BRANZ

House Insulation Guide

6th edition

Acknowledgements

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Preface

The BRANZ *House insulation guide* has been completely updated in this 6th edition, following publication of Building Code Acceptable Solution H1/AS1 and Verification Method H1/VM1 5th edition amendment 1. Note that the tables of construction R-values are now in a separate spreadsheet, which can be accessed on the BRANZ website here.

While this guide can be used to help demonstrate compliance with Building Code clause H1 *Energy efficiency*, its intent and purpose extend far beyond that to helping architects and designers create buildings that are warm, dry and healthy and have performance beyond the Building Code minimums.

From 3 November 2022, anyone using H1/AS1 and/or H1/VM1 to demonstrate compliance with clause H1 in building consent applications can no longer use the 4th edition H1 documents but must use the 5th edition amendment 1.

The new H1/AS1 and H1/VM1 apply to all housing (including medium-density housing, apartment buildings and other multi-unit housing) and buildings other than housing up to 300 m². That is the scope of this guide. While it can provide some useful information for larger buildings, it has not been designed for use with H1/AS2 or H1/VM2 – the documents that apply to buildings greater than 300 m² (other than housing and purely industrial buildings).

The specific requirements of H1/AS1 and H1/VM1 5th edition amendment 1 and the dates when new minimum R-values will be implemented are detailed on the MBIE website here.

Publication of this 6th edition of the *House insulation guide* is part of an extensive package that BRANZ is developing to support industry in building warmer and healthier buildings. Other resources include BRANZ bulletins, the BRANZ calculation method tool and the BRANZ schedule method tool.

Contents

1. Introduction

The BRANZ *House insulation guide* 6th edition helps designers assess the thermal performance for given levels of insulation in common construction options. It can be used to help demonstrate compliance with Building Code clauses H1 *Energy efficiency* and E3 *Internal moisture* and more widely to build warm and healthy buildings.

This edition of the guide has been updated to be used with Acceptable Solution H1/AS1 and Verification Method H1/VM1 5th edition amendment 1. Previous versions of the guide should not be used with the 5th edition H1 documents as some calculation methods and assumptions behind the calculations for slab-on-ground floors and for windows, doors and skylights and curtain walling have changed.

The tables for different floor, wall and roof constructions can be used in two ways:

- To find the construction R-value (the R-value of the built system) for a given level of insulation.
- To find the level of insulation required to achieve a desired construction R-value.

The guide also outlines the generic properties of insulation and provides guidance on good installation practices.

The scope of this guide broadly matches the scope of H1/AS1 and H1/VM1, applying to all housing, and to buildings up to 300 m², although this guide focuses on stand-alone houses and medium-density housing. Not all construction options for apartments are included here.

You can find more details about the specific requirements for insulation in buildings on the Building Performance website of the Ministry of Business, Innovation and Employment (MBIE).

You can find more guidance around the installation of thermal insulation in NZS 4246:2016 *Energy efficiency – Installing bulk thermal insulation in residential buildings*.

OTHER CONSIDERATIONS BEYOND BUILDING CODE COMPLIANCE

Designers working on the thermal envelope and thermal performance of a house must look beyond just achieving Code compliance. Some key areas to be considered include:

- risks of overheating
- moisture management
- thermal bridging and gaps in insulation
- embodied carbon.

RISKS OF OVERHEATING

For many years, Building Code clause H1 and its compliance paths have focused on preventing heat loss. In the 2020s, however, many new homes can be uncomfortably hot in summer, partly the result of design trends for larger windows and a changing climate. By 2050, the number of hot days in many locations could double from the number in 2020. For Auckland, this could mean an extra month of hot weather each year.

There is a particular risk of window location, size and specification contributing to overheating. The minimum thermal performance requirements for windows in H1/AS1 and H1/VM1 5th edition amendment 1 address where heat is lost or gained from glass and/or window frame surfaces after it passes through these materials. It does not address the next most important mechanism of heat flow in windows – the passage of solar radiation through the window, measured by the solar heat gain coefficient (SHGC). Excessive radiative heat flow can lead to houses overheating, which leads to both discomfort for the occupants and increased energy use as heat pumps are increasingly used in cooling mode during hot summers.

Designers using this guide to achieve compliance with clause H1 should also ensure that their design, especially window design and specification, considers the risks of overheating.

Some of the main approaches to reducing the risk of overheating in houses:

- Incorporating external shading devices, including eaves. These can keep midsummer sun out but allow midwinter sun in. Eaves and shading devices should be designed specifically for the location and orientation of the building. Shading is especially important on the northern and western faces of a house.
- Designing for passive ventilation in warmer climates. Allowing cross-flow air movement across the building can be very effective, as can stack effect ventilation, where cooler fresh air enters from a lower point and warm air is released at a higher point.
- Considering the SHGC when specifying windows. It is possible for windows to have the same R-value but a

different SHGC. The SHGC does not necessarily have a direct correlation to the amount of visible light passing through the glazing.

- If skylights are part of the plan, specify openable skylights that will let warm air exit the house.

There are many resources available to help, including BRANZ Bulletin BU656 *Designing to avoid houses overheating*.

MOISTURE MANAGEMENT

As New Zealand houses become more airtight, better insulated and warmer inside the thermal envelope, moisture management becomes more critical. The key issue is to reduce the transfer of moisture from warm indoor living areas – especially wet areas such as kitchens and bathrooms – into cooler wall cavities or roof spaces or roof cavities in skillion roofs. Moisture transported to those areas can result in condensation, mould and potentially rot or corrosion of building materials.

Although it is physically possible for moisture to pass through some building materials, by far the most problematic transfer occurs when moisture is carried by air movement through gaps in and around building materials and elements. A classic example is older recessed downlights, which can allow significant quantities of air and moisture into the roof space (most modern downlights are much better than older ones). Other pathways include through penetrations made for other electrical and plumbing services and around poorly sealed roof access hatches.

The management of internal moisture must be considered holistically in the design of the thermal envelope. This means giving attention to issues of airtightness, ventilation and heating. It is crucial that there is mechanical ventilation in wet areas to carry moist air outside the house. In some circumstances, adding roof ventilation will help make the roof space more resilient to moisture that gets transported there, but there are limits to what can be achieved with this. The best option by far is stopping moisture from getting into the roof space in the first place.

Effective space heating is also a key component in the moisture equation. Warmer air has a higher moisture-carrying capacity. Heating the indoor air lowers the relative humidity and encourages evaporation of moisture from surfaces. This means ventilation will remove more moisture from the building.

THERMAL BRIDGING AND GAPS IN INSULATION

Thermal bridges are materials or elements that are better at conducting heat than other materials around them. Heat flows more easily through them than other materials from the warmer interior of a building to the colder exterior. Houses with lots of thermal bridges are harder to keep warm. Timber framing is a thermal bridge. As the percentage of framing in the wall increases compared to the area of insulation, total wall R-value (a measure of thermal resistance or insulation value) falls.

Research has shown that thermal bridging and gaps in insulation around the building envelope are common in New Zealand houses. A research project funded by the Building Research Levy and carried out by Beacon Pathway assessed 47 new houses under construction to determine the as-built framing content and the extent of thermal bridging in exterior walls. It found that:

- the average percentage of framing in walls was 34% of wall area (range 24–57%)
- most wall panels have framing percentages of 20–50% but some have percentages of 50–100% – smaller panels can have framing as high as 70–100%
- wall cavities with missing insulation account for 3% of the wall area on average (range 0.5–10%).

The uninsulated areas in the thermal envelope are largely the result of construction detailing and work sequencing. Areas such as corners and internal/external wall junctions can become inaccessible after building underlay is installed, yet insulation is generally installed after the underlay is in place.

It is possible for a house to comply with the Building Code and yet still have thermal bridges and uninsulated gaps that will make it less comfortable to live in and require more purchased energy to keep warm. Designing out these weak points in the thermal envelope will bring a significant benefit to the thermal performance of a house.

There are many resources that provide more background details and guidance for better performance, including the PHINZ *High-performance construction details handbook*.

This 6th edition of the *House insulation guide* gives options for higher percentages of framing in walls than earlier editions of the guide.

EMBODIED CARBON

New Zealand has set in law a target to reduce net emissions of greenhouse gases (except methane from plants and animals) to zero by 2050. The greenhouse gas emissions produced by house construction and operation in New Zealand need to fall significantly to help the country achieve this target.

There is currently no requirement in the Building Code for designers to measure the embodied carbon in their house designs or to demonstrate waste minimisation or recovery plans. However, MBIE has flagged that these are being considered for future addition to the Building Code as part of its Building for Climate Change programme.

There are many practical ways to contribute right now to low-carbon construction by specifying insulation products that:

- are made from renewable source materials such as sheep's wool or wood fibre products
- are made partly or wholly from recycled materials
- are from manufacturers who take back unused materials to recycle
- come with an ecolabel such as that from Environmental Choice New Zealand showing that the product has less negative impact on the environment than some others
- come from a manufacturer whose business has an independent assessment showing that it is reducing its carbon emissions such as certification under Toitū net carbonzero
- are manufactured using energy from renewable sources. In New Zealand, over 80% of our electricity is generated from renewable sources, while the figure is vastly lower in many other countries.

You can find more information around embodied energy and carbon footprinting on the BRANZ website.

The BRANZ CO_2RE tool enables users to:

- find out the estimated climate change impact for different types of residential roof, wall and floor constructions
- compare the carbon performance of alternative roof, wall and floor constructions according to a desired minimum construction R-value.

The BRANZ CO_2NSTRUCT tool enables users to:

- find out the embodied greenhouse gas values for a range of construction materials including thermal insulation materials such as glass wool, mineral wool, EPS and XPS polystyrene, polyurethane spray foam and wood fibre board - values are provided up to the factory gate of the manufacturer
- compare the carbon performance of alternative roof, wall and floor constructions according to a desired minimum construction R-value.

2. Statutory requirements

NEW ZEALAND BUILDING CODE

All new building work must comply with the Building Code. For thermal insulation, the relevant clauses are E3 *Internal moisture* and especially H1 *Energy efficiency*. There are many ways of demonstrating compliance, including Acceptable Solutions and Verification Methods.

H1 *ENERGY EFFICIENCY*

The first performance requirement of clause H1 (H1.3.1) is that: "The building envelope enclosing spaces where the temperature or humidity (or both) are modified must be constructed to – (a) provide adequate thermal resistance, and (b) limit uncontrollable airflow."

Adequate thermal resistance is provided by installing insulation under floors, in walls and in roofs and using materials/elements that slow down heat loss such as insulating glass units (IGUs – double or triple glazing) in the windows. Explanations of how to work out how much thermal resistance is required in houses to comply with clause H1 are provided in H1/AS1 and H1/VM1.

From 3 November 2022, anyone using H1/AS1 and/or H1/VM1 for building consent applications can no longer use the 4th edition documents but must use the 5th edition amendment 1.

However, where building consent applications for housing are submitted before 1 May 2023, roof, wall and floor minimum construction R-values can be equivalent to the previous (4th edition) requirements.

All vertical window and door construction in new housing has a two-step increase. The first step is a minimum construction R-value of R0.37 for the whole country from 3 November 2022. After that, the date of the second step varies by climate zone:

- From 1 May 2023, the minimum R-value rises to R0.46 in climate zones 3 and 4 and rises to R0.50 in climate zones 5 and 6.
- From 2 November 2023, the minimum R-value rises to R0.46 in climate zones 1 and 2.

For the period 3 November 2022 to 30 April 2023, skylights in housing will have the same minimum R0.37 requirement as vertical windows and doors. Starting on 1 May 2023, the minimum R-value for skylights in housing will be R0.46 in climate zones 1 and 2, R0.54 in climate zones 3 and 4 and R0.62 in climate zones 5 and 6.

The new minimum R-values apply to all buildings up to 300 m² other than housing from 3 November 2022, with the exception of vertical windows and doors in climate zones 1 and 2. With these, the minimum requirement is R0.37 from 3 November 2022, and R0.46 from 2 November 2023.

H1/AS1 includes two ways of demonstrating compliance – the schedule method and the calculation method. H1/VM1 uses the modelling method.

Designers using the **schedule method** must ensure that each building element (floors, walls, roof and so on) meet or exceed certain minimum construction R-values (Table 1). All doors, including opaque doors, are now subject to the window and door minimum R-values. Previously, there were no R-value requirements for opaque doors and opaque parts of doors.

There are some limits with the schedule method:

- The glazing area can be no more than 30% of the total wall area.
- The combined glazing area on east, south and west-facing walls can be no more than 30% of the total wall area of these walls.
- The skylight area can be no more than 1.5 m² or 1.5% of the total roof area (whichever is greater).
- The opaque door area can be no more than 6 m² or 6% of the total wall area (whichever is greater).

The **calculation method** allows greater flexibility. It compares a building with a reference building (which the schedule method figures are applied to). The whole building must perform at least as well as the reference building, but the insulation level of any individual building element can be above or below the reference building/schedule method figures – higher insulation in one element can be used to compensate for lower insulation in another.

There are some limits with the calculation method:

- The calculation method can only be used where glazing is 40% or less of the total wall area.
- The construction R-value for roofs, walls and floors in the proposed building must be at least 50% of the construction R-value of the corresponding building element in the reference building.
- The calculation method cannot be used to reduce the performance of slab floors, walls or ceilings that have embedded heating systems.

- E3/AS1 also specifies minimum R-values for walls, roofs and ceilings. The calculation method cannot be used to provide lower values than these.

Like the calculation method, the **modelling method** allows more flexibility, with higher insulation in one element being used to compensate for lower insulation in another. Under this method, the energy use of the proposed building design must be shown not to exceed the energy use of the reference building using the computer modelling described in Appendix D in H1/VM1.

There are some limits with the modelling method:

- Where a proposed building includes a heated ceiling, wall or floor, minimum construction R-values apply for that particular element.
- E3/AS1 also specifies minimum R-values for walls, roofs and ceilings. The modelling method cannot be used to provide lower values than these.

The specific minimum required construction R-values vary around the country, with areas of colder climate typically requiring higher construction R-values than warmer locations. There are six climate zones (Table 2). For more detail of the zones, see Appendix C in H1/AS1 and H1/VM1, which includes a map and a table showing which climate zone applies to each territorial authority.

See sections 8-11 for more detail about the specific requirements for floors, walls, roofs, windows and doors.

Table 1. Minimum construction R-values and implementation dates for new building work for housing under the H1/AS1 5th edition amendment 1 schedule method.

Options	Climate zone					
	1	2	3	4	5	6
Roofs						
Current minimum requirements	R2.9		R2.9/3.3		R3.3	
From 1 May 2023	R6.6↑					
Walls						
Current minimum requirements	R1.9		R1.9/2.0		R2.0	
From 1 May 2023	R2.0↑					
Floors						
Current minimum requirements	R1.3					
Slab-on-ground (unheated) from 1 May 2023	R1.5↑				R1.6↑	R1.7↑
Other floors and all heated floors from 1 May 2023	R2.5↑			R2.8↑	R3.0↑	
Windows and doors						
Current minimum requirements	R0.26					
From 3 November 2022	R0.37↑					
From 1 May 2023	R0.37		R0.46↑		R0.50↑	
From 2 November 2023	R0.46↑		R0.46		R0.50	
Skylights						
Current minimum requirements	R0.26		R0.26/0.31		R0.31	
From 3 November 2022	R0.37↑					
From 1 May 2023	R0.46↑		R0.54↑		R0.62↑	

Note: The new minimum R-values apply to all buildings up to 300 m² other than housing from 3 November 2022, with the exception of vertical windows and doors in climate zones 1 and 2. With these, the requirement is R0.37 from 3 November 2022 and R0.46 from 2 November 2023.

Table 2. The six climate zones for H1/AS1 and H1/VM1 5th edition amendment 1.

	Climate zone	Description
↑ Coldest - Warmest ↓	1	Northland, Auckland, Coromandel and Bay of Plenty
	2	Hamilton, Waikato, New Plymouth, Whanganui, East Coast and Hawke's Bay
	3	Manawatū, Palmerston North, Horowhenua, Kāpiti Coast, Wellington, Hutt City, Nelson, Tasman, Marlborough, Kaikōura and Chatham Islands
	4	Rotorua, Central Plateau, Wairarapa, Upper Hutt and West Coast
	5	Canterbury and Coastal Otago
	6	Inland Otago, Southland and Stewart Island

E3 *INTERNAL MOISTURE*

One of the performance requirements of clause E3 (E3.3.1) is that: "An adequate combination of thermal resistance, ventilation, and space temperature must be provided to all habitable spaces, bathrooms, laundries, and other spaces where moisture may be generated or may accumulate."

E3/AS1 1.1 *Thermal resistance* states that: "R-values for walls, roofs and ceilings shall be no less than:

a. For light timber frame wall or other framed wall constructions with cavities, 1.5.

b. For single skin normal weight masonry-based wall construction without a cavity, 0.6.

c. For solid timber wall systems no less than 60 mm thick, 0.6.

d. For roof or ceilings of any construction, 1.5."

The minimum R-value requirements under the schedule method in H1/AS1 5th edition amendment 1 are higher than the minimum requirements in E3/AS1. This means that any design that complies with the thermal requirements of clause H1 following the schedule method will therefore also comply with the thermal resistance requirements in clause E3.

Using the calculation or modelling methods in H1/AS1 and H1/VM1 allows individual building elements to have lower construction R-values than those required in the schedule method. The minimum requirements of E1/AS1 must be borne in mind if you are using the calculation or modelling methods under clause H1.

NEW ZEALAND STANDARDS

There are a number of standards relevant to the selection of insulation for houses:

- NZS 4214:2006 *Methods of determining the total thermal resistance of parts of buildings* is an acceptable method for determining the thermal resistance (R-values) of walls, roofs and floors other than slab-on-ground floors. This standard is cited in H1/AS1 and H1/VM1.
- NZS 4246:2016 *Energy efficiency - Installing bulk thermal insulation in residential buildings* sections 5, 6, 7 and 10 provide acceptable methods for installing bulk thermal insulation in light timber-framed and steel-framed residential buildings. This standard is cited in H1/AS1.
- AS/NZS 4859.1:2018 *Thermal insulation materials for buildings - Part 1: General criteria and technical provisions* can be used to verify the thermal resistance (R-values) of insulation materials. This standard is cited in H1/AS1 and H1/VM1.

3. How insulation works

Most of the insulation materials used in New Zealand today slow the transfer of heat by incorporating tiny pockets of still air in their structure (Figure 1) - air is a poor conductor of heat. These bulk materials include:

- segments or blankets of glass wool, sheep's wool, polyester or blends of these
- rigid sheets such as EPS (expanded polystyrene), XPS (extruded polystyrene) or PIR (polyisocyanurate)
- structural insulated panels (SIPs) - sandwich panels made of two face layers and an insulating inner core
- semi-rigid sheet insulation
- loose fill such as glass wool, sheep's wool, mineral fibre or cellulose fibre
- spray foam insulation.

IGUs - windows with double or triple glazing - work on the same principle, with a gap between two (or three) panes of glass that slows down heat transfer. These gaps can be filled with dry air or, for greater performance, a gas such as argon or krypton.

Reflective foils were used as underfloor insulation in the past but installing or repairing foil insulation under suspended floors is now illegal. (Some installers died when metal staples pierced live cables. This made the foil live and they were electrocuted.)

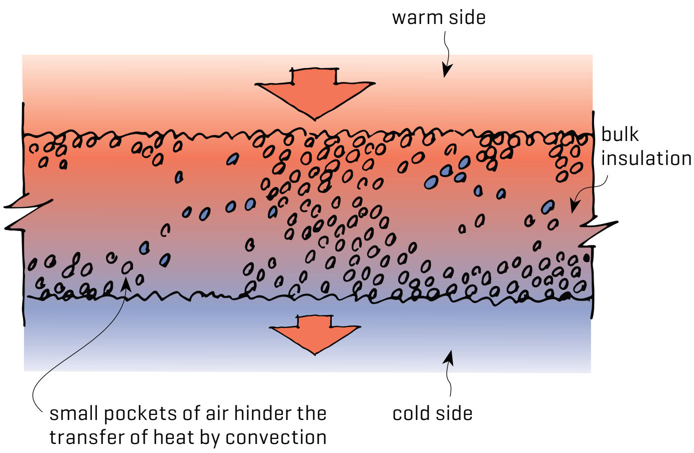

Figure 1. Bulk insulating materials work when the trapped air reduces the speed of heat transfer.

INSTALLATION

There is a crucial point to understand about insulation: it must be installed properly for it to work. This is not just a matter of good practice, it is a specific requirement in H1/AS1 and H1/VM1. Installation is so important that it has its own section in this guide - see section 5.

A common sight on houses under construction - an external corner junction showing light coming from outside through the wall underlay. Installing insulation in the gap between the wall studs is practically impossible at this stage with the underlay already in place. Heat can escape through this uninsulated gap.

Another key to allowing insulation to do its job is to install it everywhere it should be installed. A study of 47 new New Zealand houses found that, on average, insulation was missing from 3% of the wall area, including external corners and internal/external wall junctions. The uninsulated areas in the thermal envelope are largely the result of problems of detailing and work sequencing. Areas such as internal/external wall junctions can become inaccessible after building underlay is installed, yet insulation is generally not installed until after the underlay is in place. These areas of missing insulation should be avoided as far as possible.

THERMAL BRIDGES AND THERMAL BREAKS

The introduction to this guide highlights the problem of thermal bridges such as wall framing panels where the framing occupies a high proportion of the wall space, crowding out the insulation. Designers should reduce this type of thermal bridging as far as possible to allow insulation to do its job.

Thermal bridges are also found in windows, especially aluminium windows. Much higher performance can be gained from aluminium windows that incorporate a thermal break in the frame or windows with uPVC or timber frames - see section 11.

4. Selection of insulation

Insulation products are typically designed for installation in specific areas of a house and should only be used in those areas. For example, insulation designed for use under suspended floors should not be used in a roof space and vice versa. Specify insulation that the manufacturer recommends for a given location and install the product according to the manufacturer's instructions.

As a general principle, it is better to specify the highest-performing insulation the clients can afford for each part of a building rather than just the minimum required to comply with the Building Code. It is vastly easier and less expensive to install better than Code-minimum insulation in the walls of a house when the walls are open during house construction than trying to retrofit insulation at a later date when wall claddings and linings are in place. In practice, there are limits to the amount of insulation that can physically be installed in some constructions depending on framing dimensions. There may be advantages in increasing framing depths to accommodate products with higher R-values.

On the matter of maximising performance, be aware that installing two layers of insulation may not automatically double the R-value. If carefully designed and selected, multiple layers can work (some manufacturers have products that specifically allow a double-layer system), but with some types of insulation, there are risks of the bottom layer being compressed under the weight of the top layer and thus having its effectiveness reduced. For example, two layers of R1.8 insulation with one on top of the other may not give a total of R3.6. If you plan to install two layers, contact the manufacturer or supplier for their advice.

In the past, mixing and matching different insulation materials - for example, putting two different types one above the other under a suspended floor - was sometimes considered as an option for improved performance (typically as part of a retrofit). This approach in new construction is unlikely to find support from either manufacturers or building consent authorities (BCAs) largely because of uncertainty around performance. BRANZ does not recommend this approach in new construction.

CERTIFICATION

There are many types of certification available for thermal insulation products and manufacturers that can help with product selection. They include the following:

- **CodeMark** - products and methods certified under MBIE's CodeMark scheme must be accepted by BCAs as complying with the Building Code as long as they are installed and used in accordance with CodeMark instructions.
- **BRANZ Appraisal** - an in-depth and independent evaluation of a building product or system to assess whether it is fit for purpose and meets Building Code performance requirements.
- **Environmental Choice New Zealand** - an independent guide to products that are proven to be better for the environment (a type 1 ecolabel under ISO 14024:2018 *Environmental labels and declarations - Type 1 environmental labelling - Principles and procedures*).
- **Toitū net carbonzero** - an independent assessment that an organisation is reducing its carbon emissions.

SUSTAINABILITY

On the topic of sustainability and net-zero carbon construction, it is technically possible that second-hand thermal insulation in as-new condition will still perform effectively. Reusing old insulation obviously has environmental/net-zero carbon benefits. Unfortunately, at the present time, it also has significant problems:

- It may be contaminated.
- The R-value may not be known.
- It is unlikely to have continued warranty support from the manufacturer.
- It may not be covered by certification (CodeMark, BRANZ Appraisal) that applies to more recently manufactured products.
- BCAs may be unwilling to accept it as being Code compliant.

The information in this guide is based on new insulation materials and products.

Table 3 shows some commonly available thermal insulation materials and their key properties.

Table 3. Properties of some common insulating materials.

Glass wool	· Glass wool (fibreglass) can be manufactured with a significant proportion of recycled glass. · Recyclable. · Available in rolls or as precut segments and as loose fill (see below). · A wide range of thicknesses and R-values are available. · Glass wool cuts easily with a craft knife and can also be pulled apart. · Installers should always wear gloves, a dust mask and long-sleeved clothing when working with glass wool to avoid irritation.
Polyester	· Available in rolls or as precut segments and as loose fill (see below). · Can be produced from recycled plastics (such as PET bottles). · Recyclable. · Some products are not as easy to cut as glass wool. · Can be handled without protective clothing. · Available in blends with other materials such as sheep's wool.
Sheep's wool	· ·Available in rolls or as precut segments and as loose fill (see below). · Produced from a natural, sustainable resource. · Recyclable. · Some is made from the waste in carpet and textile manufacture. · Available as a blend with polyester. · Can be handled without protective clothing.
Mineral wool	· Formed from spun or drawn molten rock or minerals. · Manufactured as slabs, segments, blankets or rolls or rigid panels for walls and roof spaces and under suspended timber floors or as blown-in loose-fill insulation for ceilings and walls.
Rigid sheet materials	· Expanded (EPS) and extruded (XPS) polystyrene products come in rigid foam sheets and are often used for insulating under concrete slab-on-ground floors and suspended floors. · Can also be used to insulate walls or roofs and used in some proprietary exterior cladding systems. · At a component level, all foamed plastics must comply with the flame propagation criteria specified in AS 1366 *Rigid cellular plastics sheets for thermal insulation*. A completed system that includes a foamed plastic component will typically be required to achieve a system Group Number unless the surface is suffciently robust and securely fixed. For foamed plastics, they will generally require testing in accordance with ISO 9705:1993 *Fire tests – Full-scale room tests for surface products*. · SIPs are sandwich panels made of two face layers and an insulating inner core manufactured in a factory. Timber (such as oriented strand board), metal and cement-based boards are commonly used as face layers. Typical core materials are polymer foams such as expanded polystyrene, polyurethane or polyisocyanurate. · PIR (polyisocyanurate) is a rigid foam insulation board that typically has foil or glass reinforced facings. · PUR (polyurethane rigid foam) is similar to PIR but is sometimes not faced. · Phenolic is another material in this group of products and is sometimes faced. · Debris from cutting some rigid foams can disperse easily into the environment.
Semi-rigid sheet materials	· Sheets are typically self-supporting in a vertical or horizontal space but can be folded when required. · Medium to high density.

Loose-fill materials	• Macerated paper (cellulose fibre), glass wool and mineral wool (rock wool) are the most common loose-fill materials, with new or recycled wool also available. • Loose-fill insulation is machine-blown into roof spaces, although it is generally not recommended for skillion roofs. Loose fill is also generally not recommended for walls unless it is stabilised to reduce compression. • Loose-fill insulation must be installed using specialist equipment. It is often easier and quicker to install than blanket types and may be an option for getting insulation into a difficult roof space. However, some types can be dusty and messy, so it is not suitable if the roof space is likely to be used for storage and therefore accessed from time to time. Special care is also required in roofs with recessed downlights, chimneys and flues.
Foam	• Polyurethane thermal insulation spray-in foam uses the blowing agent hydrofluoroolefin (HFO). • Manufacturers say that foam's low thermal conductivity means that a thinner layer than most other insulation materials is needed to get the same level of energy efficiency. • Imported from Europe.
Wood fibre board	• With boards made using a dry process, the fibres from wood chips are dried and then a small amount of binder added to make them into panels. • Imported from Europe.

INSULATION AND STEEL FRAMING

Where a house has steel framing, both the insulation and the thermal break must be specified. It may be more cost-effective to specify a thermal break with a higher R-value, especially if thicker insulation would require a deeper stud size.

The calculations in this guide are based on steel framing that is 90 mm deep and 45 mm wide or 140 mm deep and 45 mm wide and assume that the thermal break is a sheet, so the added R-value is already included.

SELECTING INSULATION FOR RETROFITS

Selection of insulation for retrofitting into existing houses is covered in section 12.

5. Installation

H1/AS1 5th edition amendment 1 has a specific requirement that insulation is properly installed. It states that insulation must be installed "in a way that achieves the intended thermal performance". NZS 4246:2016 is cited. Sections 5, 6, 7 and 10 provide acceptable methods for installing bulk thermal insulation in light timber-framed and steel-framed residential buildings.

To give the full R-value performance, insulation must be installed with no gaps, folds or compression. Some examples of the impact these can make:

- Insulation can lose its effective R-value by approximately 3% for every 1 mm gap around the edge.
- A 16 mm gap – roughly the thickness of an adult finger – can therefore cut the R-value by almost half.
- Face gaps (where insulation thickness is less than frame depth or where insulation shrinks) together with edge gaps can reduce performance to almost nothing.
- Insulation that is R2.0 and 100 mm thick can, when compressed to just 80 mm thickness, have its R-value reduced to R1.6.
- Settlement of loose fill can reduce the R-value by approximately 1% for every 5 mm of settlement.

Another key factor in installation is to avoid any air movement between the insulation and the building element it abuts. This is especially important in roof spaces and under suspended floors. For example, if polystyrene sheets are being inserted between joists under a suspended floor, they should be pushed hard up under the floor. There must be no air movement allowed between the underside of the flooring and the insulation because this will reduce performance.

Wherever there is an unavoidable air space between the insulation and the element it abuts, that air space must be still.

Where there is a risk that wind may dislodge insulation – for example, under pole houses or other homes where there is an open or semi-open subfloor space – sheet material should be fixed underneath it to keep it in place and avoid excessive air movement.

There are two main sources of information about how to install an insulation product – NZS 4246:2016 and the manufacturer's instructions. Keep both of these on hand when installation is under way. Many manufacturers have also produced instructional videos.

Insulation must be installed with no gaps, folds or compression.

Consider the installation from the earliest stages of construction. In many cases, work sequencing without thought of insulation has resulted in wall underlay rendering many spaces such as external corners inaccessible to those trying to install insulation at a later date.

> Just specifying materials with the appropriate R-value is not enough to comply with the Building Code. Insulation must be installed in a way that achieves its intended thermal performance.

CLEARANCES

Before starting work installing the insulation, it is crucial to fully understand the clearances required between the insulation and various other building materials and elements. For example, in the roof space, there must be a minimum 25 mm gap between insulation and flexible roof underlay. (Some manufacturers require a 25 mm gap clearance between their insulation product and any roofing material.)

Understanding how roof insulation is installed around/over different types of recessed downlights is also crucial. Recessed downlights that are labelled IC and IC-F can have insulation abutted up to them and placed over them.

NZS 4246:2016 has good information and drawings around how to install insulation in a roof with recessed downlights.

Insulation must be separated from fixtures that get hot such as flues. A flue with no casing must be separated from heat-sensitive material by four times its diameter. A flue with two casings and 25 mm air gaps between casings and flue requires a 25 mm gap. For a single casing, the separation would be twice the flue diameter. See AS/NZS 2918:2018 *Domestic solid fuel burning appliances - Installation* for more details. NZS 4246:2016 also has guidance on this, as well as for clearances to other electrical equipment.

See sections 8-10 for other details relevant to floors, walls and roofs.

PRECAUTIONS WHEN INSTALLING INSULATION

Take the following precautions when installing insulation:

- Follow the manufacturer's recommendations for safety and handling. In some cases, these will recommend a dust mask and safety glasses and comfortable work clothes covering arms and legs.
- Take care where electrical cables run under the floor or in the walls or roof space and treat all cables as live.
- When working in the roof space, ensure you only stand on framing members that can support your weight.
- Keep polystyrene separated from PVC-sheathed electrical cables by running the cables through a protective sleeve. Over time, the cable sheathing will become brittle if these two materials stay in contact.
- Do not allow insulation to get wet as this will reduce performance.

6. Calculating R-values

All materials have some degree of thermal resistance – they slow down the transfer of heat. This is measured as an R-value. The higher the R-value of a material, the more it slows down the transfer of heat. Materials with higher R-values therefore have better insulating properties.

An R-value is expressed as m²°C/W or m²K/W.

The R-value of specific materials can be calculated by dividing the material thickness (expressed here by the letter d) by its k value (thermal conductivity – W/dK or W/d°C).

$$R = \frac{d \text{ (material thickness)}}{k \text{ (thermal conductivity)}}$$

In calculations of the thermal performance of a house, two types of R-value are considered – the R-value of the insulation material or product itself and the construction R-value of the building element.

The required thermal performance of building elements in H1/AS1 and H1/VM1 is generally expressed in terms of construction R-value. This is the total thermal resistance of all the physical elements that make up or impact on a building element. For example, with walls, it includes the wall lining, insulation, underlay and cladding and wall framing where applicable. With concrete slab-on-ground floors, the construction R-value includes the insulating effect of the ground under the floor. The construction R-value can be higher or lower than the R-value of the insulation material used in the building element.

R-VALUE CALCULATIONS IN H1/AS1 AND H1/VM1 5TH EDITION

In the 5th edition of the clause H1 compliance documents, the way that the thermal resistance and construction R-value of slab-on-ground floors, windows, doors and skylights has been determined has changed from the previous edition. There has been a change to some of the assumptions behind the calculations and in the calculation methods themselves.

FLOORS

The construction R-value of slab floors is verified using Appendix F in H1/AS1 or H1/VM1. Appendix F in H1/AS1 provides look-up tables while H1/VM1 involves calculation based on 2D or 3D computer simulation of the slab floor.

The construction R-value of other types of floors, including suspended floors, is verified using NZS 4214:2006.

WINDOWS AND DOORS

The requirements for working out the construction R-value of windows, doors and skylights are given in Appendix E in H1/AS1 and H1/VM1. The look-up table in Appendix E in H1/AS1 is to be used for housing only. For other building types, use the calculation method in H1/VM1.

WALLS AND ROOFS

Acceptable methods for determining the R-values of walls and roofs are given in NZS 4214:2006.

BPI CALCULATION

Calculating the building performance index (BPI) by itself is not sufficient to demonstrate compliance with clause H1.3.1(a) (that the building envelope provides adequate thermal resistance).

DETERMINING THE THERMAL RESISTANCE OF BUILDING COMPONENTS AND ELEMENTS

Table E1 in NZS 4214:2006 provides indicative R-values for different construction materials, including board and sheet materials, masonry materials, framing, floor and cladding materials and so on.

7. How to use the tables in this guide

The *House insulation guide* tables can be downloaded from the BRANZ website here. They show the construction R-values for different floor, wall and roof constructions with thermal insulation material of varying R-values. The tables can be used in two main ways:

- To find the construction R-value (the R-value of the built system) for a given level of insulation.
- To find the level of insulation required to achieve a desired construction R-value.

Information taken from the tables can be used to help demonstrate compliance with Building Code clauses E3 *Internal moisture* and H1 *Energy efficiency* in building consent applications. The construction R-values have been calculated using the same methodology as specified in H1/AS1 and H1/VM1.

To be conservative, the construction R-values given in these tables have been rounded down to the nearest 0.1.

The tables have the target R-value for the particular building element and the R-value calculated from the construction options selected. The construction options are selected in drop-down menus at the top of each table. Here are examples of the options to select:

- Timber-framed skillion roof: roof cladding, whether nogs or battens, rafter spacing, insulation R-value, whether there is a secondary interior insulation layer.
- Timber-framed roof with roof space: roof cladding, joist dimensions, whether there is a secondary insulation layer, joist spacing, insulation R-value and conductivity.
- Framed wall: type of wall cladding, whether there is an exterior secondary insulation layer, details of bracing/rigid air barrier, primary frame (timber or steel and thickness), whether there is an interior secondary insulation layer.
- Concrete slab-on-ground floor: type of slab (waffle, standard with various insulation options), whether there is perimeter insulation, whether brick veneer walls, whether there is floor topper insulation, wall depth, area-to-perimeter (A/P) ratio.
- Suspended timber floor: joist height, insulation material conductivity, whether lined or unlined, joist spacing, R-value.

Beside each table is a drawing. The drawings are indicative only, illustrating general cladding, framing and lining options. They are not detailed working drawings and typically do not show the fixings, flashings and so on that are required in construction. For detailed construction requirements, designers will need to refer to other reference sources such as NZS 3604:2011 *Timber-framed buildings* and E2/AS1.

8. Floor constructions

H1/AS1 and H1/VM1 have different minimum construction R-value requirements for slab-on-ground floors and other floors, which are mainly suspended floors (Table 4).

For building consent applications made before 1 May 2023 for housing only, the R-values for floors (as for walls and roofs) can be the equivalent of the requirements under H1/AS1 and H1/VM1 4th edition.

Where part of a concrete floor is in contact with the ground and part suspended, the part in ground contact must be treated as a slab-on-ground floor and the other part treated as an other floor type.

With floors, the construction R-value is the total thermal resistance of all the physical elements that make up the floor (including the insulating effect of the ground under slab-on-ground floors) but ignores the effects of floor coverings such as carpets.

The calculation and modelling methods may allow a designer to use floors that would not comply under the schedule method in Table 4 if the performance of other building elements such as the walls is enhanced to compensate. The exception is heated floors, where the figures in Table 4 apply in all cases.

To allow greater flexibility of building use - for example, possible conversion of an unconditioned garage space to a spare bedroom - it would be prudent to insulate the floor of any unconditioned space that could be converted to a habitable space in the future.

SLAB-ON-GROUND FLOORS

The construction R-values for selected generic concrete slab-on-ground floors (in accordance with their individual A/P ratios) are shown in a series of tables in Appendix F in H1/AS1. The tables cover different:

- floor types - slab floors or concrete raft foundation floors
- floor insulation types - no insulation, R1.0 vertical edge insulation, R1.2 or R2.4 full cover underslab insulation, a 1.2 m wide strip of R1.2 or R2.4 underslab insulation along the slab perimeter, a combination of edge and underslab insulation
- external wall types - the slab under masonry veneer walls has a step-down, giving it different heat transfer characteristics compared to slab floors with other types of walls, so slabs under masonry walls are therefore treated separately.

The polystyrene pods in concrete raft foundation floors are not considered insulation under H1/AS1. Raft floors with polystyrene pods but no additional insulation (such as edge insulation or continuous insulation that also covers the concrete ribs) are regarded as uninsulated.

Clause H1 does not require insulation under slab-on-ground footings. While adding insulation under the footing would provide a significant increase in thermal performance, it requires specific engineering design.

To use the tables, you need to know the slab A/P ratio and the effective thickness of the external wall. The slab A/P ratio is the area of the slab inside the interior surfaces of the walls that form the thermal envelope divided by the perimeter, measuring along the interior surfaces of the walls that form the thermal envelope. Areas outside the thermal envelope such as porches or attached garages are not included in the measurements. (H1/AS1 gives a second option for measuring A/P ratio in F.1.2.4(b) using the external slab dimensions. The result should be almost identical to the first method.)

Table 4. Minimum construction R-values required for floors in new building work under the schedule method in H1/AS1 5th edition amendment 1. (Note that there is a delayed implementation date for housing, explained in section 2.)

Options	Minimum construction R-values (m^2K/W)					
	Climate zone 1	Climate zone 2	Climate zone 3	Climate zone 4	Climate zone 5	Climate zone 6
Slab-on-ground floors	1.5				1.6	1.7
Other floors and all heated floors	2.5			2.8	3.0	

Where the actual ratio of the proposed floor is not given in the table, select the construction R-value based on the nearest figure that is smaller. As an example, if the actual ratio is 3.5 but the table only gives 3.4 and 3.6, choose 3.4 to find the R-value.

The greater the A/P ratio, the higher the slab-on-ground R-value, everything else being equal. Larger slabs have higher A/P ratios and therefore higher R-values than smaller slabs of similar shape and insulation. Slabs with regular shapes such as squares or rectangles have higher A/P ratios and therefore higher R-values than irregularly shaped slabs of similar size and insulation.

Figure 2 shows two examples of calculations. The regular shape (a) is 256 m²/64 m, giving an A/P ratio of 4. The irregular shape (b) is 47 m²/38 m, giving an A/P ratio of 1.24.

The minimum A/P ratio shown in the tables in H1/AS1 is 1.6. Houses with an A/P ratio below this – such as house (b) in Figure 2 with its ratio of 1.24 – would not be able to use the tables as a means of demonstrating compliance with clause H1. Another approach is required. This could be the modelling method in H1/VM1. You could still use the schedule or calculation methods, but you would need to calculate the R-value of the slab floor using the method in Appendix F in H1/VM1, which is cited by Appendix F in H1/AS1. An Alternative Solution is also possible.

The slab R-values in the tables in Appendix F in H1/AS1 also depend on the effective thickness of the external walls of the proposed building. The effective thickness of an external wall on a slab also has a small impact on the thermal performance of the slab. A slab with thicker external walls will have slightly better thermal performance. The thickness of the external walls dictates the location of the interior lining, which forms part of the thermal envelope, in relation to the vertical edge of the floor slab. Thicker walls potentially mean that a reduced amount of heat transfer occurs (including through the slab), and the slab therefore has slightly better thermal performance. The thickness of the external wall is measured from the interior wall surface to the exterior concrete slab vertical edge face at floor level (Figure 3).

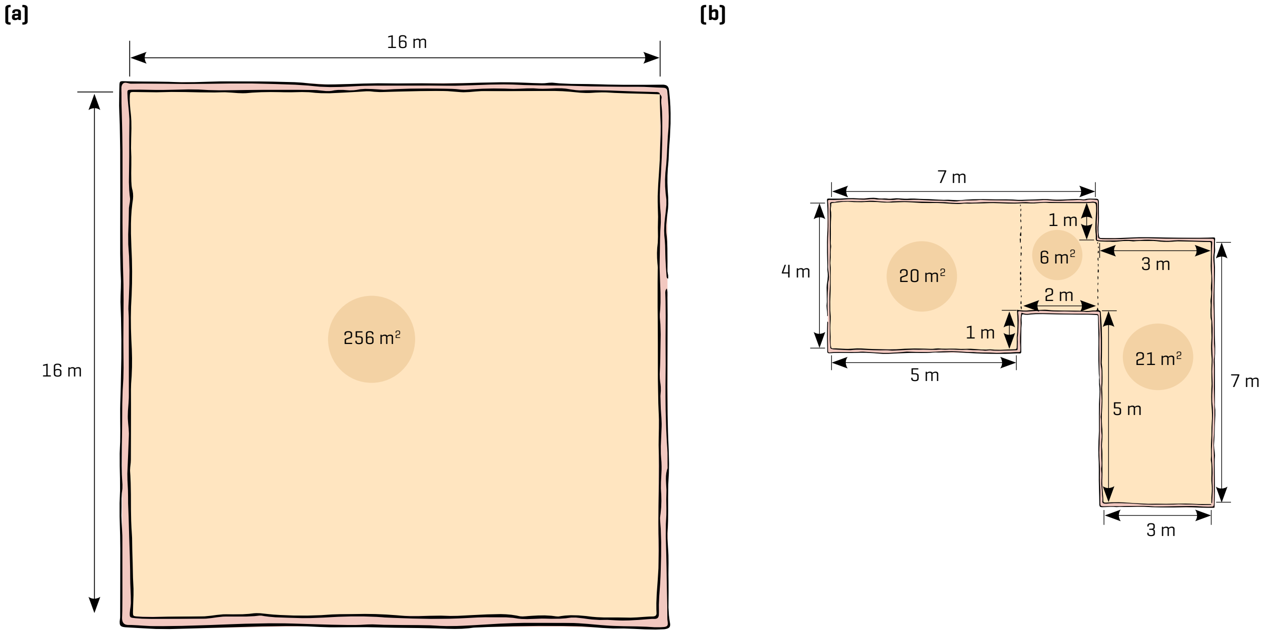

Figure 2. To use the tables for slab-on-ground floors in H1/AS1, you need to know the A/P ratio of the proposed building.

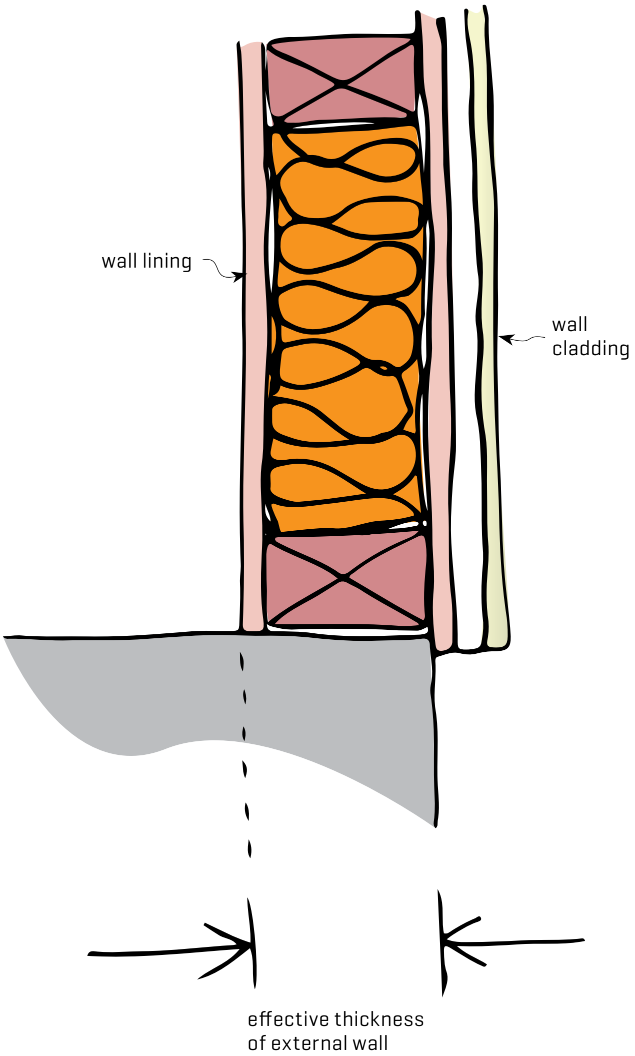

Figure 3. The effective thickness of an external wall is the horizontal distance between the external concrete slab edge at floor level and the interior surface of the wall.

VERTICAL SLAB EDGE INSULATION

Some of the tables in Appendix F in H1/AS1 cover slab construction with R1.0 vertical edge insulation. This addresses the fact that, in some cases, a significant amount of the slab floor heat transfer can be through the slab's vertical edge. The edge insulation is assumed to be installed on all exterior exposed vertical faces of the concrete slab from the top edge and down to the bottom of the footing.

Construction R-values are only given in Appendix F in H1/AS1 for edge insulation of R1.0. BRANZ research has found that there are very limited benefits of installing edge insulation with a higher R-value than this.

Slab edge insulation, which is typically XPS (extruded) polystyrene, must be protected against impact damage, ultraviolet light exposure and water absorption.

OTHER FLOOR TYPES – SUSPENDED FLOORS

As Table 4 shows, the minimum construction R-value requirement for floors other than slab floors (which are likely to be predominantly timber-framed suspended floors) is R2.5 in climate zones 1-3, R2.8 in zone 4 and R3.0 in zones 5-6. In most cases, by far the largest part of this thermal performance will come from the insulation material. Floor coverings, including carpets, are not counted in the construction R-value.

Acceptable methods for determining the thermal resistance (R-values) of floors other than slab-on-ground floors are contained in NZS 4214:2006.

Underfloor insulation available in New Zealand includes polystyrene panels inserted between the floor joists and glass wool (fibreglass), wool or polyester sheets fitted between the floor joists and securely fixed or strapped in place. Check that the subfloor framing timbers are of a sufficient size for the new insulation to be properly installed. For very exposed subfloors, insulation should be protected by fixing a sheet lining material under the insulation.

Installing a vapour barrier on the ground under suspended timber floors is recommended to help prevent moisture/condensation problems under the flooring. All ground releases water vapour, even when it looks as if it is dry on the surface. This vapour barrier is usually a 0.25 mm (250 micron) thick polythene sheet over the whole subfloor area, overlapped 150 mm at the joints, butted against foundation walls and piles (and taped if possible) and weighed down with bricks or rocks to stay in place. The ground under it must be shaped so that water drains to the outside and does not pond on the ground cover. NZS 4246:2016 has detailed instructions for ground vapour barriers.

VERIFICATION METHOD

While the schedule and calculation methods of demonstrating compliance with clause H1 are included in H1/AS1, the modelling method is set out in Part 2 of H1/VM1.

Under this method, the energy use of the proposed building design must be shown not to exceed the energy use of the reference building using the computer modelling described in Appendix D in H1/VM1.

As with the calculation method, the modelling method may allow a designer to use floors that would not comply under the schedule method if the performance of other building elements such as the walls is enhanced to compensate.

Where a proposed building includes a heated ceiling, wall or floor, however, minimum construction R-values apply for that particular element.

One option for achieving the elevated slab R-values required for heated floors can be applying thermal insulation and a floating unreinforced concrete screed on top of the slab. The screed encloses the underfloor heating system – a common construction practice overseas in countries such as Germany. Attention must be given to detailing at the screed-to-wall junction to avoid thermal bridging.

The construction R-value of slab floors is verified using Appendix F in H1/AS1 or H1/VM1. Appendix F in H1/AS1 provides look-up tables while H1/VM1 involves calculation based on 2D or 3D computer simulation of the slab floor.

The construction R-value of other types of floors is verified using NZS 4214:2006.

9. Wall constructions

Under H1/AS1 5th edition amendment 1, the minimum wall construction R-value is R2.0 for all climate zones.

For building consent applications made before 1 May 2023 for housing only, the R-values for walls (as for floors and roofs) can be the equivalent of the requirements under H1/AS1 and H1/VM1 4th edition.

For framed walls, the R-value must include the effects of studs, dwangs, top plates and bottom plates. However, it can exclude the effects of lintels, sills, additional studs that support lintels and sills and additional studs at corners and junctions.

H1/AS1 5th edition amendment 1 does not make allowances for higher thermal mass walls such as solid timber, concrete or masonry. H1/VM1 provides a better way to determine insulation requirements in these types of buildings.

Buildings with curtain walling are also excluded from H1/AS1. Compliance with this construction method can be demonstrated via H1/VM1 or an Alternative Solution.

BRANZ EXTERNAL RESEARCH REPORT ER53 [2020]

Measuring the Extent of Thermal Bridging in External Timber Framed Walls in New Zealand Beacon Pathway Inc.

Funded by the Building Research Levy, stage one of the Wall Project measured the extent of timber framing in 47 new-build dwellings in Auckland, Christchurch, Wellington, and Hamilton. The results show that the average percentage of timber framing compared to the area of the wall is above 34% - based on the 47-dwelling case study sample. This is much higher than the 14-18% framing content generally assumed by both regulators and the industry when undertaking compliance calculations.

When individual house levels across the sample were looked at, the minimum percentage of timber framing found was 24%, while the maximum was slightly over 57%.

H1/VM1 5TH EDITION AMENDMENT 1

2.1.3.2 The *thermal resistance (R-values)* of insulation materials may be verified by using AS/NZS 4859.1.

2.1.3.3 The *construction R-values of building elements* shall be calculated as follows:

a. For walls and *roofs*, the *R-value* is of a typical area of the building element; and

b. For framed walls, the *R-value* shall include the effects of studs, dwangs, top plates and bottom plates, but may exclude the effects of lintels, sills, additional studs that support lintels and sills, and additional studs at corners and junctions; and

c. For walls without frames, the *R-value* excludes any attachment requirements for windows and doors; ...

Clause 2.1.3.3 b) clearly enables compliance by including all wall framing, and since stage two of the ER53 project found that only a small part of the wall framing (1-3%) was added on site, the frame fraction could in principle be obtained from the frame manufacturer.

The path for demonstrating compliance when excluding some of that framing is not explained in clause 2.1.3.3, nor anywhere else in the H1 documentation. That path is clearly not expressed as being to simply assume the nominal stud and dwang spacings (plus top and bottom plates) and to ignore all other framing that is affecting the thermal performance.

THERMAL BRIDGING

A big challenge in the thermal performance of walls comes from high levels of framing that result in large areas of thermal bridging. For details, see BRANZ reports ER53 *Measuring the extent of thermal bridging in external timber-framed walls in New Zealand* and ER64 *Thermal bridging in external walls: Stage two* (Part Three provides examples of how thermal bridging can be effectively reduced). Designers should aim to minimise thermal bridging in walls as much as possible.

One proven option for reducing thermal bridging and enhancing thermal performance is using battens to create a second wall cavity that can also be insulated. For more details, see the PHINZ *High-performance construction details handbook*.

WALLS AND STEEL FRAMING

Where a house has steel framing, both the insulation and the thermal break must be specified. It may be more cost-effective to specify a thermal break with a higher R-value, especially if thicker insulation would require a deeper stud size.

The calculations in this guide are based on steel framing that is 90 mm deep and 45 mm wide or 140 mm deep and 45 mm wide and assume that the thermal break is a sheet, so the added R-value is already included.

10. Roof constructions

When using the schedule method in H1/AS1 5th edition amendment 1 to demonstrate Building Code compliance, the roof construction R-value must be a minimum R6.6 in all climate zones.

For building consent applications made before 1 May 2023 for housing only, the R-values for roofs (as for walls and floors) can be the equivalent of the requirements under H1/AS1 and H1/VM1 4th edition.

With the calculation method, you can reduce the roof R-value below this by compensating with a higher construction R-value in another element such as walls or floors. In this case, the R6.6 applies to the reference building only. The modelling method in H1/VM1 gives similar flexibility.

Bulk insulation in roofs with roof spaces is commonly installed between ceiling joists or bottom chords of trusses over the ceiling lining. Designers need to consider the thickness of the insulation products they plan to use. For example, one glass wool R7.0 roof insulation product currently on the market is 260 mm thick. The thickness is relevant because of the required 25 mm minimum clearance between insulation and flexible roof underlay.

For skillion roofs, care will need to be given to the framing required to ensure the R6.6 schedule method minimum R-value is achieved. For example, deeper rafters (or purlins where the insulation is installed over a sarked ceiling) may be required.

Issues around installation of roof insulation - for example, how recessed downlights are treated and what gaps are required around flues - are covered in section 5.

The requirements in H1/AS1 5th edition amendment 1 make allowance for the fact that the insulation required may be too thick to extend right to the ceiling edge under a sloping roof. In roof spaces where insulation is installed over a horizontal ceiling, the R-value may be reduced to R3.3 for up to 500 mm from the edge where there is not enough space for the thicker insulation required to achieve R6.6.

If designers wish, they can specify a higher construction R-value for the central portion of the roof to compensate for the lower R3.3 around the perimeter in order to lift the overall whole-roof construction R-value to R6.6. Table 5 shows what is required for ceilings with different A/P ratios. Note that this procedure is not a requirement in H1/AS1.

For clause H1 compliance using the schedule method, the ceiling R-value (minimum R6.6) does not need to be corrected for the reduced edge R-value provided the width is no more than 500 mm and the reduced R-value is at least R3.3.

To estimate the area of the reduced ceiling insulation along the perimeter, multiply the ceiling perimeter by the width of the reduced insulation strip (for example, 500 mm as per schedule method allowance). The area of the full ceiling insulation is then simply the difference between the total ceiling area and the reduced insulation ceiling area.

If the calculation or modelling methods are used, the impact of reduced insulation at perimeter will need to be accounted for. A method for doing this is set out in BRANZ Bulletin BU677 *Specifying roofs under H1*.

While considering roof insulation, it is crucial that designers pay close attention to the quality of the ceiling air barrier. Specifically, try to avoid as far as possible any gaps where air (and moisture carried with the air) can move from living spaces through to the roof space. This means ideally avoiding recessed downlights (or specifying ones with a good air seal) and specifying access hatches that have a good air seal.

Table 5. Determining the construction R-value in the main central portion of the roof to lift the construction R-value of the overall roof to R6.6, assuming the roof perimeter construction R-value is R3.3.

A/P ratio	Effective overall construction R-value with R6.6 in the central portion of the roof and R3.3 around the perimeter	Construction R-value required in the central portion of the roof to give a whole-roof construction R-value of R6.6
1.6	5.1	11.1
1.8	5.2	10.1
2	5.3	9.5
2.2	5.4	9.1
2.4	5.5	8.8
2.6	5.6	8.5
2.8	5.6	8.3
3	5.7	8.1

11. Windows and doors

There is a two-step transition to the new performance requirements for all vertical windows and doors in climate zones 1 and 2:

- From 3 November 2022, the minimum R-value is R0.37.
- From November 2023, the minimum rises to R0.46.

For housing only, in zones 3-6 there is also a two-step process:

- From 3 November 2022, the minimum R-value is R0.37 for climate zones 3-6.
- From 1 May 2023, the minimum rises to R0.46 for climate zones 3 and 4.
- From 1 May 2023, the minimum rises to R0.50 for climate zones 5 and 6.

H1/AS1 and H1/V1 5th edition amendment 1 brought in some changes to the coverage of windows and doors:

- Decorative glazing and transparent/translucent louvres are now subject to the window and door minimum R-values.
- All doors including opaque doors are now subject to the window and door minimum R-values. (Previously, there were no R-value requirements for opaque doors and opaque parts of doors.)
- Using the schedule method, the opaque door area can be no more than 6 m² or 6% of the total wall area (whichever is greater).

The requirements for working out the construction R-value of windows, doors and skylights are given in Appendix E in H1/AS1 and H1/VM1.

The table in Appendix E in H1/AS1 is to be used for housing only. The construction options for IGUs in the table are:

- framing material - aluminium, thermally broken aluminium, uPVC and timber
- glazing - double or triple pane (single glazing is not an option using the schedule method)
- spacer type - aluminium or thermally improved
- gas fill - dry air, argon or krypton
- glass - low-E (emissivity) with four performance levels or clear glazing
- U-value (in W/m²K) for the thermal transmittance of the centre of the glazing unit only (U-values are the inverse of R-values)
- R-value (in m²K/W) for the thermal resistance of complete windows, accounting for both the glazing and the frames.

FRAMING MATERIAL

Timber and uPVC window frames are relatively poor conductors of heat and give the best thermal performance. Next are thermally broken aluminium frames. Aluminium's high thermal conductivity means that simple aluminium frames with no thermal break incorporated give a poor thermal performance.

THERMALLY BROKEN ALUMINIUM

To prevent rapid heat loss or gain through a solid aluminium frame between the interior and the exterior, a thermal break is designed into the frame. The inner and outer parts of the frame are held together by a connection with very low thermal conductivity - typically an extremely tough and durable type of reinforced plastic called polyamide. BRANZ testing has confirmed that aluminium frames with this feature can significantly reduce heat transfer through the frame.

The thermal performance of thermally broken aluminium frames, in contrast to uPVC or timber frames, relies on installation that ensures that the internal aluminium half-shell is not exposed to outside air. The thermal breaks of thermally broken aluminium frames cannot fulfil their function if outside air can reach the internal half-shell.

Table 6. Minimum construction R-values required for vertical windows and doors in new building work in housing under the schedule method.

	Minimum construction R-values (m²K/W)					
	Climate zone 1	Climate zone 2	Climate zone 3	Climate zone 4	Climate zone 5	Climate zone 6
From 3 November 2022	0.37	0.37	0.37	0.37	0.37	0.37
From 1 May 2023	0.37	0.37	0.46	0.46	0.50	0.50
From 2 November 2023	0.46	0.46	0.46	0.46	0.50	0.50

SPACERS

Spacers separate the glass panes in a double or triple-glazed window. They can be made of aluminium or, preferably, from a material with much lower thermal conductivity that reduces heat loss (commonly described as a warm edge spacer or thermally improved spacer).

LOW-E

Low-E (low-emissivity) glass has a microscopically thin transparent metal coating that allows light through in both directions but reflects long-wave infrared radiation and associated heat back, allowing glazing to keep a house warmer in winter or cooler in summer. The impact of low-E glazing in both summer and winter needs to be considered - a slight compromise at one time of year may be necessary to achieve an overall better energy performance outcome.

While low-E glazing is sometimes discussed as if it were a single product, in fact there is a wide range of low-E coatings available with different attributes and levels of performance. The table in Appendix E in H1/AS1 refers to Low-E_1 to Low-E_4. These descriptions were developed for the purpose of the clause H1 window table. The numbers indicate different thermal performance levels of low-E coatings, from basic to very high.

The technology of low-E glass has improved considerably in recent years, with newer products in some cases giving 10 times the thermal performance of older low-E glazing. Double glazing with the newest low-E coatings can perform about as well as some entry-level triple glazing but without the additional weight and size of triple-glazed windows.

The thermal performance of glazing in New Zealand is measured according to the European standard (EN 673), which differs slightly from US American standards. Glazing thermal performance values can be converted unless low-emissivity panes are included in the glazing. The emissivity of glazing in US America is calculated according to NFRC 301, which is a very different way from the standard used in NZ (EN 12898), and there is no easy way to convert between the values. Hence it is critical that the emissivity of low-E panes is measured and reported in accordance with EN 12898 in New Zealand.

GAS FILL

The options for the gas fill in IGUs in H1/AS1 and H1/VM1 are air, argon and krypton.

Argon is a common gas (it forms about 1% of Earth's atmosphere) and is a better insulator than air, reducing window heat loss by 3-9% compared with an air-filled IGU. Krypton is an even better insulator than argon but is only one part per million of the atmosphere so is more expensive. IGUs with krypton filling have not been commercially produced in New Zealand to date although that may change. Overseas, krypton is often used in reglazing heritage windows where there is a narrower gap between panes.

WEERS

BRANZ and the Window & Glass Association NZ developed a scheme for industry called the Window Energy Efficiency Rating System (WEERS). It combines the thermal performance of the frame and glazing together with window size to calculate the specific thermal performance for any window. Windows suppliers can use this to calculate the thermal performance of windows for housing and small buildings (Figure 4). Some window suppliers provide a WEERS certificate that records the R-value of each window and the R-value for the house lot. WEERS implements ISO 10077-2:2017 *Thermal performance of windows, doors and shutters – Calculation of thermal transmittance – Part 2: Numerical method for frames*. The calculation used by WEERS is consistent with the H1/VM1 window construction calculation methodology.

Figure 4. A WEERS label shows the thermal performance of windows.

SPECIFYING WINDOWS AND DOORS

Determining the thermal performance of a window should come before considering other requirements such as visible light transmission, UV elimination, SHGC, durability, safety, security, privacy, noise control and ease of cleaning.

To check for compliance, the construction R-values for vertical windows and glazing in doors (R_{window}) in housing can be determined using Table E.1.1.1 in Appendix E in H1/AS1. The table gives overall area-weighted average R-values from two houselots of windows for each of four different frame types (aluminium, thermally broken aluminium, uPVC and timber) and a range of glazing options. This table is reproduced below in Table 7, with the addition of solar heat gain coefficients (SHGCs).

SKYLIGHTS

The minimum requirements for skylights using the schedule method are shown in Table 8.

There is no table showing construction R-values of generic skylights in H1/AS1 or H1/VM1, but Appendix E in the documents provides guidance for calculating construction R-values.

Table 7. Construction R-values for generic vertical window systems in H1 5th edition and solar heat gain coefficients (SHGC).

The glazing unit R-values are based on IGUs available from large New Zealand suppliers (some may not be readily available currently)						**Generic frame types and average frame %**			
						Aluminium	**Thermally broken**	**uPVC**	**Timber – 56 mm**
						23%	**27%**	**34%**	**41%**
	Generic IGU description	Gas fill	Spacer	U_g (m²K/W)	Typical SHGC	R_{window} (m²K/W)			
Double glazing	4 Clear / 16 / 4 Clear	Air	Aluminium	2.7	0.77	0.26	0.32	0.40	0.44
Double glazing	Low-E_1 / Clear	Argon	Aluminium	1.9	0.56	0.30	0.39	0.50	0.56
Double glazing	Low-E_2 / Clear	Argon	Improved	1.6	0.55	0.33	0.42	0.56	0.63
Double glazing	Low-E_3 / Clear	Argon	Improved	1.3	0.57	0.35	0.46	0.63	0.71
Double glazing	Low-E_4 / Clear	Argon	Improved	1.1	0.54	0.37	0.50	0.69	0.77
Double glazing	Low-E_4 / Clear	Krypton	Improved	0.9	0.37	0.40	0.54	0.76	0.85
Triple glazing	Clear / Clear / Clear	Air	Improved	1.9	0.69	Not available	0.38	0.50	0.56
Triple glazing	Low-E_2 / Clear / Clear	Argon	Improved	1.2	0.50	Not available	0.48	0.66	0.74
Triple glazing	Low-E_3 / Clear / Clear	Argon	Improved	1.0	0.52	Not available	0.52	0.73	0.81
Triple glazing	Low-E_3 / Low-E_3 / Clear	Argon	Improved	0.7	0.47	Not available	0.59	0.86	0.95
Triple glazing	Low-E_4 / Low-E_4 / Clear	Argon	Improved	0.6	0.43	Not available	0.62	0.91	1.01

Table 8. Minimum construction R-values required for skylights in new building work for housing under the schedule method.

	Minimum construction R-values (m²K/W)					
	Climate zone 1	**Climate zone 2**	**Climate zone 3**	**Climate zone 4**	**Climate zone 5**	**Climate zone 6**
From 3 November 2022	0.37	0.37	0.37	0.37	0.37	0.37
From 1 May 2023	0.46	0.46	0.54	0.54	0.62	0.62

Skylight R-value calculations must consider the effects of horizontal or angled glazing on the heat transfer. The performance reduction for inclined IGUs means that the values for vertical windows and doors in Table E.1.1.1 in H1/AS1 do not represent the performance values for skylight frame and glazing combinations. Check that R-values claimed by suppliers do not represent vertical installation.

If you want to use the schedule method of determining compliance, the skylight area must be no more than 1.5 m² or 1.5% of the total roof area (whichever is greater).

RISK OF OVERHEATING

This guide focuses on Building Code compliance. Currently, the Building Code does not address very well the increasing problem of houses overheating. In addition to Building Code compliance, designers must take other action to ensure comfortable year-round temperatures in a house. Specifically, this means careful consideration of the following:

- Solar heat gain. The calculations for windows and doors in H1/AS1 and H1/VM1 5th edition amendment 1 do not address solar radiation passing through the window, measured by the SHGC. This is a number between 0 and 1. The lower the SHGC, the less solar heat is transmitted. Two windows can both have the same construction R-value but different SHGC measures.
- Shade devices. These may include eaves (especially on north-facing windows) and roller blinds or other devices on west-facing windows.
- The opening area of windows and how far they open to allow ventilation for cooling in summer.
- Whether to specify skylights. Skylights should be used sparingly because of two performance drawbacks. Over a whole year, they almost always lose more energy than they gain, yet in summer months, they can contribute to a house overheating.
- Passive ventilation to cool the house interior on hot summer days, ensuring there are good airflow paths through the building and cross-flow ventilation where possible.

There are many resources available to help, including BRANZ Bulletin BU656 *Designing to avoid houses overheating*.

12. Retrofitting insulation

There is currently no requirement in the Building Act or Building Code to retrofit insulation into existing owner-occupied buildings. The healthy homes standards require certain levels of thermal insulation in rental housing where it is practicable to install it, regardless of the age of the building.

Where an existing house is having new rooms added or existing rooms are being substantially rebuilt and a building consent is required, Code-compliant insulation will be required in these rooms.

Where work is being carried out under Schedule 1 of the Building Act and is exempt from requiring a building consent, it generally does not need to follow the same rules. In these circumstances, the Building Act requires that, after the renovations are done, the building must comply with the Building Code "to at least the same extent as before the alteration". In other words, the thermal performance must be at least as good as it was before the work started.

MBIE has flagged as part of its Building for Climate Change programme that requirements around retrofitting insulation in existing homes may be considered in future as part of the move towards a achieving a zero-energy economy by 2050.

While there may be no requirement to retrofit insulation into existing homes as yet, there is a considerable body of research showing that installing insulation can make a house more comfortable and healthier to live in and in many cases reduce the energy that must be purchased for heating. The same applies to adding insulation to areas where it is missing or replacing existing insulation that has been damaged or otherwise become ineffective (for example, through becoming wet after a leak or through becoming compressed).

If you want advice around the potential benefits to retrofitting insulation into a specific building, there are two possible sources of help:

- Eco Design Advisor - a service offered by councils in Auckland, New Plymouth, Palmerston North, Lower Hutt, Nelson, Christchurch and Dunedin.
- HomeFit - a service developed by the New Zealand Green Building Council. This looks at the health, comfort, energy efficiency and safety of homes that have been lived in for some time. One option uses an assessor going through the property, but there is also an online check that provides a basic guide to a house and how improvements can be made. HomeFit has been updated for the healthy homes standards that apply to rental properties.

There are also government grants available for retrofitting insulation to existing houses for homeowners who meet certain criteria.

RETROFITTING ROOF INSULATION

Surveys indicate that there are still a few existing houses that have no insulation at all. In these homes, the first place to start is the roof - the area of greatest heat loss (Figure 5).

Where the ceiling is accessible, as it typically is in villas, bungalows and the like, installing bulk insulation between and over ceiling joists is relatively straightforward. Where access is difficult, blown-in, loose-fill insulation may be appropriate.

Where there are older styles of recessed downlight in the ceiling, there may need to be gaps around them. It is a good idea to upgrade such older recessed downlights with modern LED downlights with an IC or IC-F rating at the same time. They will not only require less energy to run but can also be covered with insulation. This helps improve the effectiveness of the ceiling insulation. Consult the drawings and details in NZS 4246:2016.

RETROFITTING INSULATION UNDER SUSPENDED FLOORS

Existing houses may have no subfloor insulation at all or have foil insulation. Retrofitting or repairing foil insulation under houses was banned after several people using staples or nails to attach the foil to timber members accidentally pierced a live electrical cable and were electrocuted.

Select an insulation product specifically designed for use under floors. Proprietary products include polystyrene that is friction fitted between the joists and segments or blankets such as polyester, glass wool or sheep's wool that come with tabs for fixing or are held in place by strapping. Make sure the insulation is pressed firmly against the floor so there is no air movement between the insulation and the floor. Exposed subfloors may require sheet material fixed under the insulation to hold it firmly in place.

EXTERIOR WALLS

Although walls account for a significant proportion of total heat loss from uninsulated houses, it is usually too difficult and expensive to retrofit insulation. The most cost-effective option is to wait until wall linings or claddings need to be replaced and to fit insulation at that time.

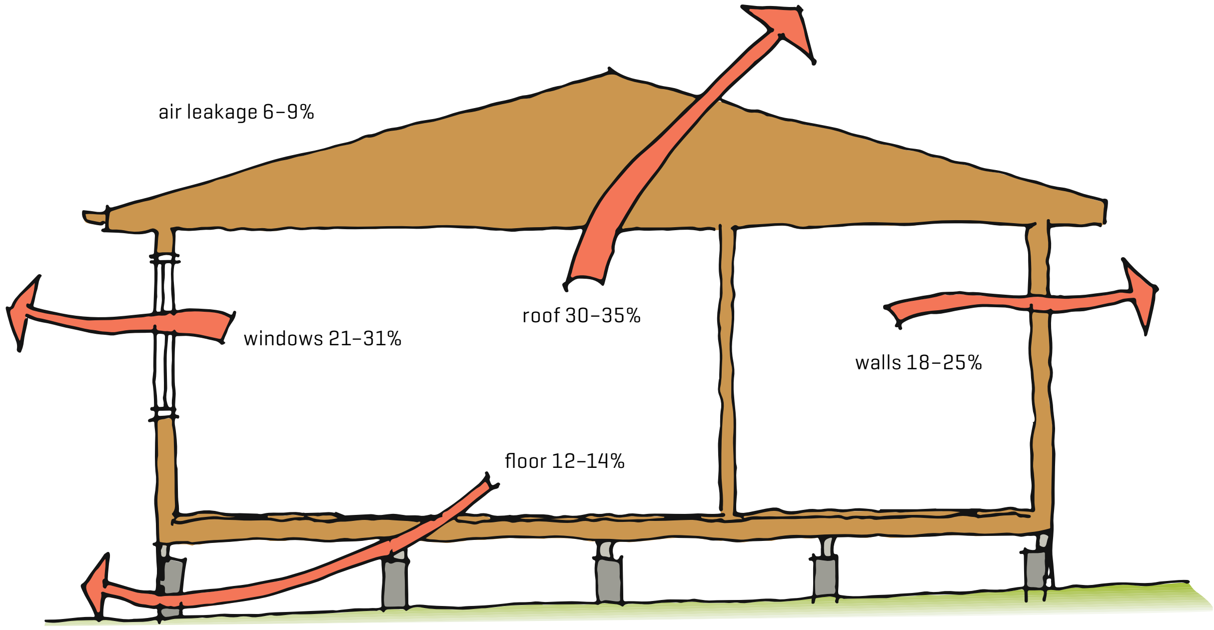

Figure 5. Approximate heat loss through building elements of a typical uninsulated house.

Retrofitting wall insulation requires building consent. Part of the reason for this is that insulation badly installed to existing walls can potentially act as a pathway for rain. This penetrates through gaps in the cladding to pass to the wall framing and also wick, via the insulation, to the interior. It can also reduce the drying potential of walls, trapping occasional moisture for longer. All of this can cause weathertightness problems.

WINDOWS AND GLAZING

As Figure 5 shows, a significant proportion of the heat lost from uninsulated houses is lost through the windows. For many existing windows, IGUs can be retrofitted, but for a whole house, this is likely to be expensive.

Secondary glazing can be a very cost-effective option. With this, plastic film, magnetically attached plastic sheet, plain glass or low-E glass is installed inside the existing glass with a still air gap between them. Research (largely carried out at BRANZ) found that secondary glazing gave R-values from R0.36 to R0.57. This confirms that secondary glazing can be used as a functional alternative to retrofitted IGUs in existing domestic single-glazed window frames. Depending on circumstances, secondary glazing may only be installed over the winter months.

For more information on timber-framed windows, see BRANZ Bulletin BU659 *Upgrading the thermal performance of timber windows*.

Glossary

Acceptable Solution (AS)	A solution that must be accepted as complying with the Building Code.
alternative method	A solution that is partly or completely different from the methods described in Acceptable Solutions or Verification Methods. An alternative method becomes an Alternative Solution once consented.
Alternative Solution	A solution that is compliant with the Building Code but is not part of an Acceptable Solution or Verification Method.
area-to-perimeter (A/P) ratio	The area of a slab-on-ground floor inside the interior surfaces of the walls that form the thermal envelope divided by the perimeter measuring along the interior surfaces of the walls that form the thermal envelope.
argon	A gas used between the glass panes in some IGUs.
BCA	Building consent authority - an organisation that can issue building consents, inspect construction and certify completion of building work. All territorial authorities (city and district councils) are accredited as BCAs.
BPI	Building performance index - a definitive measure of the heating energy required for a specific house design. The precise definition is detailed in Appendix B in H1/AS1 and H1/VM1.
BRANZ Appraisal	A technical opinion of a product or system's fitness for purpose based on specific Building Code requirements.
carbon footprint	The sum of greenhouse gas emissions and removals in a product system expressed as CO_2 equivalent and based on a life cycle assessment (ISO, 2013).
cavity	Described in E2/AS1 as a nominal 20 mm deep bottom-vented cavity behind lightweight wall claddings, a cavity is an air space between cladding and underlay designed to dry and/or drain any water that might penetrate the cladding.
CodeMark certification	Building products and methods that have obtained a CodeMark certificate must be accepted by BCAs as being Building Code compliant if the product/method is being used according to the certificate and its instructions.
compliance path	A way to demonstrate that proposed work complies with the Building Code. Compliance paths include Acceptable Solutions, Verification Methods and product certification.
concrete raft foundation floor	A slab-on-ground floor where polystyrene pods are incorporated under the floor slab. Sometimes called a waffle pod slab floor.
construction R-value	Defined in H1/AS1 as the total thermal resistance (R-value) of a typical area of a building element. In many cases, the construction R-value may be lower than the R-value of the insulation alone.
direct-fixed cladding	Wall cladding that is fixed over a wall underlay and directly to the framing, not over a cavity.
EIFS	Exterior insulation and finish system - a wall cladding system where polystyrene sheets are typically plastered with a reinforced polymer-modified cement-based plaster and then painted.
embodied energy	All the energy used over the life of a material or building, starting from the extraction of raw materials for manufacture and going through to disposal.
environmental product declaration (EPD)	An independently verified, science-based declaration of environmental performance of a material or product for all or part of its life cycle.
EPS	Expanded polystyrene.
HL	Heat loss.

IGU	Insulating glass unit (double or triple glazing).
joists	Horizontal framing members that support a floor or ceiling. Floor joists sit above the bearers.
krypton	A gas used between the glass panes in some IGUs.
k-value	Thermal conductivity – k-value – is the intrinsic property of a material that indicates its ability to conduct heat. The units are W/mK or W/m°C.
life cycle assessment (LCA)	A systematic means of considering the impact of a material or component over its life from extraction to processing/manufacturing to construction/installation to use to eventual disposal.
low-E	Low-emissivity glass has a thin film of metallic oxide coating that allows the passage of short-wave solar energy into a building but prevents long-wave energy produced by heating systems and lighting from escaping outside. Low-E glass allows light to enter while also providing thermal insulation.
MBIE	Ministry of Business, Innovation and Employment.
phenolic	A rigid insulation board that is sometimes faced.
PIR	Polyisocyanurate – a rigid foam insulation board that typically has foil or glass reinforced facings.
proprietary	A product manufactured or sold by a particular company that typically has trademark or copyright ownership. No manufacturer has intellectual property ownership of a generic product.
PUR	Polyurethane rigid foam – similar to PIR but sometimes not faced.
R-value	This is defined in H1/AS1 as the common abbreviation for describing the values of both thermal resistance and total thermal resistance.
SHGC	Solar heat gain coefficient – a measurement of the passage of solar radiation through a window.
SIPs	Structural insulated panels – sandwich panels made of two face layers and an insulating inner core.
skillion roof	A pitched roof where the roof cladding and ceiling lining are parallel and close to each other with no accessible roof space.
stucco	A wall cladding where a painted, reinforced sand/cement plaster is applied to a backing, often with a textured finish.
thermal break	An insulating material placed on the external side of framing that prevents heat moving from one body to another. It must be installed on the external side of the framing member.
thermal bridge	A thermal bridge occurs where heat is more easily able to move from one body to another.
thermally broken aluminium	A plastic insert with higher thermal performance separates two sections of aluminium. Used in some window frames primarily to reduce heat loss to the outside.
U-value	A measure of air-to-air heat transmittance (loss or gain) due to thermal conductance and the difference in indoor and outdoor temperatures. As the U-value decreases, so does the amount of heat that is transferred through the material. The lower the U-value, the better the insulation. The U-value is the reciprocal of the R-value.
veneer	Heavy cladding (bricks or concrete blocks) supported by a structural base that is separated from the supporting framing by a ventilated cavity.
Verification Method (VM)	A method by which compliance with the Building Code may be verified using an identified testing regime or method of calculation.
waffle pod slab floor	A slab-on-ground floor where polystyrene pods are incorporated under the floor slab. H1/AS1 calls them concrete raft foundation floors.
WEERS	Window Energy Efficiency Rating System – rates energy performance of windows, including frames.
XPS	Extruded polystyrene.

Note that there is a list of MBIE's definitions of particular word and terms in Appendix B in H1/AS1 and H1/VM1.

Links and resources

BRANZ

Bulletins

BU656 *Designing houses to avoid overheating*

BU659 *Upgrading the thermal performance of timber windows*

BU670 *Specifying windows and doors under H1*

BU672 *Specifying floors under H1*

BU676 *Complying with H1 - housing, and buildings up to 300 m²*

BU677 *Specifying roofs under H1*

BU678 *H1 Calculation method - housing, and buildings up to 300 m²*

BU679 *Introduction to calculating whole-of-life carbon footprints of houses*

BU680 *Insulating glass units (IGUs)*

Research reports

SR352 *Perimeter insulation of concrete slab foundations*

ER53 *Measuring the extent of thermal bridging in external timber-framed walls in New Zealand*

ER64 *Thermal bridging in external walls: Stage two (May 2021)*

ER70 *High-performance construction details handbook*

Tools

BRANZ calculation method tool

BRANZ schedule method tool

BRANZ carbon tools

MBIE

New Zealand Building Code clause H1 *Energy efficiency*

STANDARDS NEW ZEALAND

- NZS 4214:2006 *Methods of determining the total thermal resistance of parts of buildings* is an acceptable method for determining the thermal resistance (R-values) of walls, roofs and floors other than slab-on-ground floors.
- NZS 4246:2016 *Energy efficiency - Installing bulk thermal insulation in residential buildings* sections 5, 6, 7 and 10 provide acceptable methods for installing bulk thermal insulation in light timber-framed and steel-framed residential buildings.
- AS/NZS 4859.1:2018 *Thermal insulation materials for buildings - Part 1: General criteria and technical provisions* can be used to verify the thermal resistance (R-values) of insulation materials.

OTHER

- Eco Design Advisor - a service offered by councils in Auckland, New Plymouth, Palmerston North, Lower Hutt, Nelson, Christchurch and Dunedin.
- Homestar - a service developed by the New Zealand Green Building Council. An independent rating tool for assessing the health, efficiency and sustainability of new homes.
- H1 calculation method calculator - developed by the New Zealand Green Building Council.
- HomeFit - a service developed by the New Zealand Green Building Council. This looks at the health, comfort, energy efficiency and safety of homes that have been lived in for some time. One option uses an assessor going through the property, but there is also an online check that provides a basic guide to a house and how improvements can be made. HomeFit has been updated for the healthy homes standards that apply to rental properties.