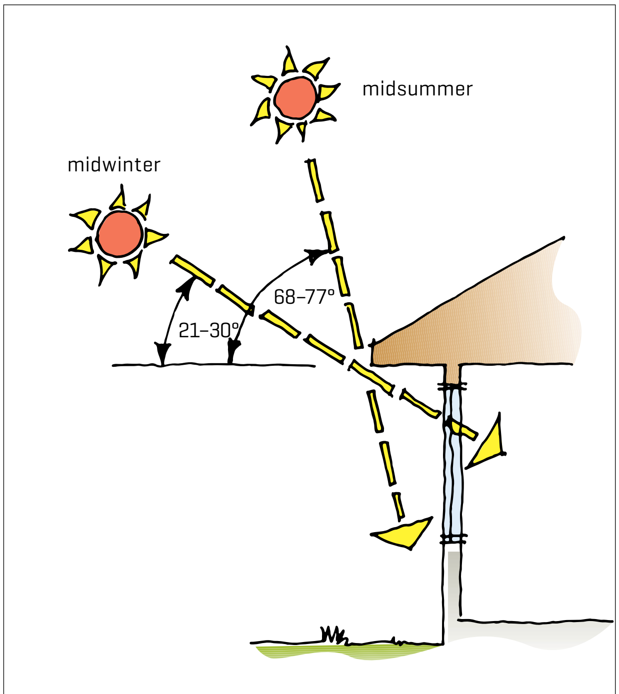
4.0.2 Curtains, blinds and other interior shade devices are good at reducing glare but do little compared to exterior shading to reduce the amount of heat coming into a house through glazing. Interior shade devices must be used in combination with ventilation to have much effect.

4.0.3 Deciduous trees and vines can be useful because they provide summer shade when in full leaf and allow in winter light when they have shed their leaves. They have the drawbacks that they can be slow growing, may grow in unexpected ways, the period in leaf may not match the household's shading needs, they often cannot be repositioned to meet changing needs and leaves can block gutters and drains. Trees should also not be planted too close to the house or buried pipes.

4.1 EAVES AND EXTERNAL SHADE DEVICES

4.1.1 External shading can be the most effective option for reducing the level of summer heat that gets into a house because it can be designed to keep midsummer sun out but allow midwinter sun in. Eaves and shading devices should be designed specifically for the location. The length of New Zealand means that differences in sun angles (Figure 1) do not allow a single optimal one-size-fits-all approach for the whole of the country.

4.1.2 Designers can obtain a sun path diagram (Figure 2) for the site they are working on – for example, from NIWA's online tool Solarview. A sun path diagram takes into account shading of the local topography (excluding trees and structures) and allows you to locate where



Location	Midsummer (22 Dec)	Midwinter (22 June)
Auckland	77°	30°
Hamilton	72°	25°
Christchurch	70°	23°
Dunedin	68°	21°

Figure 1. Midday sun angles for midsummer and midwinter at four locations (for the northern aspect only).

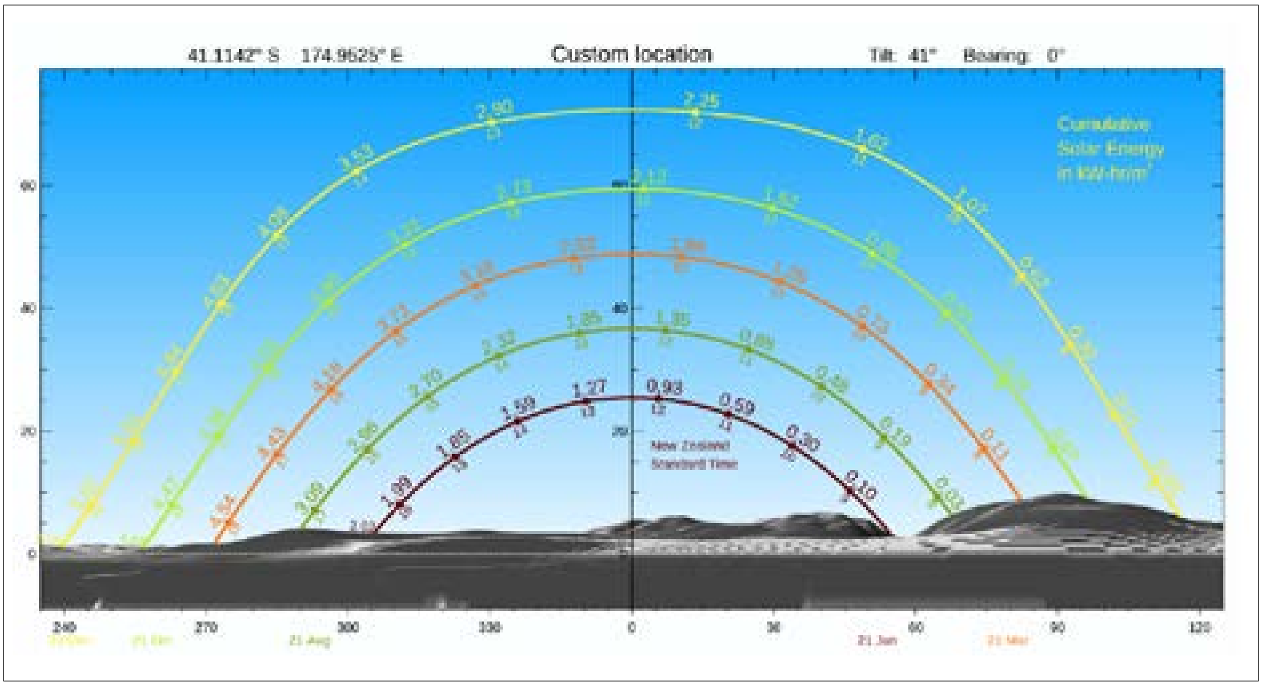


Figure 2. Sample output from NIWA's Solarview tool, showing the changing position of the sun during the day at certain dates through the year.

the sun will be in the sky at any point during the day and throughout the year. This is crucial for designing the appropriate shading devices.

4.1.3 Table 2 uses height and shading factors based on sun path diagrams for four New Zealand cities. This data can be used to design eaves, louvres or similar fixed overhangs on the northern aspect to exclude midday summer sun but allow midday winter sun into the house.

4.1.4 To calculate the depth of the overhang or shading device required (Figure 3), multiply the height (H) from the window sill to the eave by the F_{height} factor (from Table 2) for the specific location – for example, in Auckland, the F_{height} factor is 0.24. The resulting figure (A in Figure 3) is the required depth of the overhang.

4.1.5 Using Auckland as an example, if the distance between the window sill and eave is 2 metres, the calculation is 2.0 x 0.24 = 0.48. Therefore, the eave overhang should be approximately 480 mm horizontally to minimise the impact of the summer sun.

4.1.6 At the same time as calculating the best horizontal overhang dimensions for keeping out summer sun, the dimension for D in Figure 3 can be calculated to ensure the window admits winter sun. The minimum height for D is H x F_{shade}. Again using Auckland, 2.0 x 0.14 = 0.28. The minimum distance between the top of the window and the bottom of the eave overhang or shading device should be 280 mm.

4.1.7 Overhangs such as eaves do not work when the sun is low – where summer morning sun from the east or evening sun from the west is the source of overheating. In these cases, louvred shutters or other devices that can temporarily shade the whole window are required.

4.1.8 These are some other possibilities for external shading:

- Awnings – some can be retracted against the house to allow sunlight into windows.
- Screens and shutters – as with awnings, they can be fixed in place or be movable to allow in more sun.
- Horizontal fixed louvres – these should be correctly angled and spaced to allow midwinter sun. The angle will vary from around 29° in Auckland to around 20° in the lower South Island. The spacing between horizontal fixed louvres is often approximately 75% of the width.
- Porches and verandas – although they may also reduce midwinter sun entry.
- Pergolas with retractable/removable shade sails.

Table 2. Height and shade factors for four New Zealand locations.

Location	F_{height}	F_{shade}
Auckland	0.24	0.14
Wellington	0.32	0.15
Christchurch	0.35	0.15
Dunedin	0.39	0.16

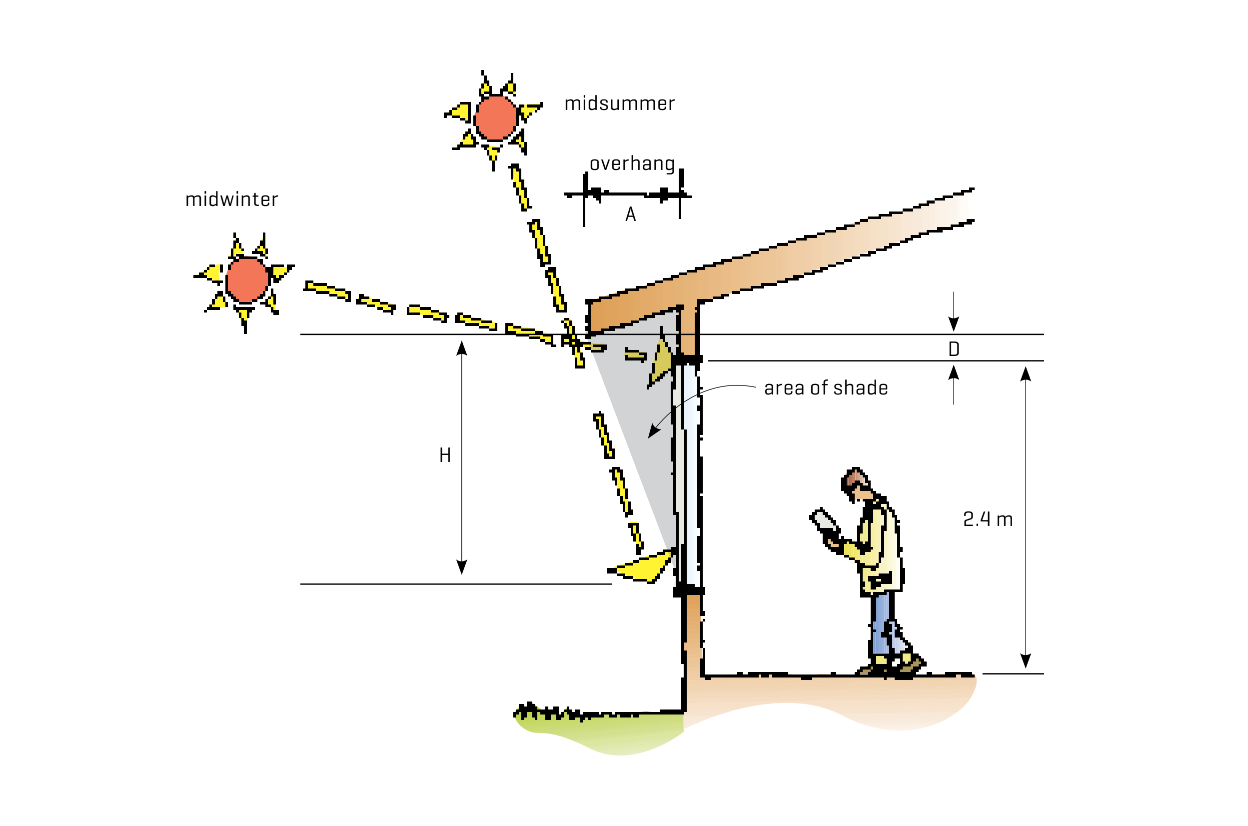


Figure 3. Measures for calculating the required depth for eaves on the northern aspect in a given location.

4.2 LAYOUT AND PASSIVE VENTILATION

4.2.1 Building orientation and layout can be designed to maximise controlled passive ventilation. Having a relatively narrow plan across the prevailing wind direction with the appropriate windows on each side will allow cross-flow air movement across the building. An open floor plan can facilitate through-flow of breezes, but check for the impact this may have on winter heating requirements. Buildings may also be elevated to catch stronger winds.

4.2.2 In some buildings, stack effect ventilation is a good option. Vertical ventilation pathways drive air movement, with cooler fresh air entering from a lower point and warm air released at a higher point – for example, through opening skylights or clerestory windows. Include low-level and high-level opening windows on each side of the building. Depending on the building dimensions, narrow louvre or clerestory windows at a high level can be designed so that they can be left open without posing a security risk.

4.2.3 There is an important social aspect to consider in passive ventilation – it typically requires occupants to open the windows or vents for it to work. It is particularly important to consider safety catches and other devices that will give occupants the confidence to leave windows open during the afternoon or overnight in summer. Where security, air and/or noise pollution is a concern, mechanical ventilation systems may be needed.

4.3 WINDOW AND GLAZING OPTIONS

4.3.1 The location and size of windows has a substantial impact on internal comfort levels. In terms of overheating risks, west-facing walls tend to be most difficult because eaves or other types of over-window shade device will not stop overheating caused by the low-angle sun. The ideal solution is to reduce the area of west-facing glazing. External shutters that temporarily cover the windows are also an option, although, unless automated, their effectiveness relies on occupants opening and closing them.

4.3.2 Considering how much reduction in solar heat gain is required and the effectiveness of different types of solar control materials is measured with the solar heat gain coefficient (SHGC). A window with an SHGC of 0 lets no heat from the sun through, while 1 means no solar heat is blocked. A typical two-pane insulating glass unit (IGU) has an SHGC of 0.8. The SHGC does not necessarily have a direct correlation to the amount of visible light passing through the glazing.

4.3.3 Frames can also have an impact on the SHGC. For example, a black frame on the north side of a house could easily reach a temperature exceeding 50°C in midsummer. Depending on the type and material of the frame, much of this heat will be radiated inside. Whether or not the frame is thermally broken will also have an impact – thermally broken frames can reduce the SHGC of a window. Therefore, consider the U-value (the rate of heat transfer) of the frame and its colour. Lighter-coloured, thermally broken frames can help to reduce overheating inside a home.

4.3.4 When specifying glazing and glazing systems, it is crucial to consider the impact at different times of day and different times of year. A glazing system that reduces the heat entering a home in midsummer will also reduce the heat entering a home in midwinter. This may be acceptable in very warm climates but not in locations that have hot summers but cold winters. In this instance, exterior shading devices that block summer sun but allow winter sun to penetrate are likely to be more appropriate.

4.3.5 Skylights have their own particular challenges, bringing a risk of midsummer overheating and heat loss in midwinter. The glazing of skylights needs to be very carefully considered. In areas with hot summers, openable roof windows can be left open to allow rising warm air to exit. They can be fitted with rain sensors that close the roof window when it starts raining.

4.4 INSULATION AND THERMAL MASS

4.4.1 Thermal insulation is almost always thought about in terms of keeping New Zealand houses warm, but insulation can also play a role in keeping houses cool in summer when a house is properly ventilated and heat gains from glazing are controlled. For example, a high level of insulation in the ceiling can reduce heat radiated from a hot roof through the ceiling into the rooms. (Light exterior paint colours and heat-reflecting paint can also be considered for exterior claddings.) It is crucial to understand that additional insulation or thermal mass must be used in conjunction with exterior shade devices, appropriate glazing and so on – by itself, additional insulation could exacerbate overheating problems.

4.4.2 Thermal mass – for example, using exposed polished concrete floors – is another feature most often thought of in terms of moderating internal temperatures in winter, but it can also play this role in summer if appropriately designed and there is sufficient ventilation (Figure 4). One BRANZ study found that removing carpet from concrete slab floors reduced overheating. Thermal mass absorbs heat from the air during the day, and passive ventilation removes the heat at night once the air cools. However, this requires very careful design and is perhaps the trickiest way to control summertime overheating. For summer cooling, thermal mass needs to be shaded from the summer sun, especially in the middle of the day and the afternoon. Designers also need to take special consideration to ensure the summertime cooling and wintertime heating thermal mass needs don't conflict.

4.4.3 A study involving side-by-side test buildings at Lincoln University – one with high mass concrete walls, one with light timber framing – found that wall thermal mass reduced annual overheating by more than 70% (235 hours). In a follow-up 1-year trial with the same two buildings, the concrete building did not overheat during the trial, while shutters and fans were unable to avoid overheating in the timber building. When the ambient air temperature was 30.0°C, the timber building reached a maximum of 30.9°C. The temperature in the concrete building peaked at 25.8°C.

4.4.4 Building with the type of concrete traditionally used for domestic construction in New Zealand results in a much higher carbon footprint that construction using timber. The trade-off calculation of benefits of using high thermal mass against higher carbon costs is a difficult one to make.

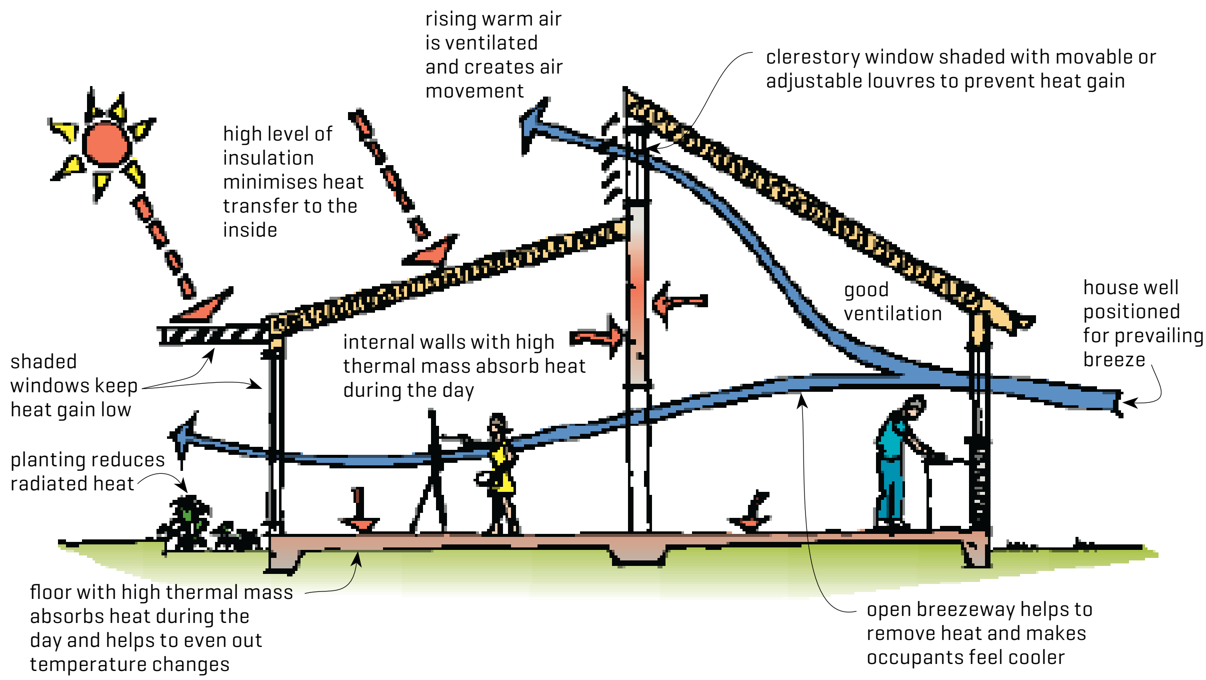


Figure 4. Features of passive design for cooling and to reduce interior heat build-up.

5 MORE INFORMATION

BRANZ RESOURCES

Bulletins

- BU607 *Passive ventilation*
- BU581 *Residential mechanical ventilation systems*
- BU566 *Applied window films*

Study reports

- SR426 *Measuring our sustainability progress: New Zealand's new detached residential housing stock (first update)*
- SR342 *Measuring our sustainability progress: Benchmarking New Zealand's new detached residential housing stock*
- SR116 *Energy efficiency of buildings with heavy walls*
- SR108 *Thermal performance of buildings with heavy walls*
- SR89 *Summertime overheating in New Zealand houses – Influences, risks and mitigation strategies*

ONLINE RESOURCES

- https://environment.govt.nz/facts-and-science/climate-change/climate-change-projections
- www.branz.co.nz/sustainable-building/up-spec/comfortable-temperatures

OTHER RESOURCES

NIWA – solarview.niwa.co.nz

SketchUp – www.sketchup.com

French, L. (2008). *Design and construction features that cause new houses in New Zealand to overheat* (Master's thesis). Victoria University of Wellington, Wellington, New Zealand.

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