Australia's National
Science Agency

Thermal Bridging for Residential Building Energy Rating – updated with NZS4214

Defaults, modelling guidance and impact on residential building energy ratings

Dong Chen and Michael Ambrose
December 2020

Report for Department of Industry, Science, Energy and Resources
(Client contact: Mark Nolan)

For Official Use Only

Energy Business Unit

Citation

Chen D and Ambrose M (2020) Thermal Bridging for Residential Building Energy Rating – Updated with NZS4214. CSIRO, Australia.

Copyright

Important disclaimer

Contents

Figures

Tables

Acknowledgments

This research is funded by the Department of Industry, Science, Energy and Resources, Australian Government. The authors would like to express their thanks for help on the establishment of default parameters for metal framed constructions from Mr Mike Kelly and his colleagues at the National Association of Steel-framed Housing Inc. (NASH).

Executive summary

To better align the NatHERS compliance pathway with the other compliance pathways in the NCC, CSIRO is commissioned by DISER to develop a set of thermal bridging default parameters, to provide a draft modelling guidance on how to apply these defaults for NatHERS rating, and to determine the impact of applying these defaults on residential building energy ratings.

By conducting a brief survey, default input parameters for timber and metal framed wall, ceiling, floor and roof constructions are recommended for thermal bridging calculation (Table 1). The proposed application of thermal bridging for various constructions was reviewed. Based on the AccuRate user interface, a draft modelling guide for data input has been developed for assessors modelling thermal bridging effect based on the NZS4214 thermal bridging calculation method. With the default input parameters and the draft guide of modelling thermal bridging effect, AccuRate simulations were carried out for a sample house design and a sample apartment design in all the 69 NatHERS climate zones with different house design variations including timber framed, metal framed, brick veneer and light cladding, slab-on-concrete design and suspended floor design, as well as different apartment locations (top apartment and ground apartment). Results show that reductions in NatHERS star ratings were seen in most climate zones when thermal bridging was applied to the status quo designs, especially with metal framed construction.

For the sample house, on average a reduction of 0.2 to 0.4 stars was seen when bridging from a timber frame was included in the modelling. For metal framed designs where no thermal barrier was included, an average reduction of around 0.7 to 1.2 stars was seen. Including a thermal barrier with the metal frame improved the thermal performance and the average drop in star rating becomes around 0.5 to 0.9 stars.

For the sample apartment, the ground floor apartment design option, which only had framing included in the external walls, saw minimal impact from including thermal bridging in the modelling runs. On average a reduction of less than or around 0.1 stars was seen when bridging from any frame material was included in the modelling. The top floor apartment which has a framed ceiling/roof system as well as the external walls, saw some impacts, especially for the metal framed options. Including bridging from the timber frame saw only a small reduction of 0.1 stars. However, an average reduction of 0.58 stars was recorded for designs with a metal frame that did not incorporate a thermal barrier using the NZS4214 implementation. Including a thermal barrier improved this to an average reduction of 0.32 stars.

It was found that with thermal barriers applied, the NZS4214 and the ISO implementation give similar star rating results for both the house and apartment design variations, although the NZS4214 generally gives slightly worse star rating results.

In order to bring the thermal performance of metal framed dwellings to be in line with the corresponding timber framed dwellings, insulation adjustment was carried out for the metal framed dwelling designs to maintain the same total R values for all the thermal bridged constructions. As expected, the thermal performance with these insulation adjusted dwelling designs are very close to their corresponding timber framed dwellings with star rating differences within ±0.1 stars.

1 Introduction

Nationwide House Energy Rating Scheme (NatHERS) software calculates the thermal energy loads of a residential building, based on information about the design and construction, climate and common operation patterns of household use. NatHERS software currently does not take thermal bridging into account in regulation mode, although in its non-regulation mode, the AccuRate software does provide the de-rating of insulation values due to thermal bridging.

The Australian Building Codes Board (ABCB) has requested the NatHERS Administrator (the Department of Industry, Science, Energy and Resources (DISER)) to include thermal bridging in its regulation mode for the National Construction Code (NCC) 2022 update. The intent is to better align the NatHERS compliance pathway with the other compliance pathways in the NCC.

DISER commissioned CSIRO to develop a set of thermal bridging default parameters; provide modelling guidance on how to apply these defaults for NatHERS rating; and determine the impact of applying these defaults on residential building energy ratings. This report details the methodology and findings of this work.

2 Methodology and Background Information

The aim of this work was to develop a set of thermal bridging default parameters; provide modelling guidance on how to apply these defaults for NatHERS rating; and determine the impact of applying these defaults on residential building energy ratings. The method used to achieve this aim was:

1. An overview of the way in which AccuRate currently accounts for thermal bridging in its non-regulation mode is provided. The overview includes how AccuRate incorporates the thermal bridging calculation method in NZS 4214: 2006, AS/NZS 4859.2:2018 and ISO 6946: 1996.
2. Typical planning documentation given to assessors is unlikely to contain all the information required by AccuRate to correctly model thermal bridging. Therefore, a set of assumptions and defaults needed to be developed to cover all the data inputs when the only information that an assessor is given is the frame material (i.e. metal or timber). The defaults needed to be based on the most likely 'worst case' scenario, that was reasonable and realistic. Appendix A was the starting point supplied by DISER. A brief survey of the current practice of framing in the Australia market was conducted to complete the default values for thermal bridging data inputs. The survey also sought to identify further additional thermal bridging materials.
3. AccuRate can model thermal bridging through all ceiling, wall and floor elements, as well as door frames. Applying thermal bridging calculation for all the building elements in a rating is considered impractical and unnecessary. A proposed method (Appendix B) has been developed by DISER in consultation with the ABCB and forms the basis of guidance for assessors on what elements of a building shall be included for thermal bridging calculations. This method was reviewed and updated.
4. Draft instructions were developed on how the default values and assumptions should be applied when conducting NatHERS ratings using AccuRate.
5. A set of 25 dwelling design variations have been developed based on a detached house Class 1 building and a unit Class 2 building. These include five variations with the insulation adjusted for the metal framed dwelling designs to maintain the same total R values as the timber framed designs.
6. Simulations were carried out using AccuBatch for all the 25 dwelling design variations in all the 69 NatHERS climate zones, applying the thermal bridging defaults, using the new NatHERS weather files – NatHERS 2016_RMY (Nov 2017 version).
7. The impact of thermal bridging on energy rating was demonstrated by analysing/comparing energy rating results for all the AccuBatch simulation results.

2.1 Overview of how AccuRate accounts for thermal bridging when in non-regulation mode

Since 2011, AccuRate Sustainability has included the thermal bridging effect in its non-regulation mode. In AccuRate Sustainability, the thermal bridging effect for non-metal frame and metal frame constructions are calculated differently.

2.1.1 Non-metal frame thermal bridge calculation

According to Australian/New Zealand Standard 'AS/NZS 4859.2:2018 Thermal insulation materials for buildings - Part 2: Design', the method of NZS 4214 shall be used to calculate the total thermal resistance of a building element assuming appropriate building design conditions (e.g. thermal bridging and compression of insulation under roofs, joists etc). For a non-metal frame, the thermal bridging effect in AccuRate Sustainability is calculated based on the New Zealand Standard 'NZS 4214:2006 Methods of Determining the total Thermal Resistance of Parts of Buildings'. Thermal bridging according to NZS 4214:2006 is determined by the isothermal planes method. Figure 1 illustrates a bridged layer *i* with insulation material 1 and bridging materials 2 and 3. The thermal resistance of layer *i*, i.e., R_i is calculated using Eq. (1).

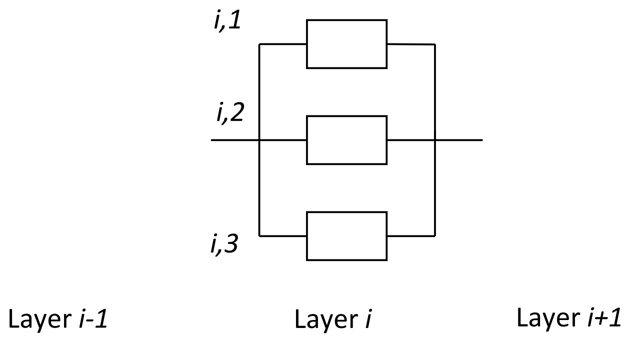


Figure 1. Illustration of a thermal bridged layer *i* with two bridge material *i,2* and *i,3*.

$$R_i = \frac{1}{\frac{f_{i,1}}{r_{i,1}} + \frac{f_{i,2}}{r_{i,2}} + \frac{f_{i,3}}{r_{i,3}}} \quad (1)$$

Here, $f_{i,1}$, $f_{i,2}$, $f_{i,3}$ are the fractional area of material 1, 2 and 3 within layer *i*. $r_{i,1}$, $r_{i,2}$, $r_{i,3}$ are the thermal resistance of the material 1, 2 and 3 within layer *i*. For a construction with *n* layers, the total thermal resistance of the construction is calculated by Equation (2):

$$R_{total} = R_{es} + \sum_{i=1}^{n} R_i + R_{is} \quad (2)$$

Here, R_{es} and R_{is} are the external side thermal resistance and internal side air film thermal resistance. The isothermal planes method Equations (1) and (2) used for non-metal thermal bridge calculation is equivalent to the lower limit resistance R_{lower} calculation specified by ISO 6946:2017.

2.1.2 Metal frame thermal bridge calculation

In a previous study, the thermal bridging effect calculation with metal frame in AccuRate is based on an adaption of the ISO 6946:1996 published by the UK Building Research Establishment (Doran and Gorgolewski, 2002; Gorgolewski, 2007), which is different from NZS 4214:2006. Details on the calculation method and the calculation energy rating results are detailed in Chen et al (2020). In the current study, thermal bridging calculation method are based on NZS 4214:2006. In NZS 4214:2006, the metal frame section is replaced by a notional enclosing equivalent rectangular as shown in Figure 1(c). The thermal resistance of the metal frame section is calculated using Eq. (3):

$$R = \frac{a \times l}{d \times k_m} + R_{c1} + R_{c2} \tag{3}$$

where *a* is the flange width (mm); *l* is the thickness or depth of the metal frame (mm); *d* is the base metal thickness; k_m is the thermal conductivity of the metal; R_{c1} and R_{c2} are the contact resistances between metal frame and facing (assumed to be 0.03 m^2·K/W).

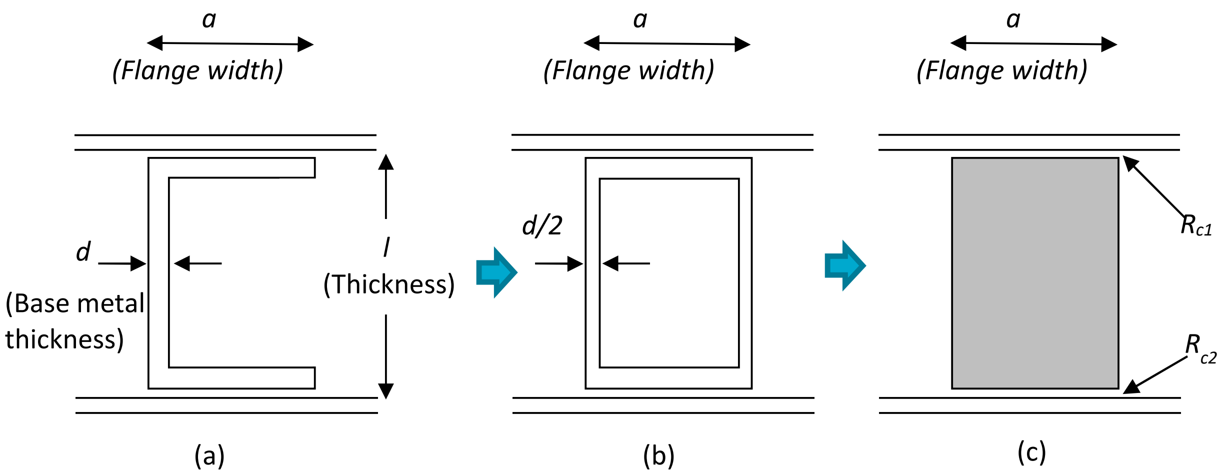


Figure 2. Transformation method for metal frame sections (NZS 4214:2006)

The thermal resistance of the bridged layer as well as the total thermal resistance of the construction are then calculated using exactly the same method as for the timber frame as described in Section 2.1.1.

It is noted that according to NZS 4214:2006, a bridged layer is never bounded by an air space. Therefore, an adjacent air gap and the bridged layer is considered as one layer. This means when writing out the construction layers in the scratch file, the air gap will be missing. This raises difficulties in the current simulation of reflective air gaps since the Chenath engine calculates the air gap resistance based on gap surface temperatures. In this study, we used an approximation method by adding the thermal resistance of the metal frame section with R0.16, which is the unventilated non-reflective 40 mm vertical air gap thermal resistance, while leaves the air gap itself as an independent layer as described in Eq. (4):

$$R = \frac{a \times l}{d \times k_m} + R_{c1} + R_{c2} + R_{airgap} \tag{4}$$

Here the airgap thermal resistance R_{airgap} is fixed at 0.16. With this method, the effect of the airgap on the metal frame section thermal bridging is considered approximation, while avoiding issue in the Chenath simulation for the air gap. A better method may be able to implement in AccuRate based on NZS 4214:2006 by keeping the air gap while reducing the bridged insulation level accordingly. However, such an implementation will require much longer time to complete and is impractical for this study.

2.1.3 AccuRate Sustainability thermal bridge implementation

In the current AccuRate Sustainability implementation, the assessors can choose bridge material from hardwood timber, softwood timber, steel, concrete and small air gap. The assessors can specify the fraction area (the area occupied by the frame over the total area of the construction) or calculate it using the embedded calculator. For each construction, up to four layers may be thermal bridged and for each thermal bridged layer, two thermal bridge materials (Bridge Material 1 and Bridge Material 2) with their specific surface fractions are allowed. Section 3.3 details the inputs for thermal bridges in AccuRate.

2.2 Development of thermal bridging defaults

A brief survey was conducted between June 9 and June 18, 2020. The survey form (Appendix C) was emailed to 16 individuals which include six assessors (among them two NatHERS software trainers), five experts in energy efficiency (among them two insulation experts), four academics with thermal bridging experience and one NatHERS software developer. Seven filled forms (as listed in Appendix D) have been collected with another five feedbacks in writing form but without suggestions in default values and two without comments. For metal frame constructions, the National Association of Steel-framed Housing Inc. (NASH) has been consulted on recommendations for default parameters. The survey also sought to identify further additional thermal bridging materials.

2.3 Thermal break requirements in NCC

The NCC requires a thermal break in metal framed buildings under a variety of circumstances. Technical notes developed by the National Association of Steel-Framed Housing (NASH) were utilised to establish the thermal break requirements for each building element (wall, ceiling/roof and floor). (National Association of Steel-Framed Housing, 2015)

Roof/Ceiling System

Where the roof construction involves metal sheet roofing directly fixed to metal purlins, metal rafters or metal battens and has no internal ceiling lining, or a lining fixed directly to the same member as the sheet roofing, a thermal break of R-Value at least 0.2 must be installed between the metal sheet roofing and the supporting roof framing. It is not required where the internal ceiling lining is fixed to battens or furring channels.

Wall System

Where the wall construction involves lightweight external cladding such as weatherboards, fibre-cement or metal sheeting and has no internal lining, or a lining fixed directly to wall framing, a thermal break of R-Value at least 0.2 must be installed between the external lightweight cladding and the steel frame.

It is not required for brick veneer construction, or where the internal lining or external cladding is fixed to battens or furring channels. The thermal break does not form part of any additional insulation the wall may require unless it extends beyond the frame across the entire wall. Expanded polystyrene 12mm thick or timber 20mm thick are deemed to achieve the required thermal break R-Value.

Floor Systems

Where the perimeter of the underfloor space is enclosed the underfloor air space and its enclosure may be included in the total R-Value calculation. A barrier is required to prevent convection into wall cavities.

Concrete slabs, both on ground and suspended, have specific installation requirements where in-slab heating is installed, and slabs-on-ground require insulation in very cold climates.

2.4 Sample dwellings used in this study

A series of framed construction types was rated using the instructions developed. The rating results of all framing construction types were then compared to the status quo in all 69 NatHERS Climate Zones. The following house configurations have been developed to establish the status quo benchmarks. The aim of all the status quo designs was to ensure that all base designs meet or exceed 6 stars in all capital cities. The specifications of the designs were adjusted to allow this to be achieved but no individual modifications have been undertaken to achieve the 6-star results for a particular climate zone. The following house configurations were used:

i. Detached Class 1, single storey, 4 bedroom, attached garage – Brick veneer on waffle pod slab.
    a. Status quo rating method (AccuRate working file for this already exists)
    b. Assuming metal frames (including at least R0.2 thermal breaks, as per NCC requirements)
    c. Assuming metal frames (excluding thermal breaks, for comparison purposes)
    d. Assuming wood frames

    e. Adjusted metal frame (to be equivalent to timber frame)

ii. Detached Class 1, single storey, 4 bedroom, attached garage – Exterior metal cladding with a suspended floor

    a. Status quo rating method
    b. Assuming metal frames (including at least R0.2 thermal breaks, as per NCC requirements)
    c. Assuming metal frames (excluding thermal breaks, for comparison purposes)
    d. Assuming wood frames
    e. Adjusted metal frame (to be equivalent to timber frame)

iii. Detached Class 1, single storey, 4 bedroom, attached garage – Lightweight cladding (eg fibre cement) on a waffle pod slab.

    a. Status quo rating method
    b. Assuming metal frames (including R0.2 thermal breaks, as per NCC requirements)
    c. Assuming metal frames (excluding thermal breaks, for comparison purposes)
    d. Assuming wood frames
    e. Adjusted metal frame (to be equivalent to timber frame)

iv. Sole Occupancy Unit Class 2 (apartment) – Exterior aluminium cladding with suspended concrete floor and ceiling/roof (Ground Floor Apartment in modelling runs).

    a. Status quo rating method (AccuRate working file for this already exists)
    b. Assuming metal frames (including R0.2 thermal breaks, as per NCC requirements)
    c. Assuming metal frames (excluding thermal breaks, for comparison purposes)
    d. Assuming wood frames
    e. Adjusted metal frame (to be equivalent to timber frame)

v. Sole Occupancy Unit Class 2 (apartment) – Exterior aluminium cladding with framed floor and ceiling/roof (Top Floor Apartment in modelling runs).

    a. Status quo rating method (AccuRate working file for this already exists)
    b. Assuming metal frames (including R0.2 thermal breaks, as per NCC requirements)
    c. Assuming metal frames (excluding thermal breaks, for comparison purposes)
    d. Assuming wood frames
    e. Adjusted metal frame (to be equivalent to timber frame)

The detached class 1 dwellings all utilise the same design layout as shown in Figure 3, which is based on Design 100 developed for the NatHERS Software Accreditation Protocol. However, in order to achieve a 6-star result in all capital cities design ii (suspended timber floor with an exterior metal clad) required some additional modifications to the original design. These included:

- Change in orientation – house was rotated 90 degrees clockwise to allow the original west facing windows to face north.
- Reduction in window area – 10% reduction in the area of the main windows.

- Subfloor added and insulated – a sub floor space was added and was insulated with R2.5 insulation. Sub floor is modelled as enclosed.
- Ceiling insulation increased to R6.0 from R4.0.
- Downlights insulated.
- Ceiling fans added to bedrooms and living areas.

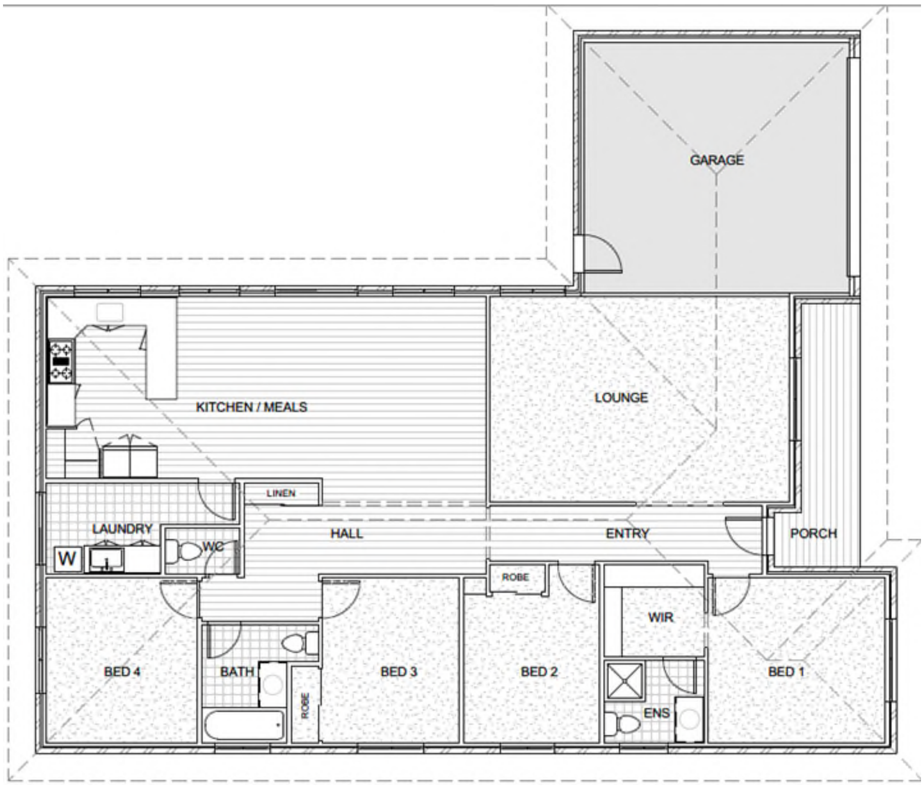


Figure 3 Class 1 floor plan

The two sole occupancy class 2 apartments both use the same design layout as shown in Figure 4, which is based on Design 630 developed for the NatHERS Software Accreditation Protocol. The inclusion of class 2 apartments with framed floor and ceiling/roof is for investigating the potential impact for low-rise units, such as units in two or three storey buildings.

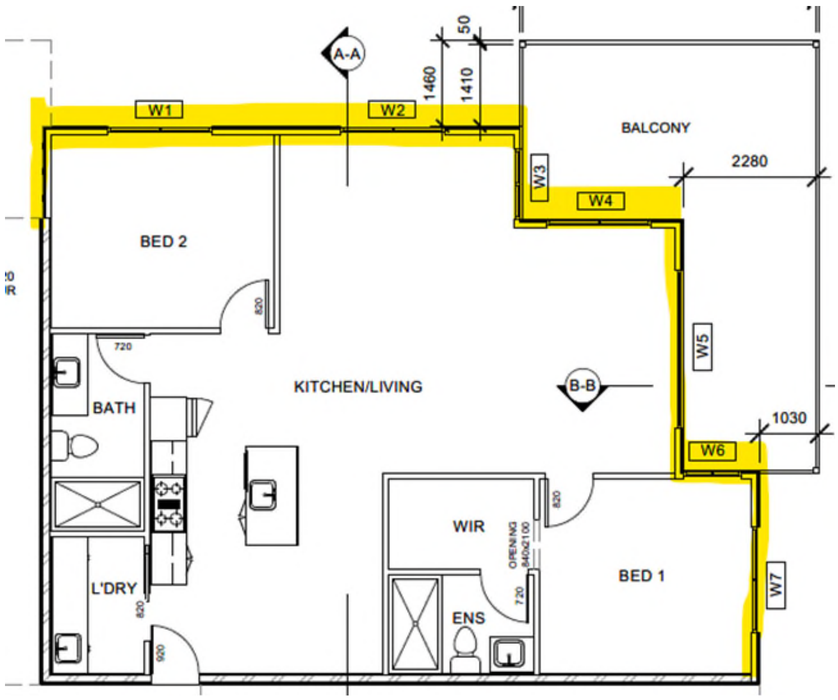


Figure 4 Class 2 floor plan

2.5 AccuRate version and weather files used in this study

In this research, AccuRate Sustainability v2.4.3.21_Trial12 with the new NatHERS weather files NatHERS2016_RMY (Nov 2017 version) was used as recommended by DISER considering that the new NatHERS weather files will likely be required to use in NCC 2022. This Trial version of AccuRate has also included the updated area correction as well as star bands based on materials supplied by NatHERS administrator.

2.6 Conducting energy ratings using AccuRate and AccuBatch

Batch simulations for sample dwellings for all 69 NatHERS climate zones were carried out using AccuBatch v2.6.0.0 in combination with AccuRate Sustainability v2.4.3.21_Trial12. AccuRate Sustainability v2.4.3.21_Trial12 is exactly the same as the commercial version of AccuRate Sustainability v2.4.3.21, except that the former has included the new NatHERS2016_RMY (Nov 2017 version) weather files, the corresponding area correction and star bands, and the metal frame NZS4214 method impelementation. AccuBatch v2.6.0.0 has also incorporated the updated weather information and thermostat settings based on NatHERS2016_RMY (Nov 2017 version).

Adding thermal bridging parameters to a simulation is done through the non-rating mode of AccuRate. Thermal bridging parameters can be applied to any construction system that may have a structural framing system associated with it. This includes wall, roof, ceiling and floor systems. Thermal bridging occurs through the structural framing material and mostly has an impact where construction elements are bounded by an indoor conditioned space and the external environment, so external walls, raised floors, raked/cathedral roof ceiling systems and ceilings that have a roof space above them are the most critical. Internal walls are not as critical even though they may have structural framing as part of their system.

The thermal bridging framing material is associated with the construction system layer where the framing system would be located. For example, Figure 5 shows a typical construction system for a brick veneer wall. The structural framing material would usually be found where the insulation material layer is added in AccuRate. In this example this is layer 3, so the “Bridged” check box is checked to indicate that a bridging frame material is present in this layer.

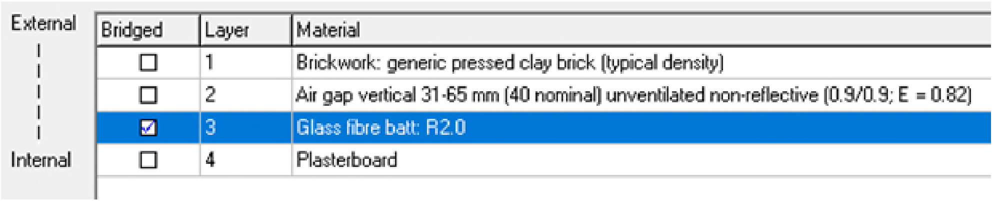


Figure 5 Applying a bridging material to an external wall layer

The bridging framing material is selected from the available bridging materials list (Figure 6) and then the bridging framing data for that material selection is entered (Figure 7). The framing data includes the frame material dimensions, the spacing of the frame members and the inclusion of noggings and their dimensions and spacings. These details then allow a frame fraction (the area occupied by the frame over the total area of the construction) to be calculated if the Calculate Fraction check box is ticked. Users can also manually enter the frame fraction calculation in which case the frame dimensional data are ignored except that the Flange width and frame depth for steel frame are still used for the thermal bridging calculation as described in Eq. (3). As shown in Figure 7, AccuRate Sustainability v2.4.3.21_Trial12 has also implemented the input for thermal break and the air gap information which is necessary as described in Section 2.1.2. Details on thermal bridging input using AccuRate Sustainability v2.4.3.21_Trial12 will be discussed in the next section.

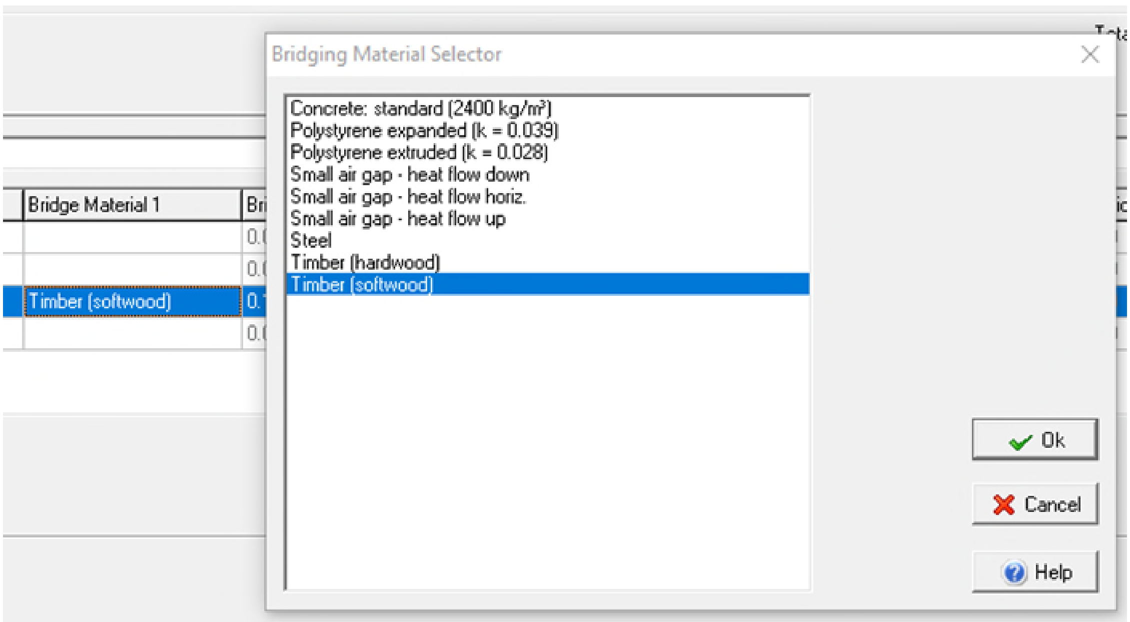


Figure 6 Bridging framing material selection

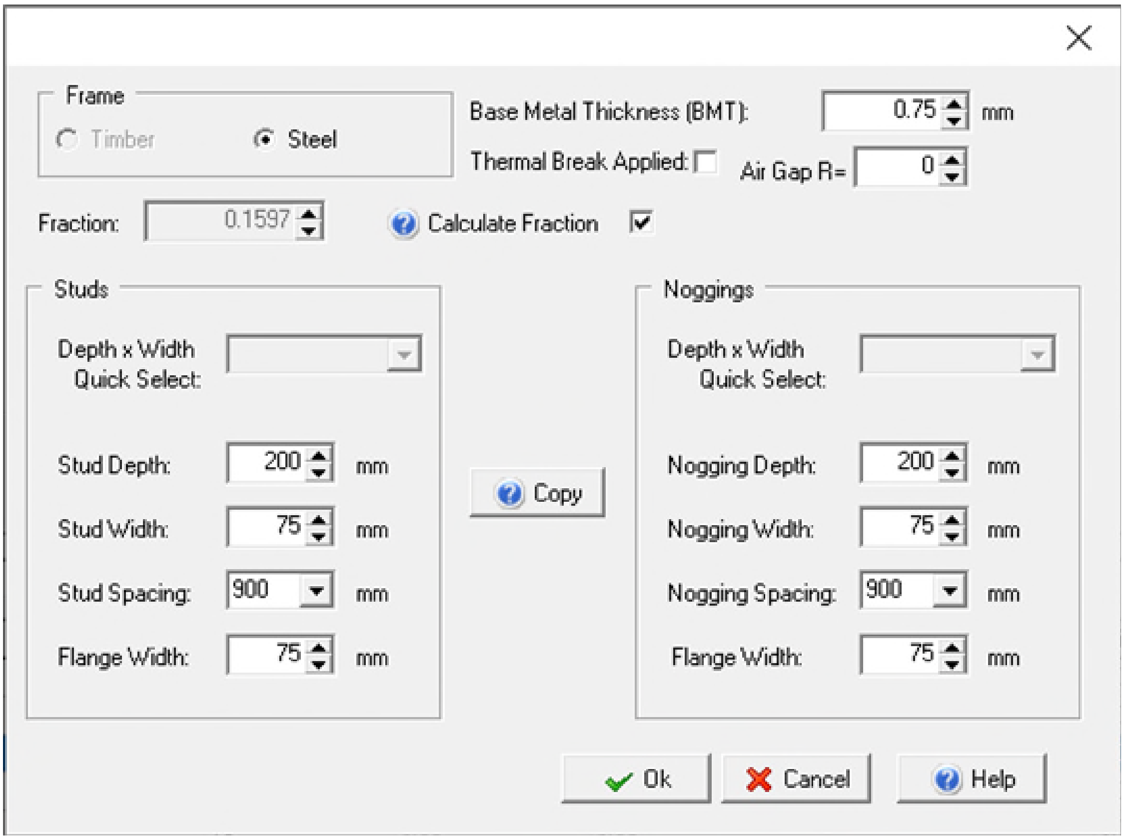


Figure 7 Bridging framing data

3 Results and Discussion

3.1 Thermal bridging default values and assumptions

The survey form (Appendix C) was emailed to 16 individuals which include six assessors (among them two NatHERS software trainers), five experts in energy efficiency (among them two insulation experts), four academics with thermal bridging experiences and one NatHERS software developer. Seven filled forms (as listed in Appendix D) have been collected with another five feedbacks in writing form but without suggestions in default values and two without comments.

It is understood that thermal bridge is an important aspect for building thermal performance calculation. However, accurate evaluation of thermal bridge is complex and challenging, especially for metal frames. The recommendation is that due to the relatively significant impact of thermal bridging on thermal performance of residential buildings, NatHERS software should consider thermal bridge, however, with simplified parameter inputs which account for the major thermal bridging effect.

3.1.1 Default parameters for timber frames

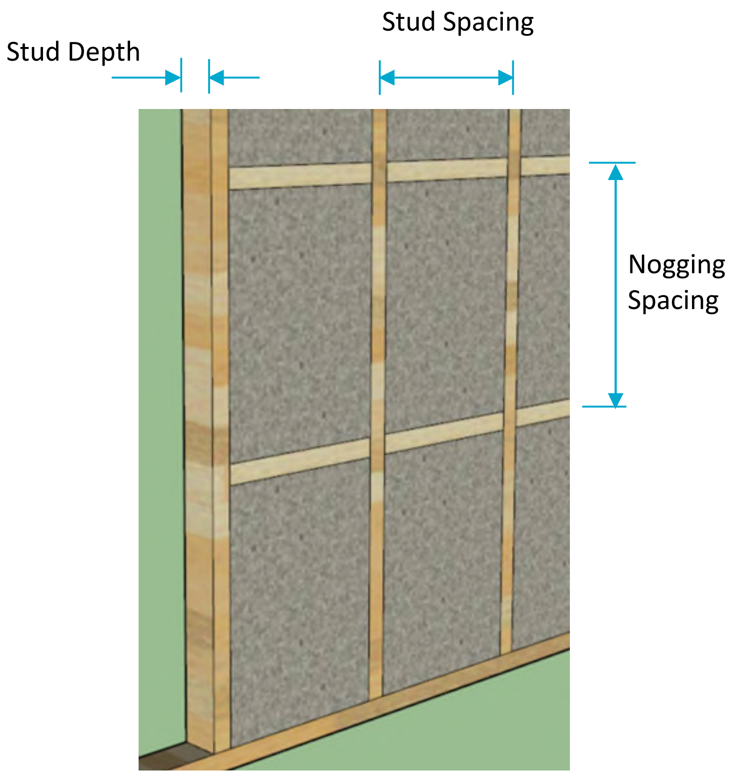
With the survey results, the parameters for timber frame are in general consistent or close among the survey respondents. Default parameters in Table 1 are recommended as the reasonable “worst case”, although they may be not the absolute “worst case”.

Figure 8 (a)-(b) illustrate the thermal bridging in a timber framed wall (a), and floor/ceiling/roof (b) respectively.

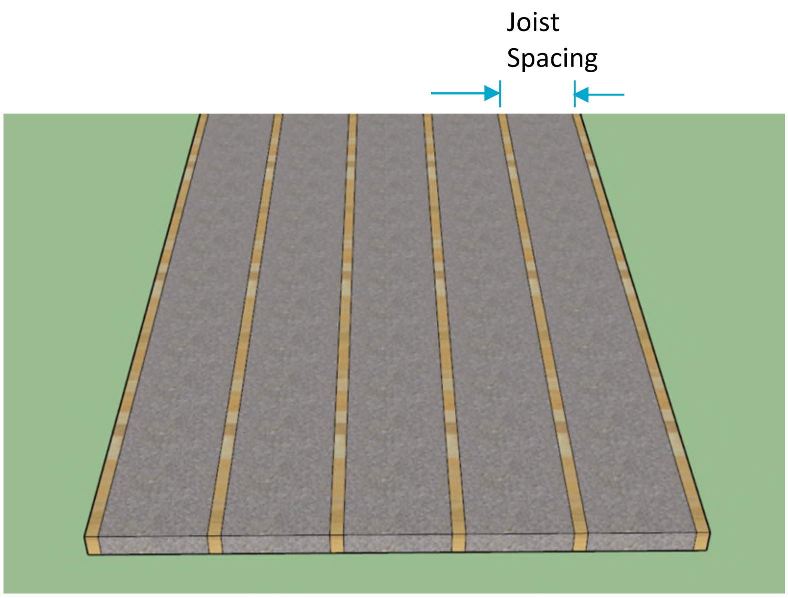
For walls, as the reasonable “worst case”, stud and nogging dimension are recommended to be 90 mm × 45 mm with the stud spacing at 450 mm and the nogging spacing of 600 mm.

For floors, as the reasonable “worst case”, the default joist dimensions are recommended to be 140 mm × 45 mm with the joist spacing at 450 mm. For ceilings, the default joist dimensions are recommended to be 140 mm × 45 mm with the joist spacing at 600 mm. For raftered roofs with concealed rafters, the default rafter dimensions are recommended to be 140 mm × 45 mm with the rafter spacing at 600 mm.

It should be noted that a modern floor/ceiling/roof may not really have noggings/battens acting as thermal bridge in practice, as illustrated in Figure 8. Consequently, in Table 1, the default dimensions for noggings/battens are suggested to be “not required” for the thermal bridging calculation for floor/ceiling/roof constructions.



(a)



(b)

Figure 8 thermal bridging in (a) timber framed wall, and (b) floor/ceiling/rafter roof

3.1.2 Default parameters for metal frames

The parameters for metal frames appear relatively inconsistent among respondents, perhaps due to the different metal frame products for structural and non-structural elements. Default values for metal frame construction elements were finalised with the help of Mr Mike Kelly (2020) from the National Association of Steel-framed Housing Inc. (NASH). The default values recommended in Table 1 are for non-cyclonic regions, which are used for thermal bridging impact analysis in this study. For cyclonic regions, the default values in Appendix E should be used.

For walls, as the reasonable “worst case”, stud and nogging dimensions are recommended to be 90 mm × 40 mm with the stud space at 600 mm and a midspan nogging space of 1200 mm considering a ceiling height of 2.4 m. A 0.75 mm base metal thickness (BMT) is recommended for steel frame. As shown in Figure 2, the thermal bridging calculation method for metal frame in NZS4214 implicitly assumes that there is an air cavity between the insulation edge and the base of the metal frame (refer to Figure 9), i.e. insulation is not inserted into the cavity of the steel frame. This is different from Chen et al. (2020) which assumed the insulation is inserted into the cavity of the steel frame based on the recommendation by Kelly (2020) from NASH.

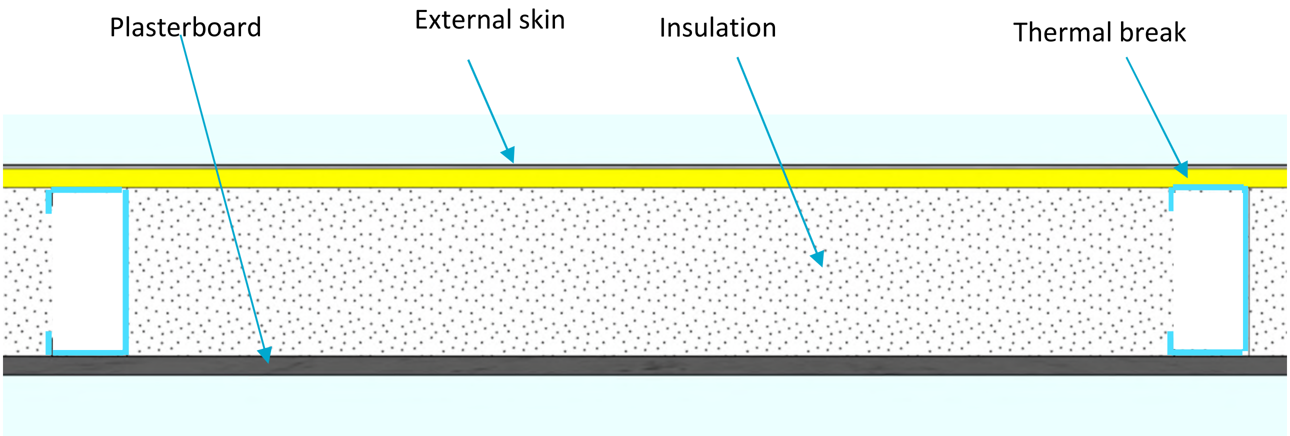


Figure 9 Illustration of a steel framed construction with a continuous thermal break

For floors, as the reasonable “worst case”, the default joist dimensions are recommended to be 100 mm × 50 mm with the joist space at 450 mm and a 1.5 mm base metal thickness (BMT). For ceilings, the default joist dimensions are recommended to be 90 mm × 40 mm with the joist space at 900 mm and a 0.75 mm base metal thickness. For raftered roofs with concealed rafters, the default rafter dimensions are recommended to be 200 mm × 75 mm with the rafter space at 900 mm and a 1.5 mm base metal thickness. Similar to timber frame, since a modern floor/ceiling/roof does not have noggings/battens acting as thermal bridge in practice, the default dimensions for noggings/battens are suggested to be “not required” for thermal bridging calculation for floor/ceiling/roof constructions.

From the survey, no further new bridging material has been suggested. One survey response suggested that Insulbreak 6.5mm (aircell product with R0.20) has been used for thermal break. According to Kinspan (2019), this product may have been updated as the AIR-CELL InsulBreak 70 which has a thermal resistance of R0.20. Since the installation of the AIR-CELL Insulbreak 70 covers the entire element, such a thermal break can be represented with a R0.20 thermal insulation layer in AccuRate simulations as shown in Figure 9.

In NZS 4214:2006, the thermal bridging effect due to metal fixing such as metal wall ties or screws is not considered. We recommend that this thermal bridging effect as generally minor be not included for NatHERS rating purposes.

Table 1 Proposed defaults for information not contained in building plans

Element		Wood (both soft and hard wood)	Steel frame
Roof elements – raftered roofs with concealed rafters or horizontal ceilings **Dependent on the design, thermal bridging may not need to be considered for roof elements. The dimensions listed are the defaults if thermal bridging exists.**	Rafter dimensions	140 x 45 mm	200 x 75 mm
	rafter spacing	600 mm	900 mm
	Base Metal Thickness	N/A	1.5
	Flange width	N/A	75 mm
	batten dimensions	N/R	N/R
	batten spacing	N/R	N/R
Walls	Stud dimensions	90 x 45 mm	90 x 40 mm
	Stud spacing	450 mm	600 mm
	Flange width	N/A	40 mm
	Base Metal Thickness	N/A	0.75 mm
	Nogging dimensions	90 x 45 mm	90 x 40 mm
	Nogging spacing	600 mm	1200 mm
Floors	Joist dimensions	140 x 45 mm	100 x 50 mm
	Joist spacing	450 mm	450 mm
	Flange width	N/A	50 mm
	Base Metal Thickness	N/A	1.5 mm
	Nogging dimensions	N/A	N/A
	Nogging spacing	N/A	N/A
Horizontal Ceiling	Ceiling joist dimensions	140 x 45 mm	90 x 40 mm
	Ceiling joist spacing	600 mm	900 mm
	Flange width	N/A	40 mm
	Base Metal Thickness	N/A	0.75 mm
	Nogging dimensions	N/A	N/A
	Nogging spacing	N/A	N/A

Notes: **Consistent to NZS 4214:2006, the thermal bridging effect of the ties or nails are not considered.**

N/R: not required.

3.2 Review of proposed application of thermal bridging

After reviewing the DISER supplied application of thermal bridging table (Appendix B), we found that the recommendations are mostly adequate. Minor suggestions (highlighted) are recommended as in Table 2 and the notes below.

Table 2 Proposed application of thermal bridging

Building element	Apply thermal bridging calculations?
Attached, unconditioned garage walls (Class 1)	Ignore the exterior walls of unconditioned attached garages. The shared garage/internal wall of the dwelling effectively becomes the dwelling's exterior wall for thermal bridging calculations. Ignore the floor and ceiling of the attached, unconditioned garage for thermal bridging purposes.
Attached, conditioned garage walls (Class 1)	Calculate thermal bridging for the external walls of the garage, as well as its ceiling and floor (if applicable). Thermal bridging may be ignored for the wall between the garage and the rest of the dwelling.
Suspended floors above unconditioned garages (Class 1)	Yes
Suspended floors above conditioned garages (Class 1)	No
External walls	Yes. Exclude attached garage 'exterior' walls unless garage is conditioned.
Internal walls	No, only if they border unconditioned garages.
Class 2 apartment walls and floors adjacent to public areas	Yes, but only where apartment walls or floors border non-neighbour'* spaces (refer Tables 2 and 3 of the NatHERS Technical Notes for definitions) such as stair wells, corridors, car parks, and other shared public spaces
Ceilings between sole occupancy class 2 dwellings	No, close enough to 'neighbour'
Internal door frames	No
External door frames	No
Window frames	Currently done as part of the window U value calculation.
Suspended ground floors	yes
Suspended upper floors above outside air	Yes
Mid-floors within single dwellings (ie 2 storey or more storey class 1)	No, close enough to 'neighbour'

Ceilings within two (or more) storey class 1 dwellings, leading to an occupied upstairs zone (conditioned or unconditioned) NB, this does not mean to a roof space	No, close enough to 'neighbour'
Ceilings in conditioned zones that lead to outside air (eg roof cavities)	Yes
Ceilings in unconditioned zones that lead to outside air (eg roof cavities)	Yes, only if bathrooms, laundries, airlocks, WC, cellars. Not garages.
Steel framing between tilt-up concrete panels	No

*The NatHERS software term 'neighbour' refers to a situation where the temperature conditions on either side of a wall/floor/ceiling are considered to be the same. This results in no heat movement through the wall/floor/ceiling. For instance, where a wall between two apartments separate opposing living rooms, they are considered to 'neighbour' one another, because they are assumed to be kept at the same temperatures (even though this is highly unlikely in real-life). Sometimes, the term 'neighbour' is used to describe adjacencies that we know aren't exactly the same as one another, but are 'close enough'. For instance, one apartment's living room that is adjacent to another apartment's bedroom.

Note:

1) As per the NCC, thermal breaks must be installed on walls and ceilings where the wall or ceiling cladding is attached to a metal frame.
2) In Table 2, ceiling also includes ceiling of flat, skillion or cathedral roof which are named as roof construction in AccuRate.
3) Thermal bridging effect is allowed to be calculated for construction elements for which thermal bridge calculation is not required in Table 2.

3.3 How to apply the default values and assumptions in AccuRate (The modelling guide)

3.3.1 Modelling thermal break in AccuRate

As discussed in Section 2, AccuRate Sustainability v2.4.3.21_Trial12 allows for framing materials and thermal bridging parameters to be set in its non-rating mode. For each of the designs modelled, different thermal bridging and framing options were selected. For the status quo designs, no framing or thermal bridging options were selected as this represents how the current NatHERS ratings are undertaken. For the timber framed options, no thermal barrier was applied to the timber frame as none is required under NCC regulations. For the metal framed options, a thermal barrier was simulated for the wall and ceiling/roof elements. No thermal barrier was applied to the floor system of the suspended floor design option for both the timber and steel frame constructions as none is required under NCC regulations. It should be noted based on the recommendation from ABCB that a metal framed construction should achieve the same thermal performance as a timber framed construction. In this study, dwelling design variations with adjusted timber frame equivalent metal frame (abbreviated as TFEMF hereafter) constructions were also developed for each design. For the TFEMF design variation, thermal barrier may be applied in external wall and suspended floor constructions if it becomes favourable.

Thermal barriers for metal frames can be achieved through several methods. A common approach is to use timber battens or furring channels between the metal frame and either (or both) of the linings of the construction system as shown in Figure 10A and 10B for a wall construction. For example, in the light clad external wall system furring channels or battens could be utilised between the external cladding and the metal frame and/or the internal plasterboard lining and the metal frame. This effectively creates an air gap between the metal frame and the lining and acts as a thermal break. Alternatively, a thermal break strip can be applied to the steel frame and the lining material is then attached to the metal frame through this thermal break strip. A thermal barrier can also be achieved with a continuous thermal break layer such as using the AIR-CELL InsulBreak 70 as shown in Figure 10C.

For continuous thermal barriers such as the AIR-CELL InsulBreak 70, the thermal break layer can be combined in the main insulation layer (by increasing the insulation layer thickness) with “thermal break applied” ticked (which assumes a thermal break R value of 0.25) as shown in Figure 11. For the cases with furring channels, battens or thermal break strips, they all function as a thermal barrier with R-values around 0.2 – 0.25. In AccuRate Sustainability v2.4.3.21_Trial12, they can be represented by ticking the “thermal break applied” in Figure 11, or alternatively by adding in the thermal break insulation level, if known, in the air gap R value.

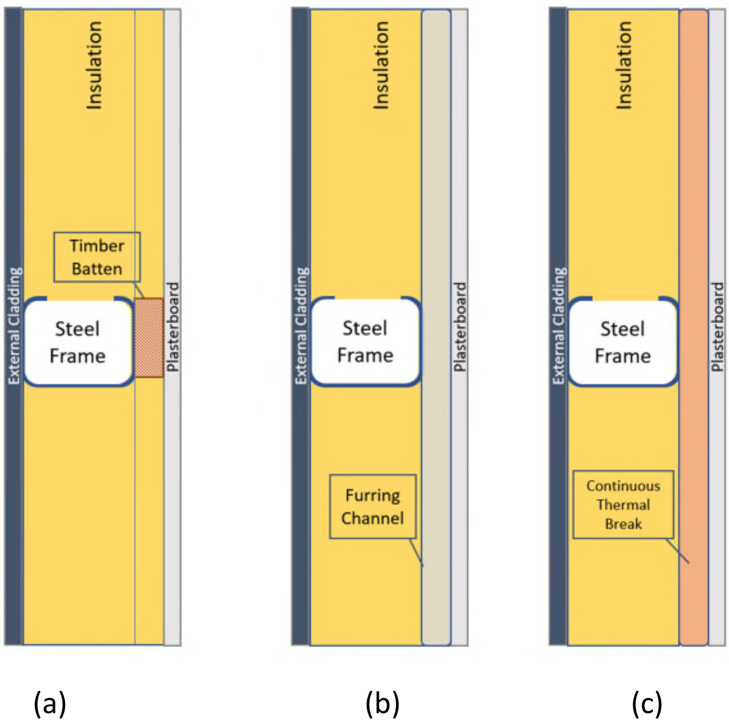


Figure 10 Illustration of a light clad steel frame wall construction (a) timber battens; (b) furring channels; (c) continuous thermal break

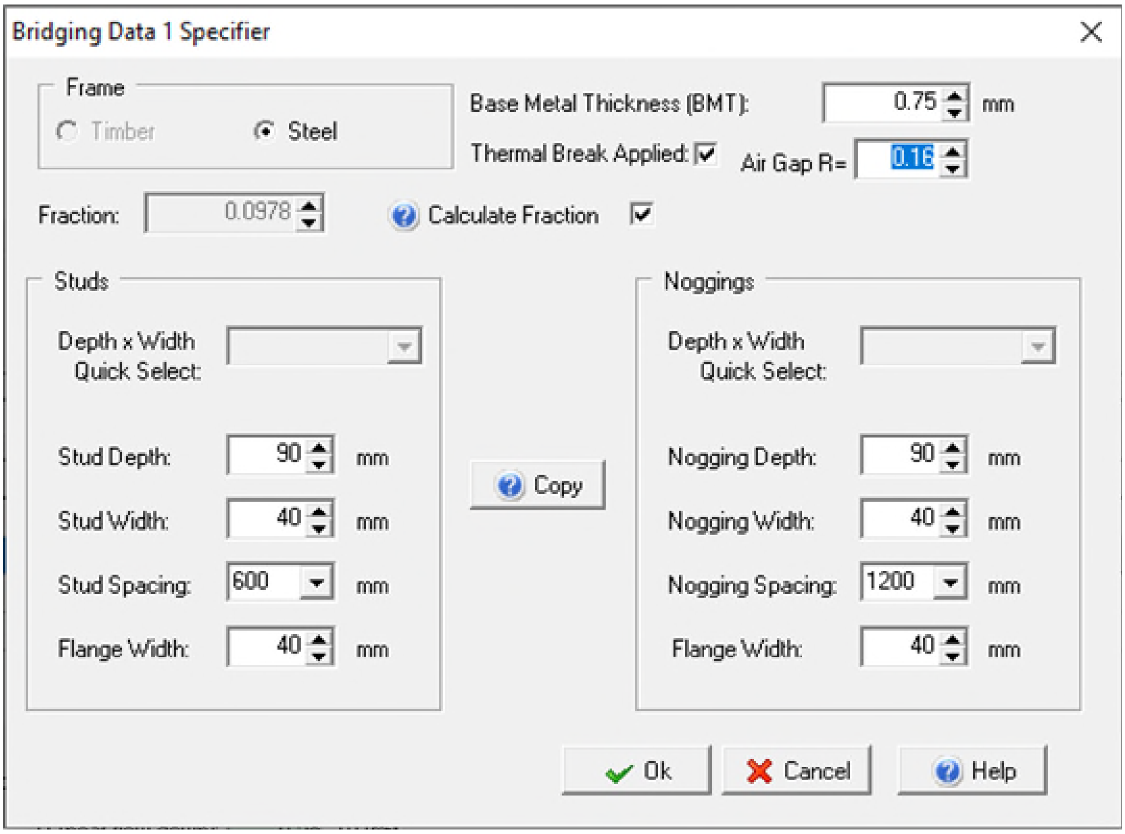


Figure 11 Example of modelling thermal barrier input in AccuRate

3.3.2 Draft modelling guide for timber frame thermal bridging calculation

The following draft modelling guide for thermal bridging calculation is based on AccuRate user interface designs. For timber framed constructions, no thermal break is required under NCC regulations. Thermal bridging input is recommended using the following steps:

1. Check Table 2 “Proposed application of thermal bridging” to determine which constructions should consider thermal bridging effect.
2. If frame parameters are specified in the designs, use the specified frame parameters. Otherwise, the default parameters in Table 1 “Proposed defaults for information not contained in building plans” should be used.
3. Compare the thickness of the insulation layer and the timber frame depth:
    a. If the insulation layer is thicker than the frame depth as shown in Figure 12A (using a ceiling construction as an example), the insulation layer should be separated into two with both thermally bridged: the top insulation bridged by small airgaps and the bottom layer bridged by timber frame.
    b. If the insulation layer is thinner than the frame depth as shown in Figures 12B and 12C (using a wall construction as an example), then, the insulation layer is thermal bridged by the timber frame, while the air gap is treated as normal air gap.

c. If the insulation layer thickness is within 10mm of the frame depth, then, the insulation layer is thermal bridged by the timber frame.

4. Select and tick “bridged” the insulation layer which has timber thermal bridge as shown in Figure 13.

5. Select “Timber (softwood)” as the thermal bridging material as shown in Figure 14. Select “Timber (softwood)”unless hardwood is specified for frame material in the designs.

6. Enter the frame data as shown in Figure 15. Note:

   a. With the current AccuRate implementation, the selected insulation layer is assumed to be bridged to its full thickness. For timber framed constructions, as long as the timber frame fraction is known, the thermal bridging effect can be calculated. Consequently, the assessor may manually enter the frame fraction (and ignore the stud and nogging dimension input) or calculate the frame fraction by entering the stud and nogging dimensions using the automatic calculation tool in AccuRate as shown in Figure 15. The timber frame fraction can be calculated with Equation (5):

$$frame\ \ fraction = \frac{Stud_{width}}{Stud_{spacing}} + \frac{Nogging_{width}}{Nogging_{spacing}} - \frac{Stud_{width} \times Nogging_{width}}{Stud_{spacing} \times Nogging_{spacing}} \qquad (5)$$

   b. There are constructions that noggings are not available or not required to be considered for thermal bridging calculation, e.g. most of the modern ceiling and floor constructions as shown in Table 1 and Figure 7B. In this case, the thermal bridge can be entered by specifying “0” for the nogging space as shown in Figure 16. In this case, the nogging dimensional data are ignored in the frame fraction calculation. Alternatively, the assessor can calculate the frame fraction using Equation (6) and specify manually.

$$frame\ \ fraction = \frac{Joist_{width}}{Joist_{spacing}} \qquad (6)$$

7. If in Step 3, a second insulation layer thermal bridged by small air gaps exists, select the second insulation layer to be thermal bridged. Otherwise, go directly to Step 10.

8. Select “Small air gap – heat flow horiz.” as the thermal bridging material as shown in Figure 17 (Here heat flow horizontal is recommended because for ceiling/floor/roof constructions, we do not know the heat flow direction); and enter the air gap thickness (the depth of the heat flow direction, i.e. the thickness of insulation layer 2 in Figure 12A) and width (the same as the stud width in Figure 12A).

9. Enter the air gap bridging data (refer to Step 6)

10. Confirm the above thermal bridging calculation in AccuRate by the Apply bottom in the construction page.

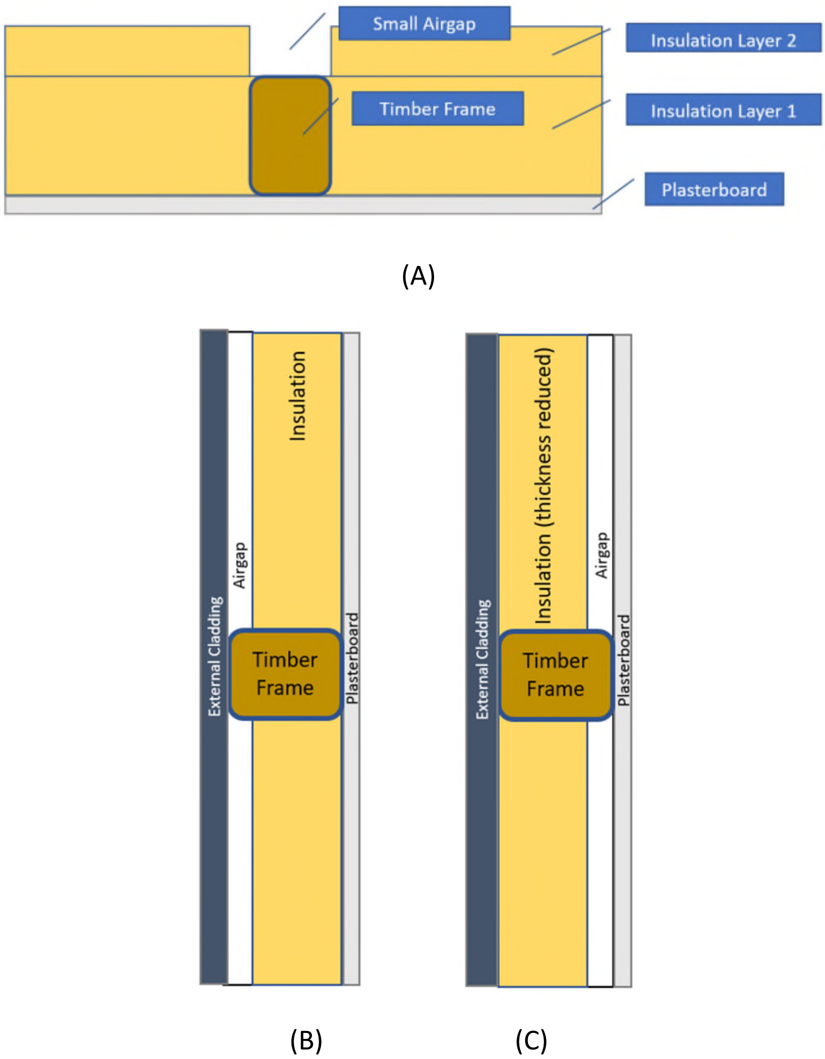


Figure 12 Timber framed construction scenarios: (A) Insulation is thicker than the frame depth; (B) Insulation is thinner than the frame depth, airgap at the inner lining side; (C) Insulation is thinner than the frame depth, airgap at the external skin side.

External	Bridged	Layer	Material
	☐	1	Brickwork: generic pressed clay brick (typical density)
	☐	2	Air gap vertical 31-65 mm (40 nominal) unventilated non-reflective (0.9/0.9; E = 0.82)
	☑	3	Glass fibre batt: R2.0
Internal	☐	4	Plasterboard

Figure 13 Select the insulation layer with thermal bridge

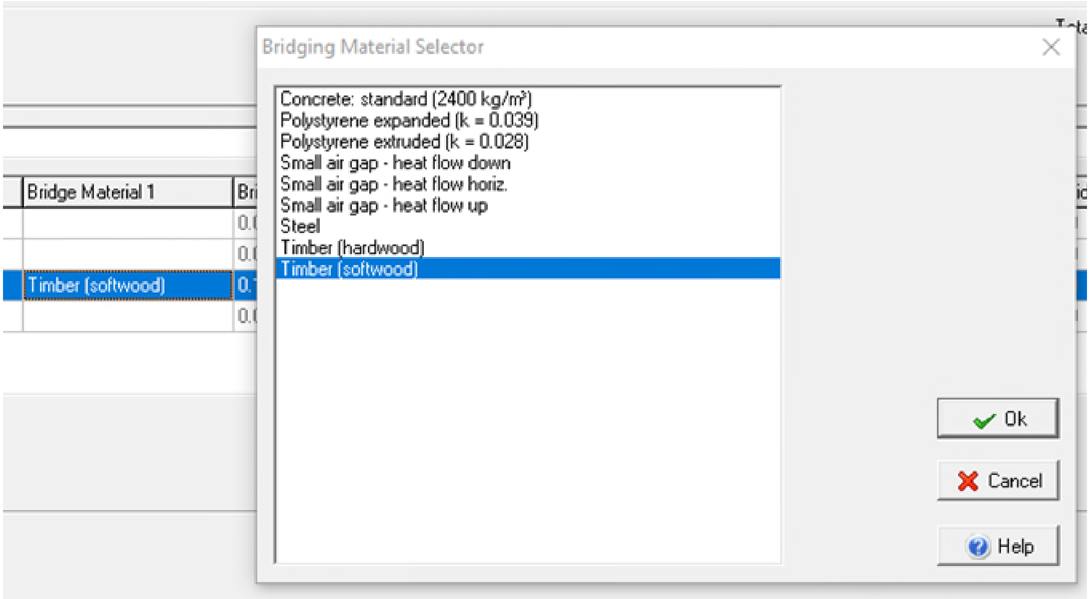


Figure 14 Select “Timber (softwood)” as the thermal bridging material

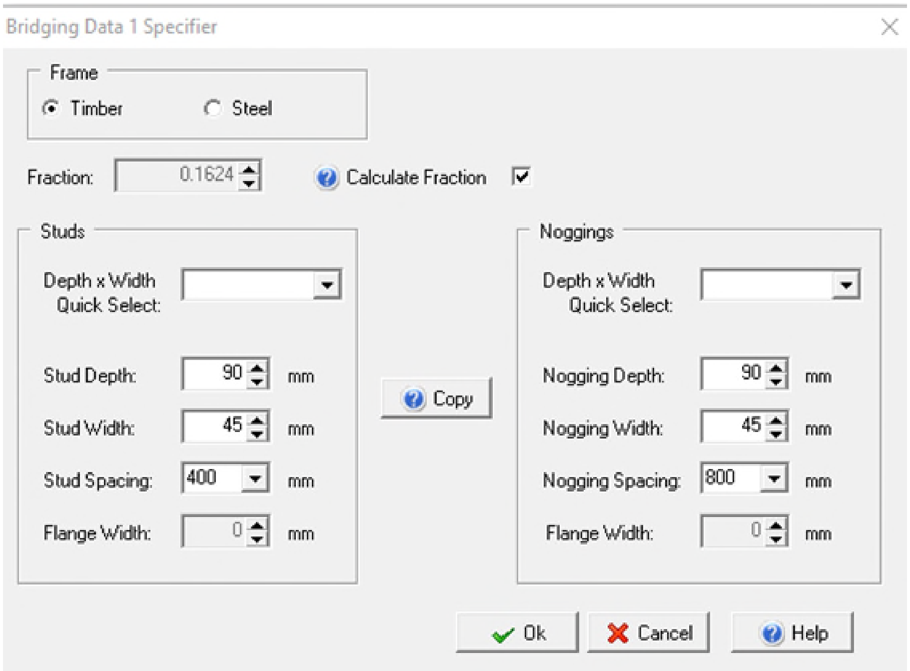


Figure 15 Enter framing data

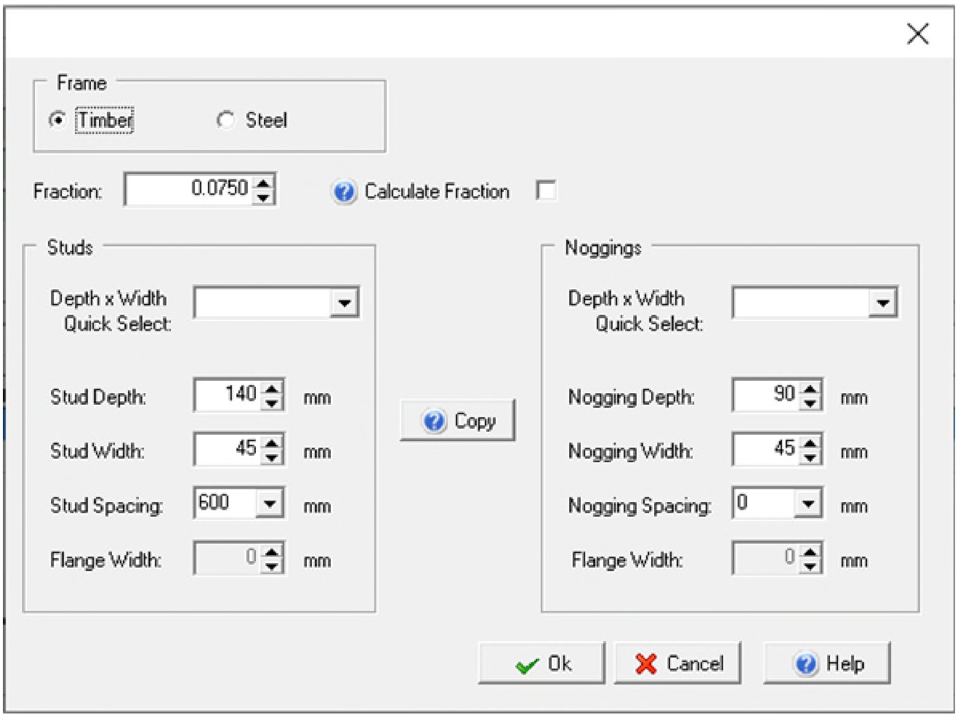


Figure 16 Bridging framing data for timber framed constructions

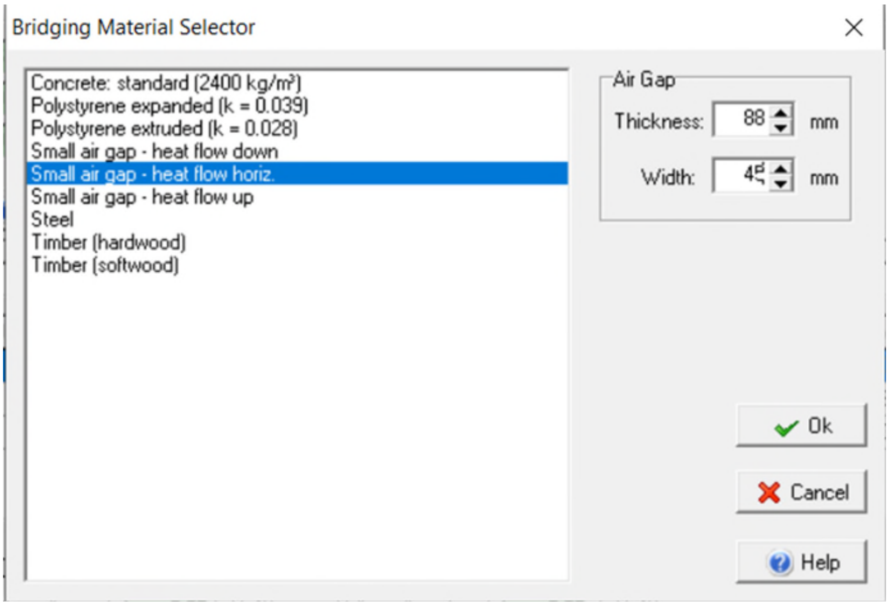


Figure 17 Select "Small air gap – heat flow horiz." as the thermal bridging material

3.3.3 Modelling guide for metal frame thermal bridging calculation – NZS4214

For metal framed constructions, the following steps are recommended for thermal bridging input when using AccuRate Sustainability v2.4.3.21_Trial12:

1. Check Table 2 “Proposed application of thermal bridging” to determine which constructions should consider thermal bridging effect.
2. If frame parameters are specified in the designs, use the specified frame parameters. Otherwise, the default parameters in Table 1 “Proposed defaults for information not contained in building plans” should be used.
3. Determine whether a thermal break is required for the construction in consideration by referring to Section 2.3. In general, for steel framed walls, when both the internal lining and the external skin of the walls are in direct contact with the steel frame, a thermal break is required for reducing the thermal bridging effect. For ceiling and roof constructions, a thermal break/batten/furring channel is required. No thermal barrier is needed for suspended floors.
4. If frame parameters are specified in the designs, use the specified frame parameters. Otherwise, the default parameters in Table 1 should be used.
5. Compare the thickness of the insulation layer and the steel frame depth.
    a. If the insulation layer is thicker than the frame depth as shown in Figure 18A (using a ceiling construction as an example), the insulation layer should be separated into two with both thermally bridged: the top insulation bridged by small airgaps and the bottom layer bridged by steel frame.
    b. If the insulation layer is thinner than the frame depth as shown in Figure 18 (using a wall construction as an example), then, the insulation layer is thermal bridged by the steel frame.
    c. If the insulation layer thickness is within 10mm of the frame depth, then, the insulation layer is thermal bridged by the steel frame.
6. Select the insulation layer which has thermal bridge as shown in Figure 19.
7. Select “Steel” as the thermal bridging material as shown in Figure 20. Enter the frame data as shown in Figure 21. The frame fraction for steel framed constructions can be automatically calculated in the AccuRate UI or manually entered. The steel frame fraction can be calculated with the following equation.

$$frame\ fraction = \frac{Stud_{width}}{Stud_{spacing}} + \frac{Nogging_{width}}{Nogging_{spacing}} - \frac{Stud_{width} \times Nogging_{width}}{Stud_{spacing} \times Nogging_{spacing}} \qquad (7)$$

It should be noted that since the thermal bridging calculation with metal frame is affected by the frame depth, the spacing and the frame flange, these parameters must be entered for metal frame.

There are constructions that noggings are not available or not required to be considered for thermal bridging calculation, e.g. most of the modern ceiling and floor constructions. In this case, the thermal bridging can be entered by specifying “0” for the nogging space as shown in Figure 21. In this case, the nogging dimensional data are ignored. In this case, the frame fraction is calculated using Equation (8).

$$frame\ \ fraction = \frac{Joist_{width}}{Joist_{spacing}} \tag{8}$$

Entering the thermal break and air gap information accordingly:

i. As shown in Figures 18B to 18E, the timber batten (or thermal break strip) and the furring channel can be represented by ticking the “thermal break applied” in Figure 21, while the air gap should be treated as normal air gap.

ii. If a continuous thermal break is used such as Figures 18F and 18G, then an additional insulation thermal break layer should be added in the construction, while the “thermal break applied” box in Figure 21 is ticked.

iii. If an air gap is adjacent the metal frame as shown in Figures 18H-18J, an air gap R0.16 is applied as shown in Figure 21.

8. If in Step 5, a second insulation layer thermal bridged by small air gaps exists, select the second insulation layer to be thermal bridged. Otherwise, go directly to Step 11.
9. Select “Small air gap – heat flow horiz.” as the thermal bridging material as shown in Figure 17 (Here heat flow horizontal is used because for ceiling/floor/roof constructions, we do not know the heat flow direction); and enter the air gap thickness (the depth of the heat flow direction, i.e. the thickness of insulation layer 2 in Figure 18A) and width (the same as the stud width in Figure 18A).
10. Enter the air gap bridging data (refer to Step 6 for the timber framed constructions).
11. Confirm the above thermal bridging calculation in AccuRate by the Apply bottom in the construction page.

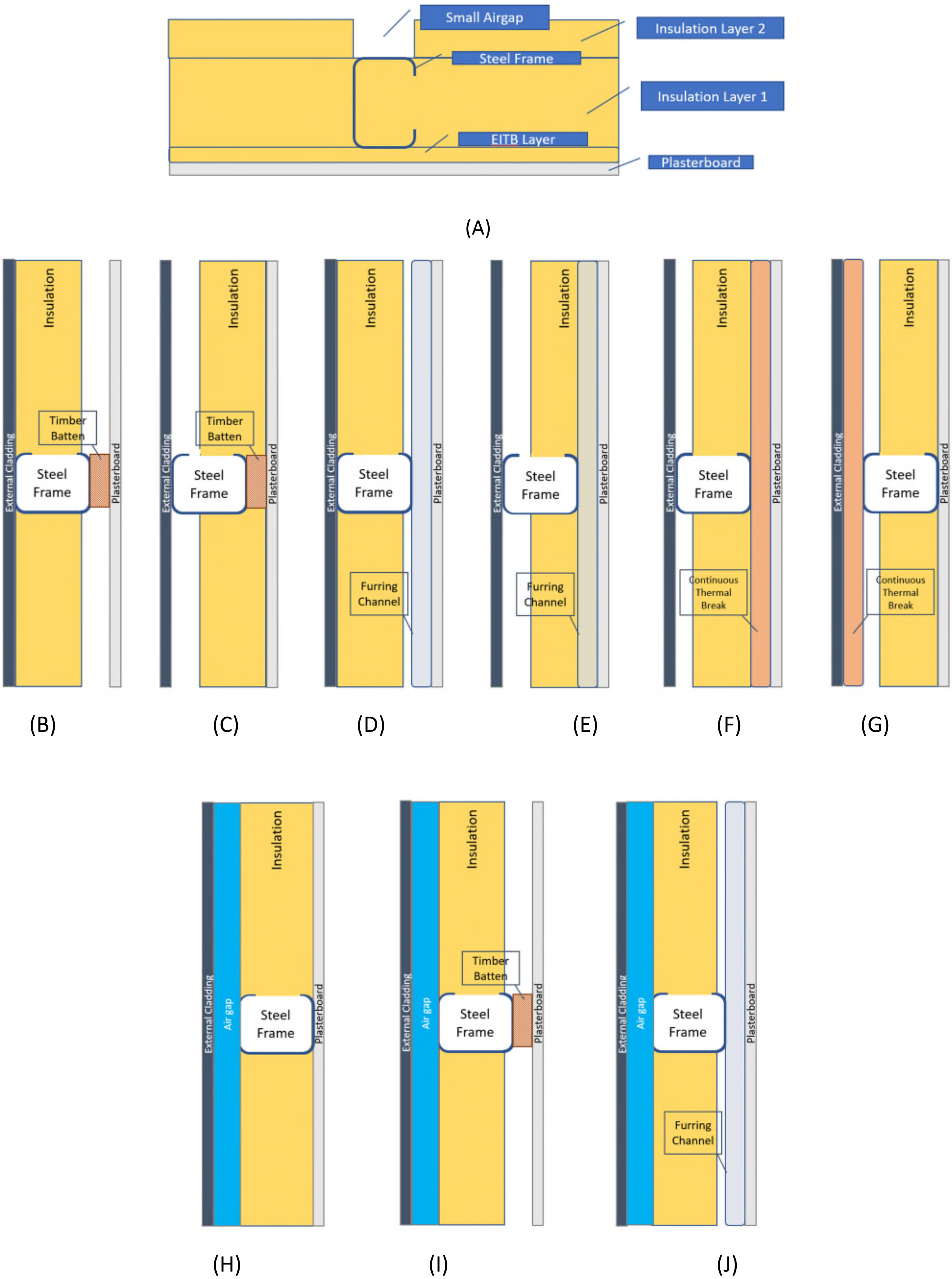


Figure 18 Steel framed construction scenarios: (A) Insulation is thicker than the frame depth; (B)-(J) Insulation is thinner than the frame depth.

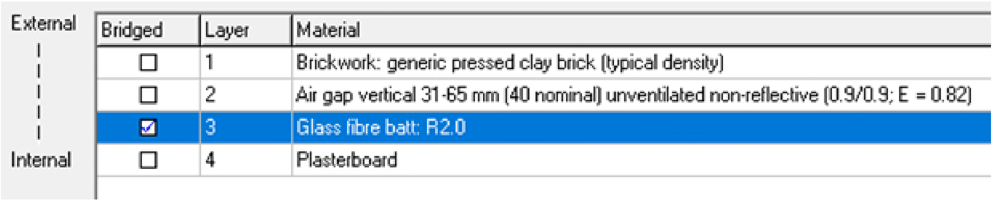


Figure 19 Select the insulation layer with thermal bridge

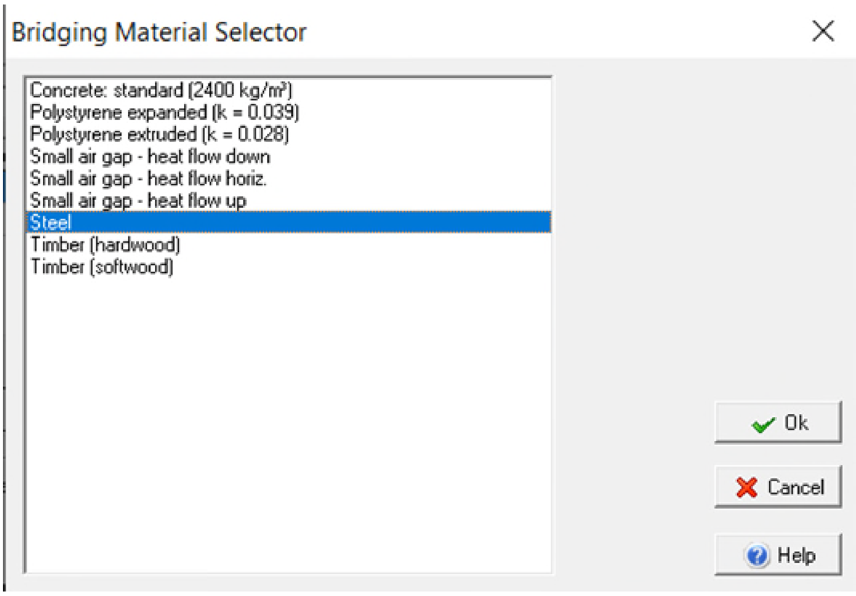


Figure 20 Select “Steel” as the thermal bridging material

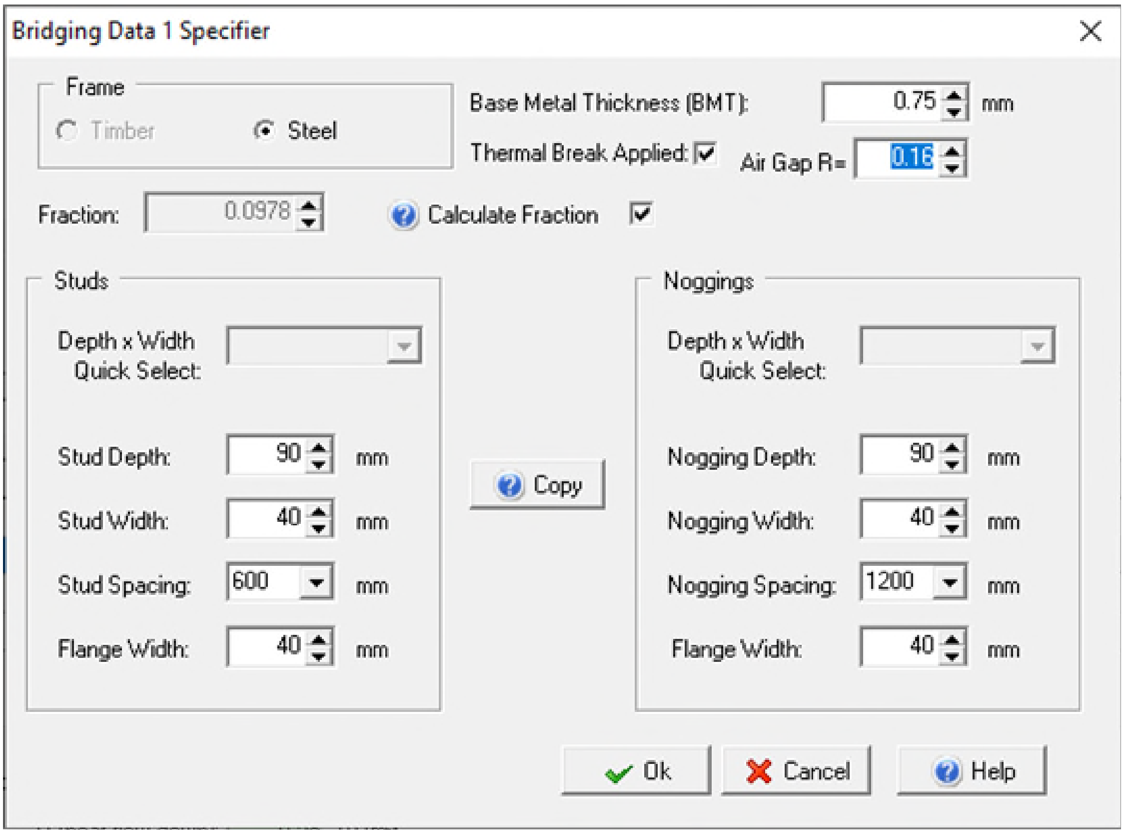
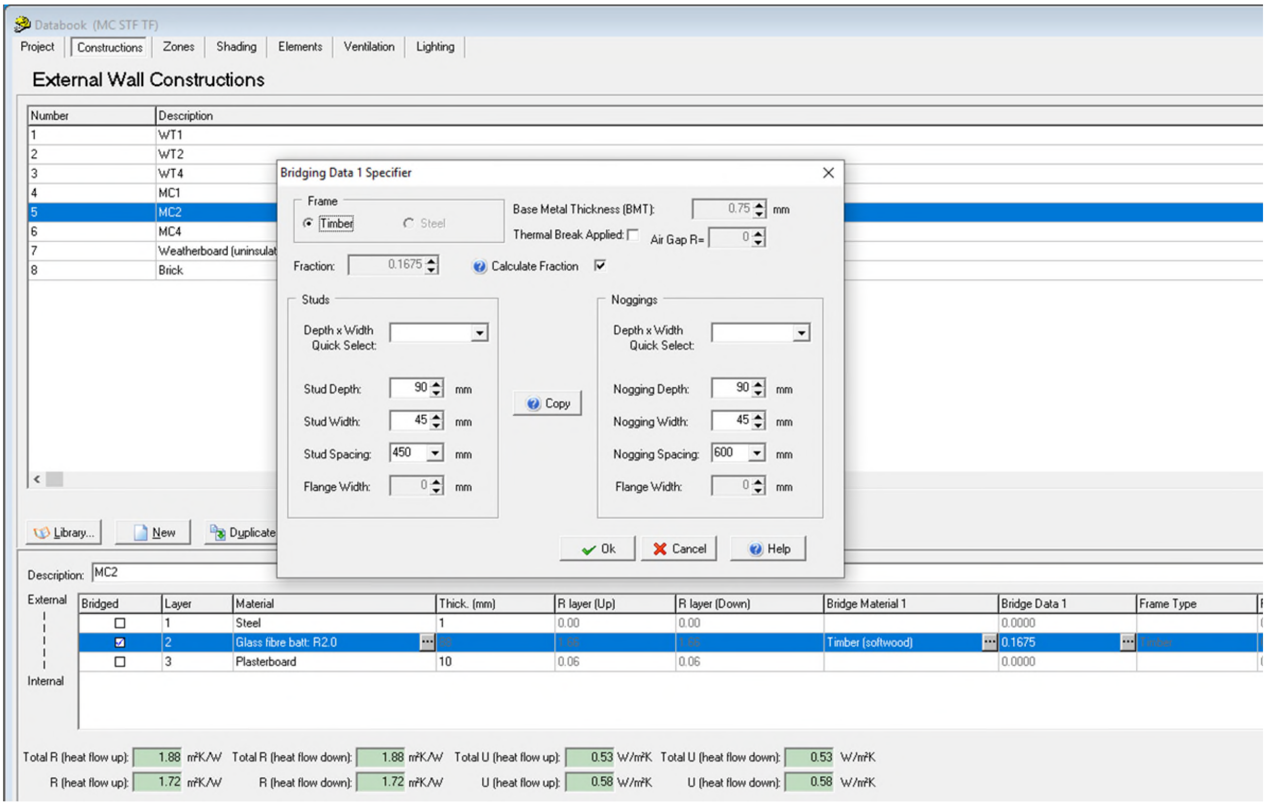


Figure 21 Enter framing data for metal framed constructions

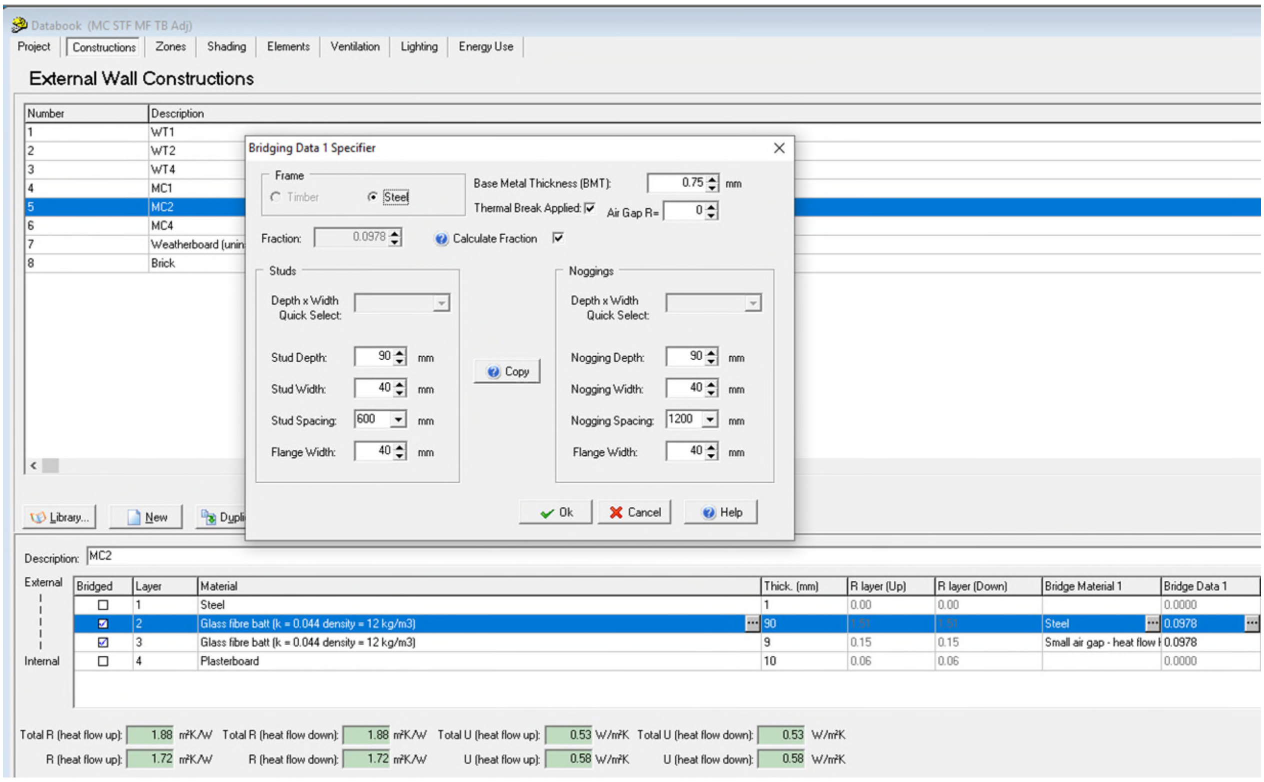
3.3.4 Modelling guide for metal frame thermal bridging calculation – adjusted to be equivalent to timber framed construction

The thermal resistance of metal framed insulated constructions could be significantly reduced in comparison with timber framed constructions which has relatively less thermal bridging impact. ABCB proposed a possible mandate for future NCC by adjusting the metal framed construction to achieve the same thermal performance as a timber framed construction. It is noted that the implementation of this method is not straightforward for AccuRate UI. In this study, a dwelling design variation with adjusted timber frame equivalent metal frame (abbreviated as TFEMF hereafter) constructions were developed for each design. This was achieved by comparing the total R value of the metal framed construction with the corresponding default timber construction. Figure 22 shows an example of achieving the TFEMF construction for the lightweight external wall construction. First, the timber frame construction and metal frame construction are entered based on Section 3.3.2 and Section 3.3.3 respectively (be aware the frame parameters are different for the timber and metal frames). Then, additional thermal insulation (a total of 11 mm glass fibre batt) and thermal break are added for the metal framed construction to achieve an equivalent total R resistance as the timber framed construction. For the TFEMF design variation, thermal barrier may be applied in external wall as well as in suspended floor constructions if it becomes favourable.

The above process, particularly the input and calculation of the thermal resistance with the equivalent the timber framed construction should be automated in AccuRate UI for minimising user input effort if this proposed approach will be used for energy rating.



(a)



(b)

Figure 22 Enter framing data for metal framed constructions for the TFEMF design variation.

3.4 Comparison of rating results for different framed construction types against status quo in 69 climate zones using AccuRate

3.4.1 Impact on star ratings – percentage change in achieving 6 stars

The aim of all the status quo designs was to ensure that all base designs meet or exceed 6 stars in all capital cities and provide a bases for investigating the thermal bridging effect. Table 3 shows the overall results for the eight capital cities in achieving the 6-star requirement. Table 3 also compares the star rating results between ISO metal frame thermal bridging calculation implementation (Chen et al., 2020) and the NZS4214 implementation in this study. For the status quo frame option, it can be seen that in all design variations 6 stars or more is achieved in all capital cities. The status quo frame option is what is currently used in NatHERS simulations and has no specific frame material set and no thermal bridging is applied. Specifying a timber frame and applying it as a bridging element results in the MCSF (metal cladding with suspended floor) design variations of the house in Adelaide, Brisbane, Perth and Sydney falling just below 6 stars.

The most dramatic impact occurs when a metal frame is applied without a thermal barrier being incorporated into the design. Overall, for the eight capital cities, the NZS4214 implementation results in worse thermal performance in comparison with the ISO metal frame thermal bridging calculation implementation. The main reason is that the NZS4214 method implicitly assumes that there is an air cavity between the insulation edge and the base of the metal frame (refer to Figure 9), i.e. insulation is not inserted into the cavity of the steel frame. This is different from the ISO metal frame thermal bridging calculation implementation in Chen et al. (2020) which assumed the insulation is inserted into the cavity of the steel frame based on the recommendation by Kelly (2020) from NASH. With the NZS4214 method and without thermal barriers, all house designs see many capital cities that are unable to achieve 6 stars. For the light clad variation and the metal clad on the suspended floor variation only one capital city achieves 6 stars (Darwin). Incorporating a thermal break with the metal frame sees some improvement in the brick veneer and light clad variations with six capital cities achieving 6 stars for the brick veneer variation, but only two achieving the mark for the light clad variation and still only Darwin achieving 6 stars for the MCSF variation.

The apartment design variations perform better with apartments with a concrete roof system being able to achieve 6 stars in all capital cities under all frame/bridging options. The metal framed roof apartment does see a drop in designs achieving 6 stars with two capital cities (Adelaide and Perth) unable to achieve 6 stars regardless of whether a thermal barrier is included or not. For the apartment design, the ISO and the NZS4214 thermal bridging calculation implementations achieve the same six star pass rate among the capital cities perhaps due to less exposed external surfaces of the apartment designs.

Table 3 Achieving 6 stars or more in the 8 capital cities (percentage and number of cities)

Frame	Bridging/ Thermal Break (TB)	Standard	Apartment				House					
			Concrete Roof		Framed Roof		BV		Light Clad		MCSF	
Status Quo	Not Applied		100%	8	100%	8	100%	8	100%	8	100%	8
Timber Frame	No TB	ISO	100%	8	100%	8	100%	8	100%	8	50%	4
Metal Frame	No TB	ISO	100%	8	75%	6	75%	6	25%	2	12.5%	1
Metal Frame	No TB	NZ	100%	8	75%	6	62.5%	5	12.5%	1	12.5%	1
Metal Frame	With TB	ISO	100%	8	75%	6	100%	8	37.5%	3	12.5%	1
Metal Frame	With TB	NZ	100%	8	75%	6	75%	6	25%	2	12.5%	1

Table 4 shows the overall results for all 69 NatHERS climate zones. For the status quo design it can be seen that not all climate zones were able to achieve 6 stars, although the majority do. The worst-case scenario is the Lightweight cladding on a waffle pod slab variation with metal frame without thermal barriers using the NZS4214 implementation. Under this scenario only 5.80% of climate zones were able to achieve 6 stars. Adding thermal barriers to this design increased this to 18.84%. Again, due to the unfilled air cavity in the metal frame assumed in NZS4214, the NZS4214 implementation results in worse thermal performance in comparison with the ISO metal frame thermal bridging calculation implementation.

Table 4 Achieving 6 stars or more in all 69 climate zones

			Apartment		House		
Frame	Bridging/Thermal Break (TB)	Standard	Concrete Roof	Framed Roof	BV	Light Clad	MCSF
Status Quo	Not Applied		94.20%	79.71%	97.10%	95.65%	86.96%
Timber Frame	No TB	ISO	92.75%	75.36%	97.10%	81.16%	57.97%
Metal Frame	No TB	ISO	91.30%	66.67%	76.81%	23.19%	18.84%
Metal Frame	No TB	NZ	89.86%	62.32%	52.17%	5.80%	14.49%
Metal Frame	With TB	ISO	92.75%	66.67%	88.41%	33.33%	24.64%
Metal Frame	With TB	NZ	91.30%	66.67%	81.16%	18.84%	15.94%

Figures 23-27 show the results for each design option for each capital city. Each chart shows the star rating, adjusted heating energy, adjusted cooling energy and the total adjusted energy for each capital city for a particular design variation for both the house and apartment designs and each of the framing scenarios for that design variation. The status quo scenario represents what is currently rated under the NatHERS requirements, that is, no framing material specified and no thermal bridging applied. Figures 23-27 also compares the results between the ISO and NZS4214 implementation for metal framed variations.

The two apartment designs that are modelled are labelled as Ground Floor and Top Floor. The Ground Floor variation refers to Design Option (iv) in Section 2.4 and has concrete floor and a suspended concrete ceiling. Top Floor refers to Design Option (v) and has a framed floor and a framed ceiling/roof system.

In most cases the capital cities that are failing to achieve 6 stars are only just below the mark. However, for the MCSF metal frame variations, we see the greatest number of cities falling below 6 stars, the lowest star rating result is 4.9 stars in both Perth and Sydney for the metal frame without the thermal barrier included using the NZS4214 implementation. When the thermal barrier is incorporated into the frame design, both these cities see the star rating results increase to 5.4 stars for these variations, which is 0.6 stars below the 6 star benchmark. For the brick veneer metal framed variations although we see only two capital cities achieving 6 stars for the metal framed variation without a thermal barrier using the NZS4214 implementation, the lowest result is 5.3 stars in Brisbane while in all other five capital cities achieved over 5.6 stars. Adding a thermal barrier to the frames saw the star rating rise 0.1 to 0.3 stars.

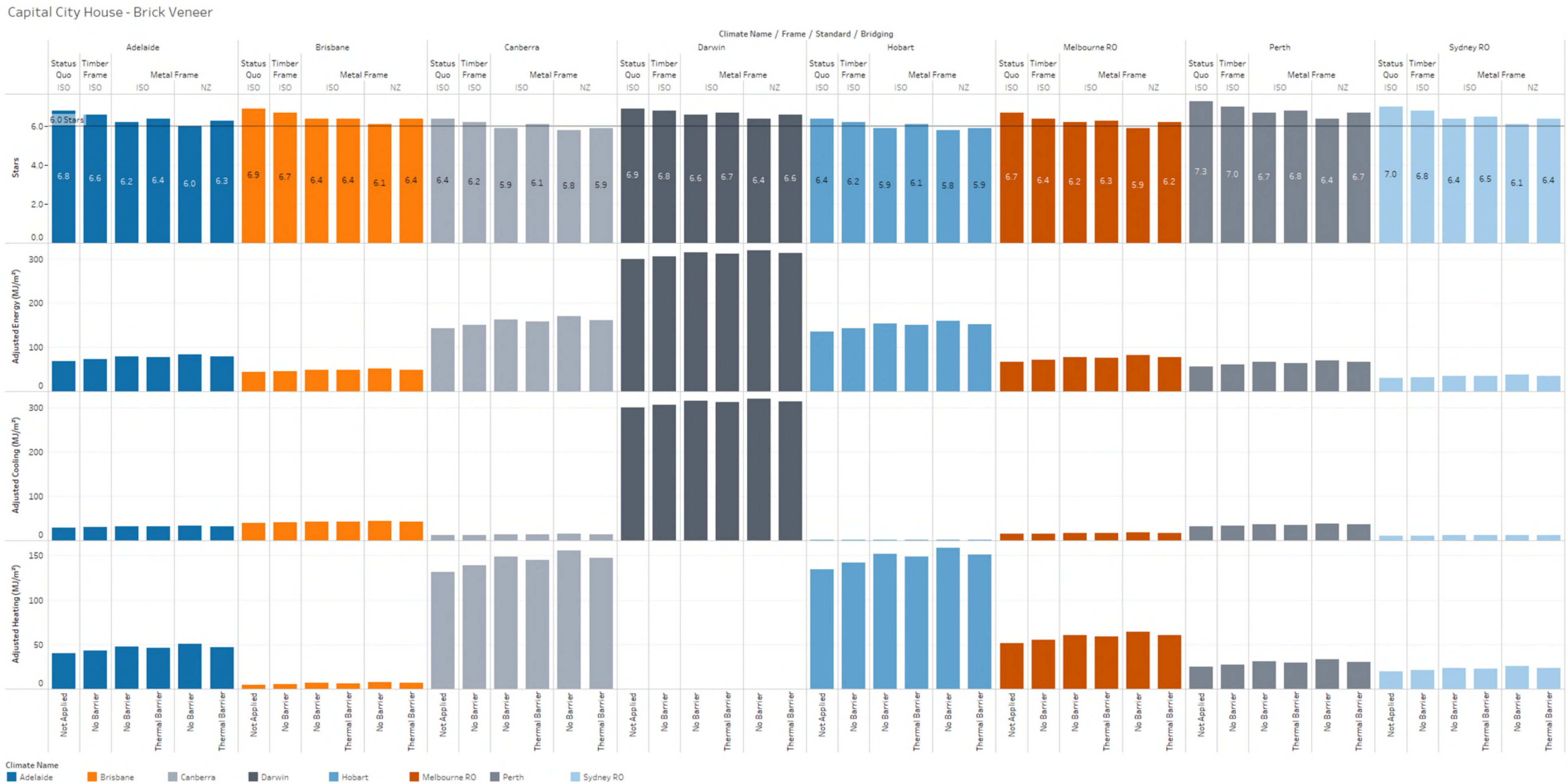


Figure 23 Detached house brick veneer design variation results for capital cities

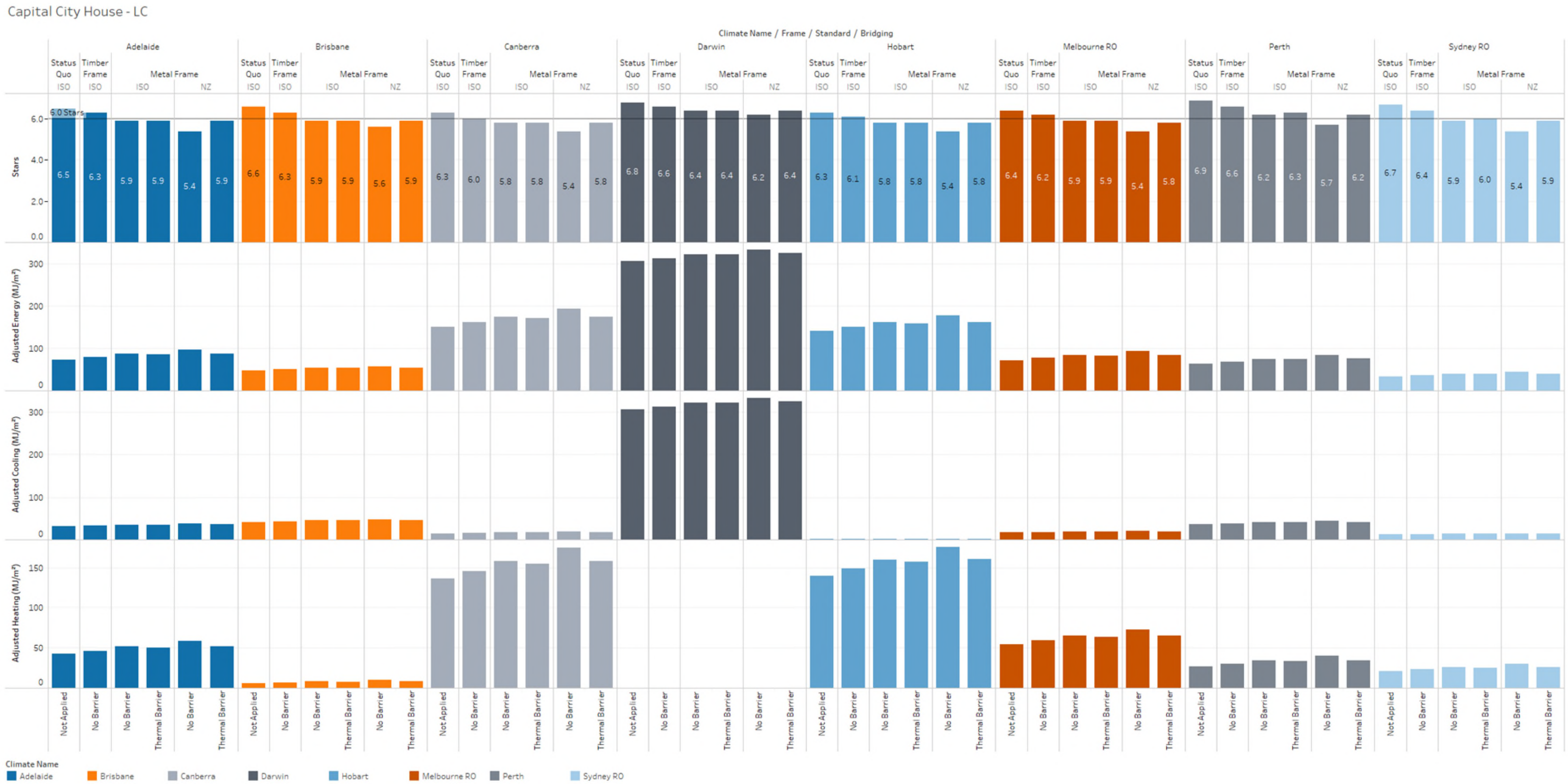


Figure 24 Detached house light clad design variation results for capital cities

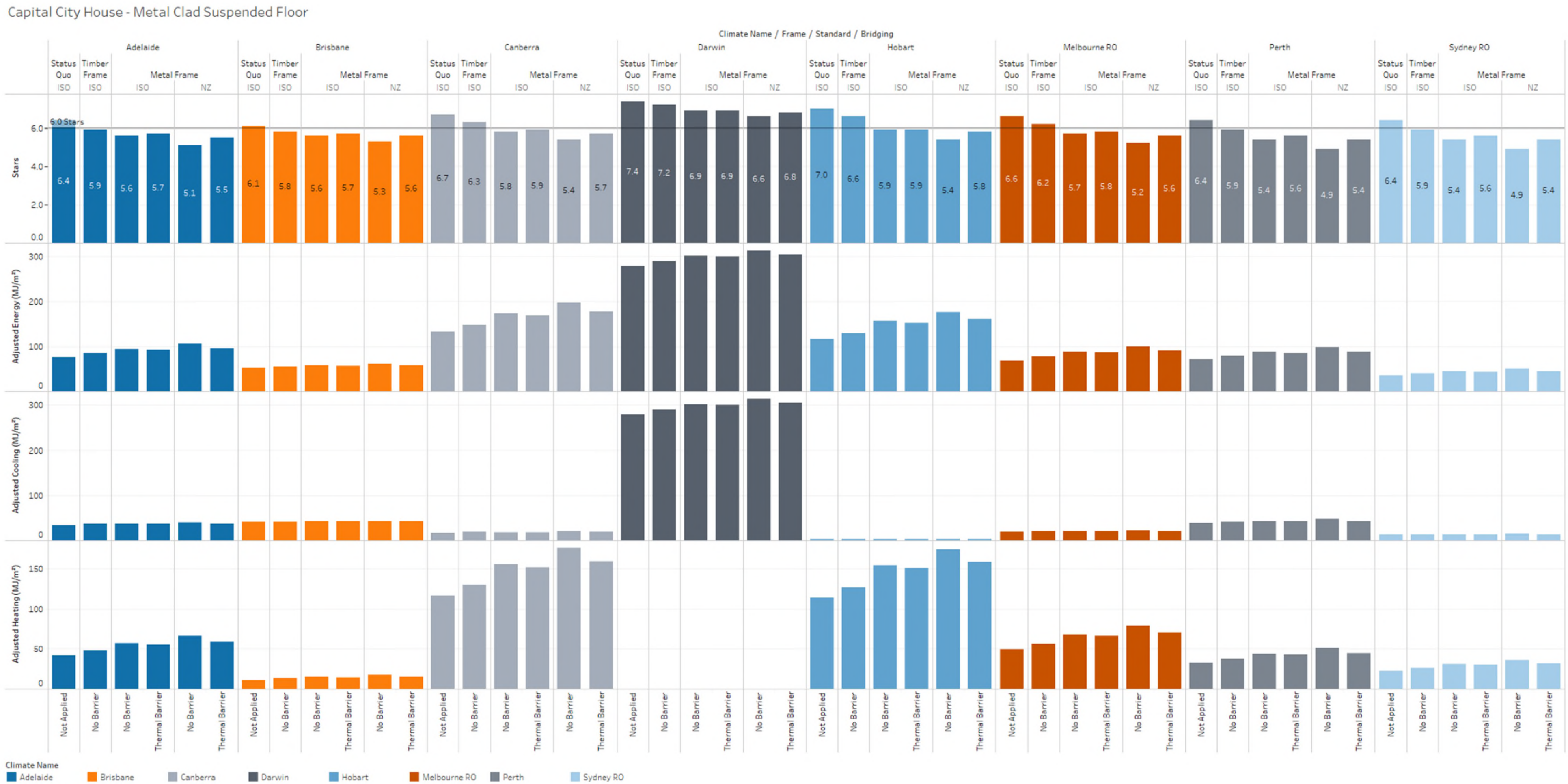


Figure 25 Detached house metal clad suspended floor design variation results for capital cities

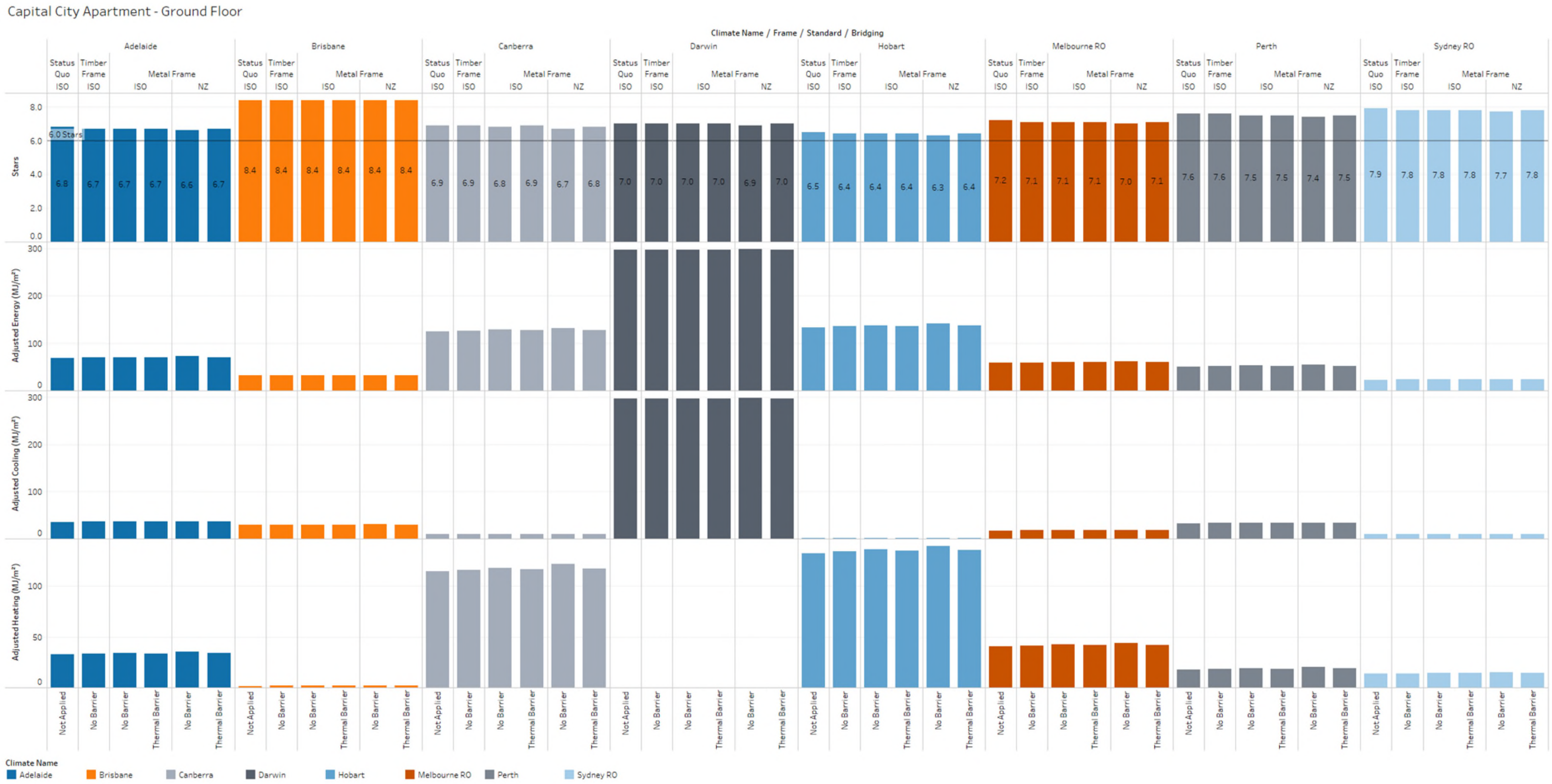


Figure 26 Class 2 apartment concrete floor design variation results for capital cities

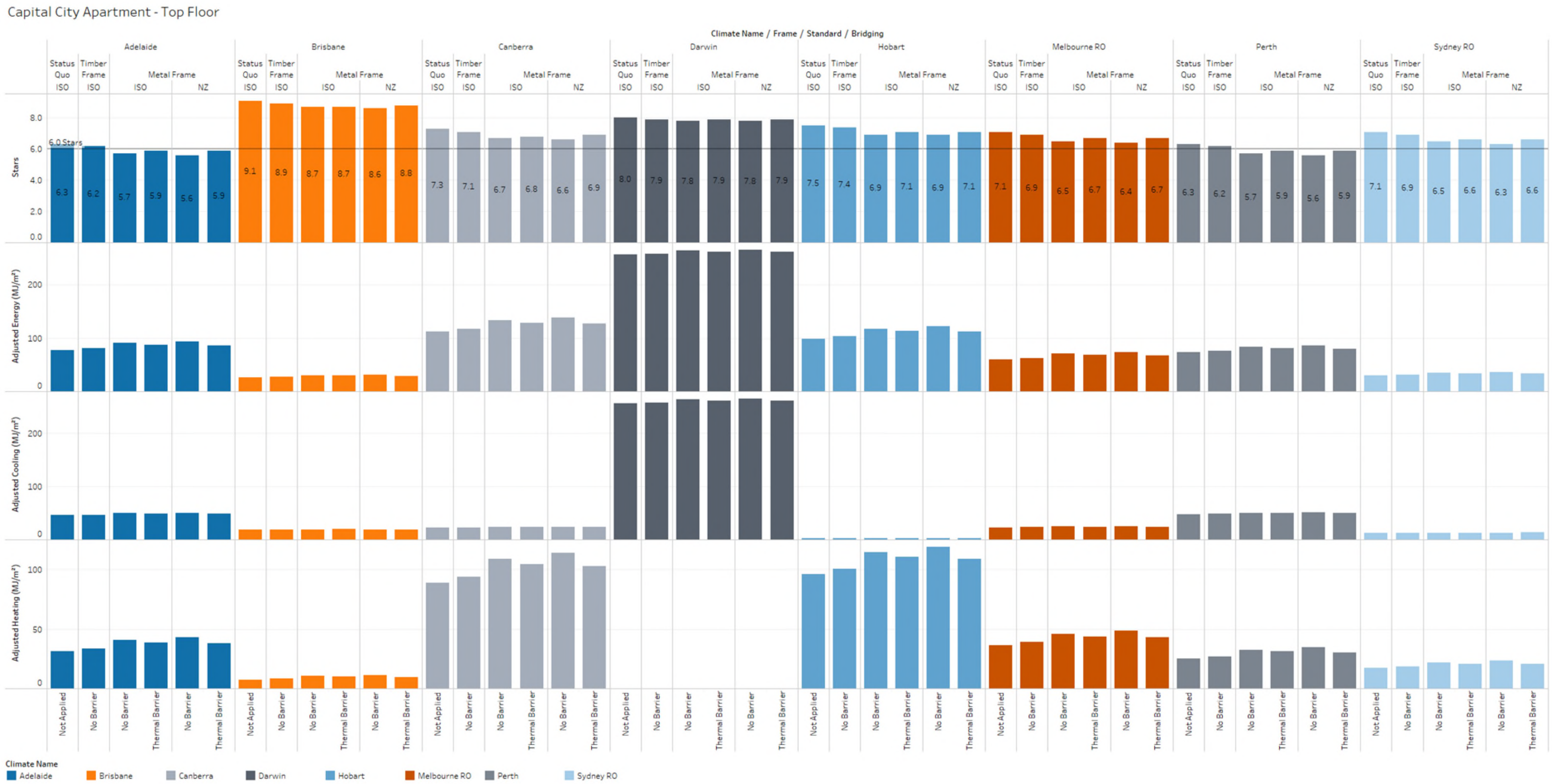


Figure 27 Class 2 apartment framed ceiling/roof design variation results for capital cities

3.4.2 Impact on star ratings – reduction in star ratings

Reductions in star ratings were seen in most climate zones when thermal bridging was applied to the status quo designs. Figure 28 shows the star rating reductions seen amongst the house design variations across the 69 climate zones. On average a reduction of 0.2 to 0.4 stars was seen when bridging from a timber frame was included in the modelling.

With the ISO metal frame thermal bridging calculation method, when no thermal barrier was included, an average reduction of around 0.5 to 0.8 stars was seen. Including a thermal barrier with the metal frame improved this slightly with an average drop of around 0.4 to 0.7 stars. The biggest reductions seen were in the MCSF metal frame variations where reductions of over 1.0 stars were seen in the metal framed option in some climate zones regardless of whether a thermal barrier was incorporated or not.

With the NZS4214 metal frame thermal bridging calculation method, there is around 0.19 to 0.42 star further reduction in comparison with those using the ISO metal frame thermal bridging calculation method for design variations without thermal barriers. The highest reduction of 0.42 star reduction is seen for the MCSF metal frame variations possibly due to the largest external surface exposure with the MCSF metal frame variations.

With the NZS4214 metal frame thermal bridging calculation method, there is around 0.08 to 0.15 star further reduction in comparison with those using the ISO method for design variations with thermal barriers. The highest reduction is again seen for the MCSF metal frame variations due to the largest external surface exposure with the MCSF metal frame variations.

These results suggest that for the house design, the star ratings are not much different between the the ISO and the NZS4214 implementations, with differences from 0.08 to 0.15 in average, if thermal barriers are applied for metal frames.

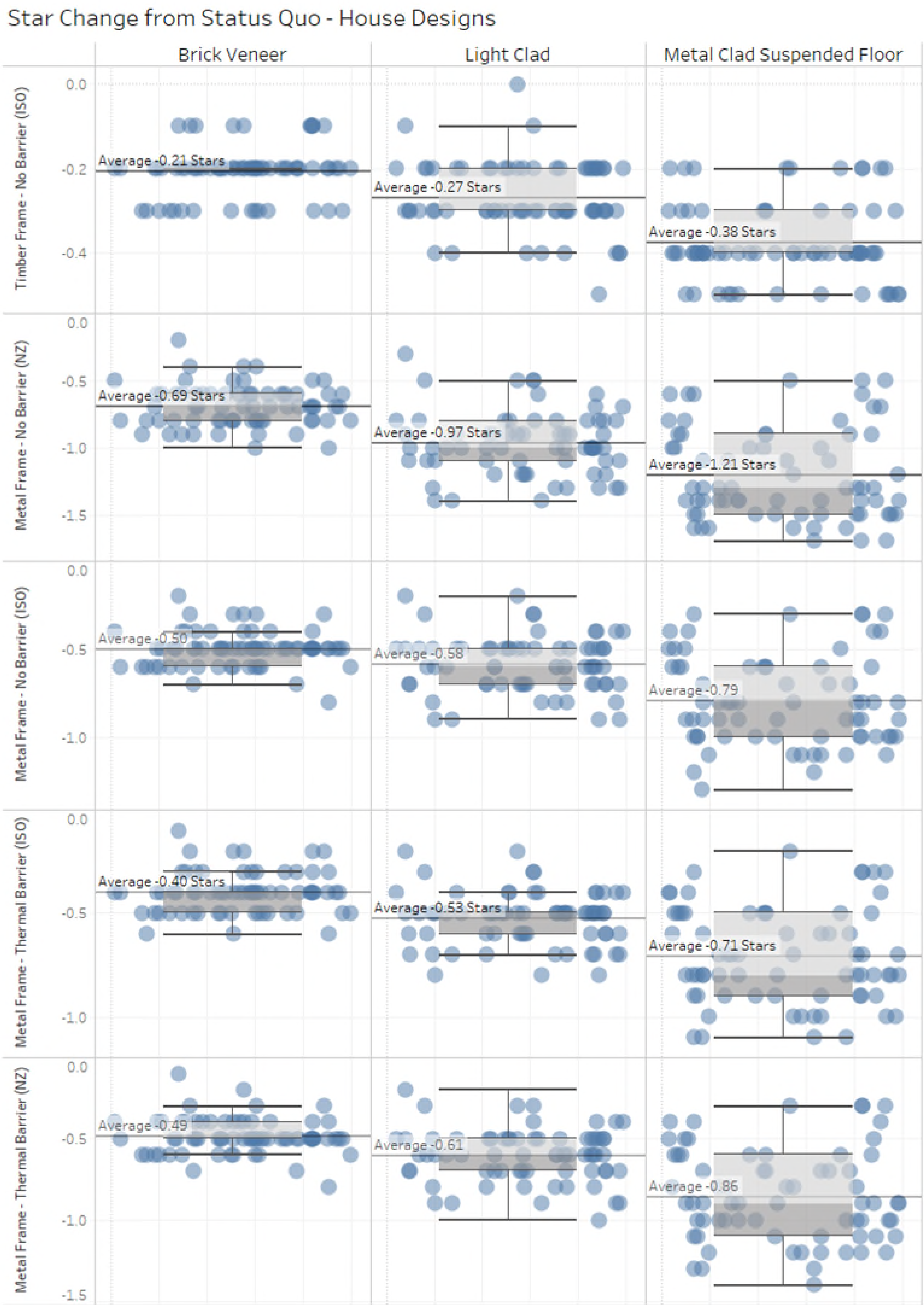


Figure 28 Star rating change from the status quo design for the house design options

Figure 29 shows the star rating reductions seen amongst the apartment design variations. The ground floor apartment design option, which only had framing included in the external walls, saw minimal impact from including thermal bridging in the modelling runs. On average a reduction of less than or around 0.1 stars was seen when bridging from any frame material was included in the modelling. The NZS4214 implementation results in slightly worse thermal performance in comparison with the ISO metal frame thermal bridging calculation implementation, especially for variations with no thermal barriers. For the ground floor apartment variations with thermal barriers, the NZS4214 implementation results in an average of 0.02 star further reduction in comparison with the ISO metal frame thermal bridging implementation.

The top floor apartment which has a framed ceiling/roof system as well as the external walls, saw some impacts, especially for the metal framed options. Including bridging from the timber frame saw only a small reduction of 0.1 stars. However, an average reduction of 0.58 stars was recorded for designs with a metal frame that did not incorporate a thermal barrier using the NZS4214 implementation with the biggest reduction being 0.9 stars which occurred in the Sydney climate zone of Mascot. In average, for the metal framed top floor apartment with no thermal barriers, the NZS4214 implementation results in an average of 0.11 star further reduction in comparison with the ISO metal frame thermal bridging implementation.

Including a thermal barrier, an average reduction of 0.32 stars was recorded for designs with a metal frame using the NZS4214 implementation. For the case with thermal barrier, the NZS4214 implementation actually results in an average of 0.05 star increase in comparison with the ISO metal frame thermal bridging calculation implementation. This is due to the different treatment of the air gap resistance in NZS4214 which increased the roof construction total R value in comparison with the ISO implementation.

These results also suggest that for the apartment design, the star ratings are not much different between the ISO and the NZS4214 implementations, with differences from 0.02 to 0.11 in average, if thermal barriers are applied for metal frames.

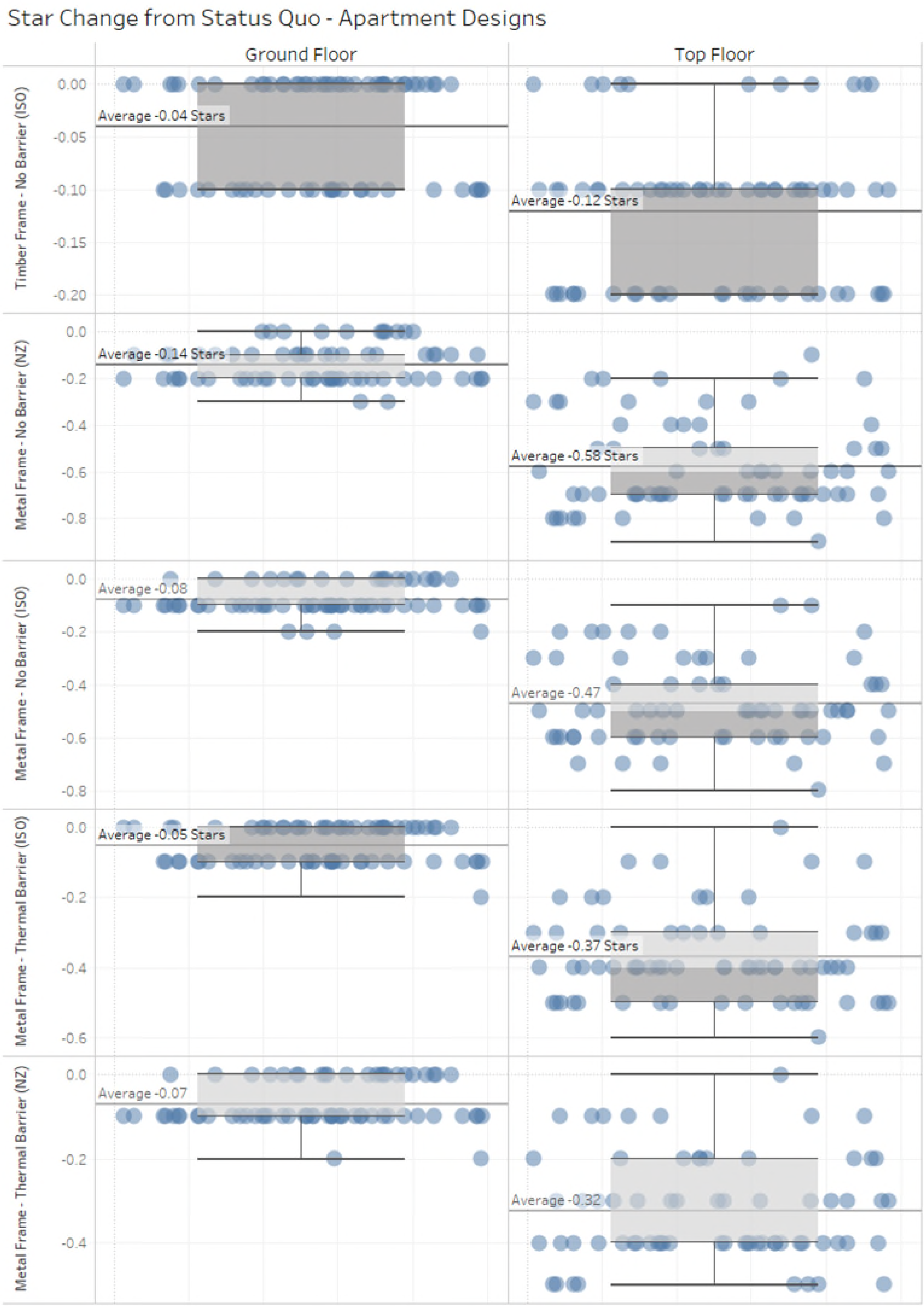


Figure 29 Star rating change from the status quo design for the apartment design options

3.4.3 Impact on energy – increase in energy

As expected, a decrease in the star rating will also result in an increase in the total heating/cooling energy that is expected when thermal bridging is included in the modelling. Figure 30 shows the percentage increase in total heating/cooling energy that was modelled for each house design variation from their status quo design. The inclusion of thermal bridging from the timber frame saw average increases of around 6-9%. The biggest increase for timber framed designs was for the MCSF variation which saw an average increase on 9.4% and the highest being 13.9% in the Albany climate zone.

With the ISO metal frame thermal bridging implementation, the metal frame variations had average increases of around 11-21% depending on design and whether thermal barriers were incorporated with the metal frame. The MCSF variation without thermal barriers had an average increase of 21.4% and a maximum of 37.2% also in the Albany climate zone. Cool temperate climate zones also experienced large increases in energy with this design variation with a 34.6% increase in Hobart and a 29.3% increase in Ballarat. Adding a thermal barrier to the metal frame does reduce the energy increase, but for the MCSF variation increases of 33.4%, 31.5% and 26.3% were modelled for Albany, Hobart and Ballarat respectively. The average increase for this variation was 19.1% across all climate zones.

Again on average, the NZS4214 implementation results in a further increase in the total heating/cooling energy in comparison with the ISO metal frame thermal bridging calculation implementation, especially with MCSF variation without thermal barriers, which see 13.2% further increase. However, with the inclusion of thermal barriers, the further increase in the total energy with the NZS4214 implementation is only around 3% in comparison with the ISO metal frame thermal bridging implementation. This is consistent with the star rating results when thermal barriers are applied.

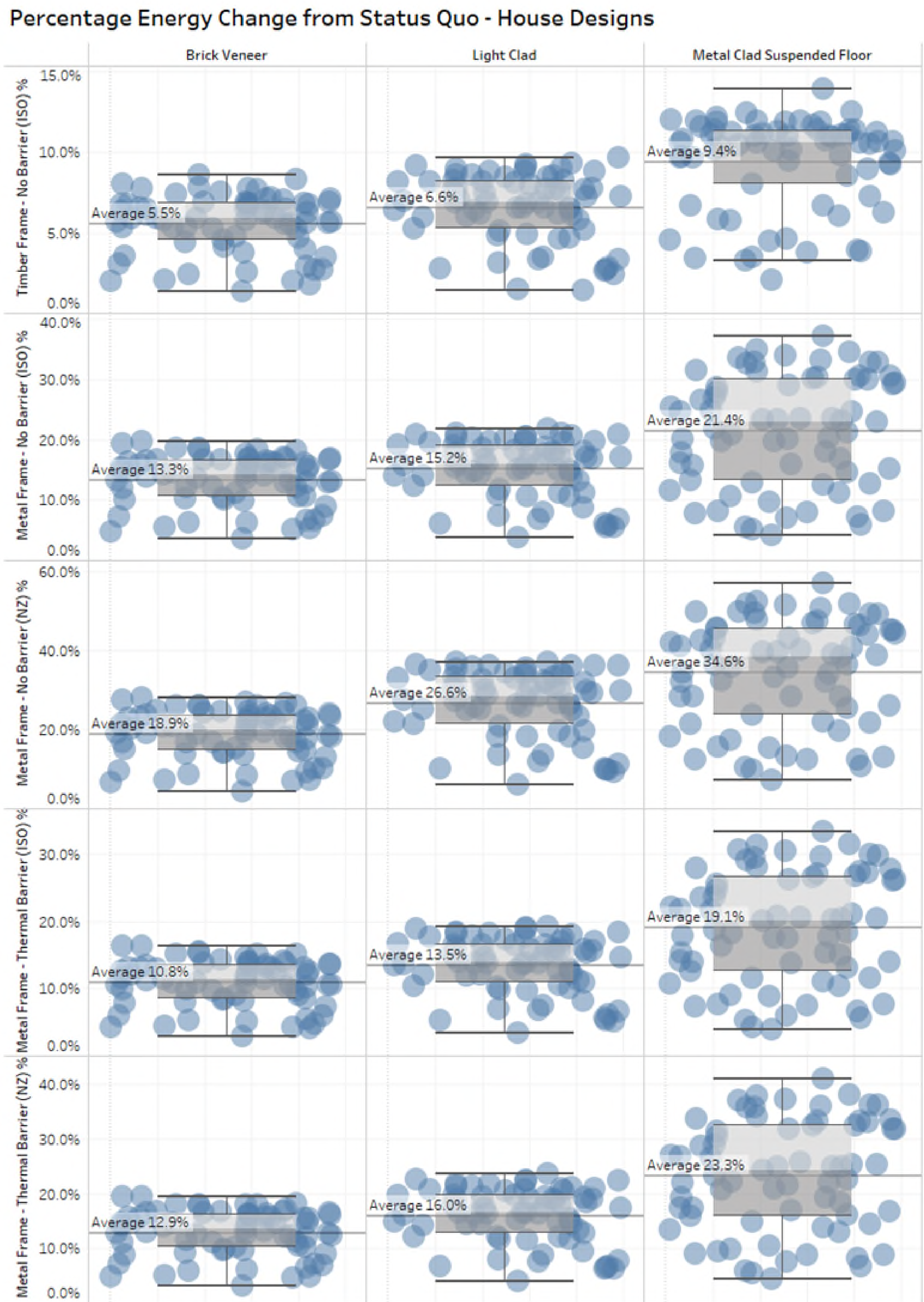


Figure 30 Percentage total energy change from the status quo design for the house design options

Figure 31 shows the modelling results for the apartment design variations. Similar to the star rating changes, the ground floor apartment only saw minimal increase in the total energy averaging between 1-4% depending on the framing options. The top floor apartment design experienced greater increases, especially for the metal framed variations.

With the ISO metal frame thermal bridging implementation, the metal framed apartments had average increases of around 10-13% depending on whether thermal barriers were included. The highest increases were seen where no thermal barrier was present with the maximum increase being 23.3% in the Albany climate zone. Large increases were also seen in Canberra (18.8%) and Adelaide (16.9%). Adding the thermal barrier reduces the increase in all climate zones with increases of 18.3%, 15.0% and 13.1% for Albany, Canberra and Adelaide respectively being modelled.

The NZS4214 implementation results in a slight further average increase of 2-3% in the total heating/cooling energy in comparison with the ISO metal frame thermal bridging calculation implementation for both the top and bottom apartment without thermal barriers. However, with the inclusion of thermal barriers, the NZS4214 implementation and the ISO metal frame thermal bridging implementation give similar total heating/cooling energy.

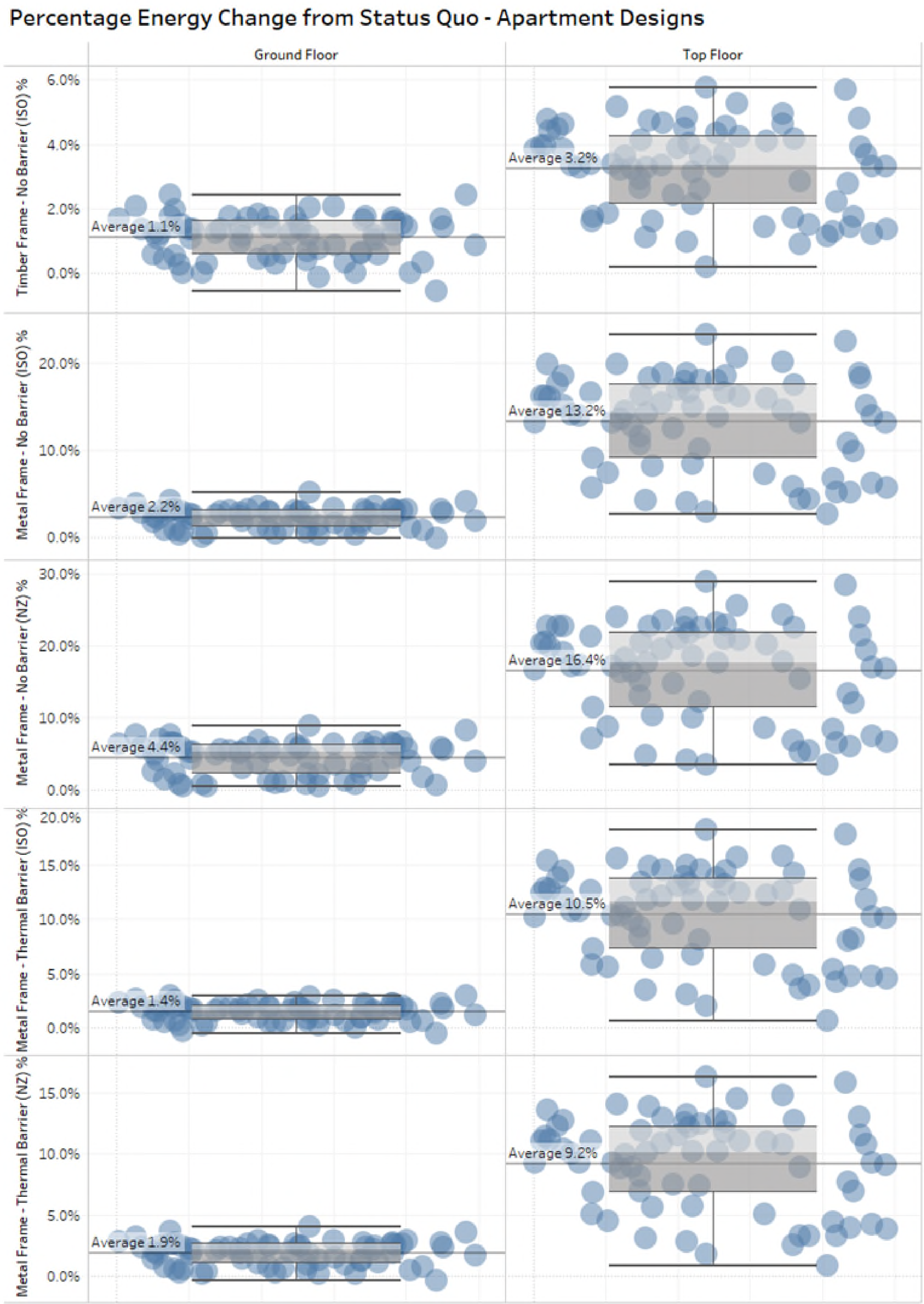


Figure 31 Percentage total energy change from the status quo design for the apartment design options

3.5 Comparison of rating results between TFEMF and timber framed design variations in 69 climate zones using AccuRate

As discussed in Section 3.3.4, dwelling design variation with adjusted timber frame equivalent metal frame (TFEMF) constructions have been developed for each design. The thermal performance with TFEMF are compared to their corresponding timber framed dwellings. Figure 32 shows the change in star rating between the ISO timber framed version of each design and the adjusted NZS4214 metal framed version. As expected, the variance is very small in all designs and in most climate zones no change in star rating occurred. For some brick veneer, light clad and metal clad with suspended floor design versions the star rating increased by 0.1 stars. The only reduction in star rating that occurred was with the apartment designs with two climate zones experiencing a 0.1 star reduction. Perth for the ground floor apartment and Giles for the top floor apartment.

The slight variation in the star rating is due to very small difference in the insulation thickness rounding.

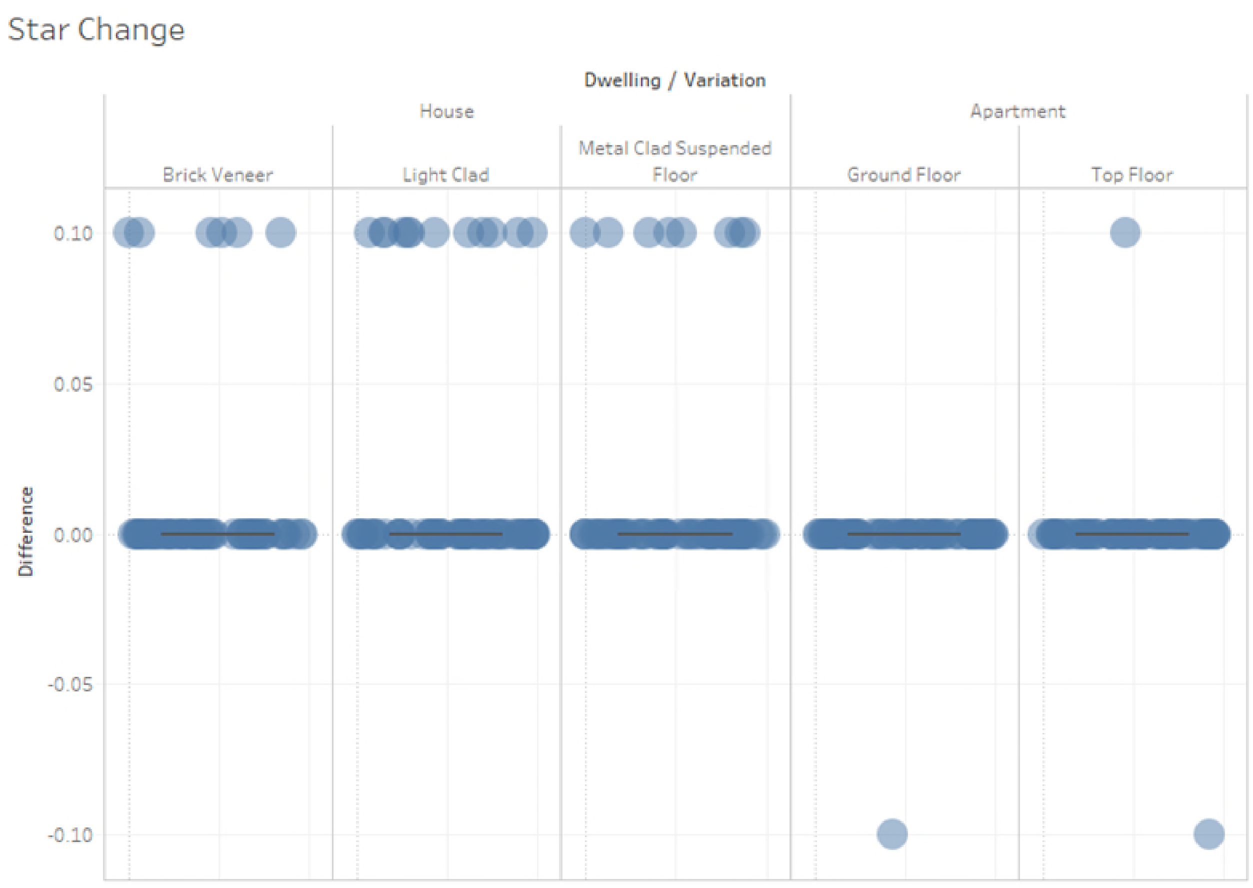


Figure 32 Star rating change from timber framed designs to adjusted NZS4214 metal framed designs

4 Conclusion

This project developed a set of thermal bridging default parameters, provided a draft modelling guidance on how to apply these defaults for NatHERS rating, and determined the impact by applying these defaults on residential building energy ratings.

By conducting a brief survey, default input parameters for timber and metal framed wall, ceiling, floor and roof constructions are recommended in Table 1 for thermal bridging calculation. After reviewing the DISER supplied application of thermal bridging table (Appendix B), we found that the recommendations are mostly adequate. Minor suggestions (highlighted) are recommended as in Table 2.

Based on AccuRate user interface, a draft modelling guide for data input has been developed for assessors modelling thermal bridging effect. With the default input parameters and the draft guide of modelling thermal bridging effect, AccuRate simulations were carried out for a sample house design and a sample apartment design in all the 69 NatHERS climate zones with different house design variations including timber framed, metal framed, brick veneer and light cladding, slab-on-concrete design and suspended floor design, as well as different apartment location (top apartment and ground apartment). Results show that reductions in NatHERS star ratings were seen in most climate zones when thermal bridging was applied to the status quo designs, especially with metal framed construction.

For the sample house, on average a reduction of 0.2 to 0.4 stars was seen when bridging from a timber frame was included in the modelling. For metal framed designs where no thermal barrier was included, an average reduction of around 0.7 to 1.2 stars was seen using the NZS4214 implementation. Including a thermal barrier for metal frames improves the thermal performance with an average drop now around 0.5 to 0.9 stars using the NZS4214 implementation.

As expected, a decrease in the star rating will also result in an increase in the total heating/cooling energy that is expected when thermal bridging is included in the modelling. The inclusion of thermal bridging from the timber frame saw average increases in the total energy of around 6-9%. The biggest increase for timber framed designs was for the MCSF variation which saw an average increase in the total energy on 9.4% and the highest being 13.9% in the Albany climate zone.

The metal frame variations had average increases in the total energy of around 12.9-34.6% using the NZS4214 implementation depending on design and whether thermal barriers were incorporated with the metal frame. The MCSF variation without thermal barriers had an average increase in the total energy of 34.6% and a maximum of 57.2% also in the Albany climate zone. Cool temperate climate zones also experienced large increases in energy with this design variation with a 51.9% increase in Hobart and a 44.5% increase in Ballarat. Adding a thermal barrier to the metal frame does reduce the energy increase, but for the MCSF variation increases of 41.1%, 38.3% and 31.9% were modelled for Albany, Hobart and Ballarat respectively. The average increase in the total energy for this variation was 23.3% averaged across all climate zones with thermal barriers.

For the sample apartment, the ground floor apartment design option, which only had framing included in the external walls, saw minimal impact from including thermal bridging in the modelling runs. On average a reduction of less than or around 0.1 stars was seen when bridging from any frame material was included in the modelling. The top floor apartment which has a framed ceiling/roof system as well as the external walls, saw some impacts, especially for the metal framed options. Including bridging from the timber frame saw only a small reduction of 0.1 stars. However, an average reduction of 0.58 stars was recorded for designs with a metal frame that did not incorporate a thermal barrier using the NZS4214 implementation with the biggest reduction being 0.9 stars which occurred in the Sydney climate zone of Mascot. Including a thermal barrier improved this to an average reduction of 0.32 stars. The biggest reductions recorded was 0.5 stars in a range of climate zones. Similar to the star rating changes, the ground floor apartment only saw minimal increase in the total energy averaging between 1-4% depending on the framing options. The top floor apartment design experienced greater increases in the total energy requirement, especially for the metal framed variations. The metal framed apartments had average increases in the total energy requirement of around 9-16% depending on whether thermal barriers were included. The highest increases were seen where no thermal barrier was present with the maximum increase in the total energy requirement being 28.8% in the Albany climate zone. Large increases in the total energy requirement were also seen in Canberra (23.7%) and Adelaide (21.0%). Adding the thermal barrier reduces the increase in the total energy requirement in all climate zones with increases of 16.3%, 13.2% and 11.5% for Albany, Canberra and Adelaide respectively being modelled.

The relatively large star rating drops and the increase in the energy requirement with metal framed house and apartment variations are thus mainly due to the roof/ceiling insulation reduction caused by metal frames.

In order to bring the thermal performance of metal framed dwellings to be in line with the corresponding timber framed dwellings, insulation adjustment was carried out for the metal framed dwelling designs to maintain the same total R values for all the thermal bridged constructions. As expected, the thermal performance with these insulation adjusted dwelling designs are very close to their corresponding timber framed dwellings with star rating differences within ±0.1 stars.

It was also found that with thermal barriers applied, the NZS4214 and the ISO implementation give similar star rating and total heating/cooling energy results for both the house and apartment design variations, although the NZS4214 generally gives slightly worse performance results.

Appendix A Proposed defaults for information not contained in building plans (*starting defaults supplied by DISER*)

Element		Wood	Metal
Roof elements (battens or rafters?)			
Walls	Stud dimensions	90 x 45 mm	
	Stud spacing	450 mm	450 mm
	Flange width	N/A	0.9 mm for metal thickness
	Nogging dimensions	90 x 45 mm	
	Nogging spacing		
Floors	Joist dimensions		
	Joist spacing		
	Flange width	N/A	
	Nogging dimensions		
	Nogging spacing		
Ceilings	Rafter dimensions		
	rafter spacing		
	Flange width	N/A	
	Nogging dimensions		
	Nogging spacing		

Appendix B Proposed application of thermal bridging (*starting form supplied by DISER*)

Building element	**Apply thermal bridging calculations?**
Attached, unconditioned garage walls (Class 1)	Ignore the exterior walls of unconditioned attached garages. The shared garage/internal wall of the dwelling effectively becomes the dwelling's exterior wall for thermal bridging calculations. Ignore the floor and ceiling of the attached, unconditioned garage for thermal bridging purposes.
Attached, conditioned garage walls (Class 1)	Calculate thermal bridging for the external walls of the garage, as well as its ceiling and floor (if applicable). Thermal bridging may be ignored for the wall between the garage and the rest of the dwelling.
Suspended floors above unconditioned garages (Class 1)	Yes
Suspended floors above conditioned garages (Class 1)	No
External walls	Yes. Exclude attached garage 'exterior' walls unless garage is conditioned.
Internal walls	No, only if they border unconditioned garages.
Class 2 apartment walls and floors adjacent to public areas	Yes, but only where apartment walls or floors border non-neighbour[1]' spaces (refer Tables 2 and 3 of the NatHERS Technical Notes for definitions) such as stair wells, corridors, car parks, and other shared public spaces
Ceilings between sole occupancy class 2 dwellings	No, close enough to 'neighbour'
Internal door frames	No
External door frames	No
Window frames	Currently done as part of the window U value calculation.
Suspended ground floors	yes
Suspended upper floors above outside air	Yes
Mid-floors within single dwellings (ie 2 storey class 1)	No, close enough to 'neighbour'
Ceilings within two (or more) storey class 1 dwellings, leading to an occupied upstairs zone (conditioned or unconditioned) NB, this does not mean to a roof space	No, close enough to 'neighbour'

[1] The NatHERS software term 'neighbour' refers to a situation where the temperature conditions on either side of a wall/floor/ceiling are considered to be the same. This results in no heat movement through the wall/floor/ceiling. For instance, where a wall between two apartments separate opposing living rooms, they are considered to 'neighbour' one another, because they are assumed to be kept at the same temperatures (even though this is highly unlikely in real-life). Sometimes, the term 'neighbour' is used to describe adjacencies that we know aren't exactly the same as one another, but are 'close enough'. For instance, one apartment's living room that is adjacent to another apartment's bedroom.

Appendix C Survey form for defaults for information not contained in building plans

Defaults for information not contained in building plans

Typical planning documentation given to assessors is unlikely to contain all of the information required by AccuRate to correctly model thermal bridging. Therefore, a set of assumptions and defaults will need to be developed to cover all of the data inputs when the only thing that an assessor is given is the frame material (i.e. metal or wood). The guiding principal for this will be that the defaults are based on the most likely 'worst case' scenario, but should not be unreasonable or unrealistic. Based on your experience, please help fill in the dimensions for wood and metal frames. There are a couple of defaults which have been entered; you may change it if you think they are not appropriate.

Element		**Wood**	**Metal**
Walls	Stud dimensions	90 x 45 mm	
	Stud spacing	450 mm	450 mm
	Flange width	Not applicable	0.9 mm for metal thickness
	Nogging dimensions	90 x 45 mm	
	Nogging spacing		
Floors	Joist dimensions		
	Joist spacing		
	Flange width	Not applicable	
	Nogging dimensions		
	Nogging spacing		
Ceilings	Rafter dimensions		
	rafter spacing		
	Flange width	Not applicable	
	Nogging dimensions		
	Nogging spacing		

Roof elements (roof may be not really thermal bridged as the insulation could be above/below the batten)	Rafter dimensions		
	rafter spacing		
	Flange width	Not applicable	
	batten dimensions		
	batten spacing		

Thermal bridging materials

Currently, AccuRate has included **timber (softwood, hardwood), steel, small air gap and concrete** as potential thermal bridging materials. If you know any other potential thermal bridging material, please enter the material name below.

Appendix D Survey responses

Appendix D.1 Survey responses by Assessor No. 1

Element	**Wood**	**Metal**	
Walls			
Stud dimensions	90 x 45 mm	Flange width	0.9 mm for metal thickness
Stud spacing	**450 mm**		**450 mm**
Height	2400-3600mm		
Nogging dimensions	90 x 45 mm		
Nogging spacing	≤1350mm		
Stud dimensions	90 x 45 mm		
Stud spacing	**600mm**		
Height	2400-3000mm		
Nogging dimensions	90 x 45 mm		
Nogging spacing	≤1350mm		
Floors (Tile roof above, (May support load bearing walls perpendicular to joists)			
Joist dimensions	140x35mm	Flange width	0.9 mm for metal thickness
Joist spacing	**450mm**		
Nogging dimensions	140x35mm		
Nogging spacing	≤1800 centre and at perimeter		
Joist dimensions	140x45mm		
Joist spacing	**600mm**		

≤1800 centre and at each perimeter end	≤1800 centre and at perimeter		
Top and bottom plates	90x45		
Ceilings			
Rafter dimensions	120x45	Flange width	
rafter spacing	400-600mm		
	Nogging dimensions		
	Nogging spacing		
Roof elements (roof may be not really thermal bridged as the insulation could be above/below the batten)			
	Rafter dimensions	120x45	
	rafter spacing	450-600mm	
	Flange width	Not applicable	
	batten dimensions	90x45	
	batten spacing		

Thermal bridging materials

Currently, AccuRate has included **timber (softwood, hardwood), steel, small air gap and concrete** as potential thermal bridging materials. If you know any other potential thermal bridging material, please enter the material name below.

Appendix D.2 Survey responses by Assessor No. 2

Element		Wood	Metal
Walls	Stud dimensions	90 x 45 mm 90 x 35 mm 70 x 45mm 70 x 35mm Sometimes a 45 x 35 batten used on face of frame to support external lining	90 x 43 -external & Internal frame 70 x 43 sometimes u Sometimes a 40 x 20 x .42 bmt batten used on face of frame to support external lining
	Stud spacing	450 mm 600 mm(most common)	450 mm 600 mm(Most Common)
	Flange width	Not applicable	0.75 mm for metal thickness
	Nogging dimensions	90 x 45 mm 90 x 35mm 70 x 45 mm 70 x 35 mm Same size as stud	90 x 43 70 x 43 Same size as stud
	Nogging spacing	1050	1050
Floors	Joist dimensions	90 x 35mm 140 x 35mm 190 x 35mm 240 x 35mm 300 x 35mm 90 x 45mm 140 x 45mm 190 x 45mm 240 x 45mm 300 x 45mm Most common now to use LVL-Laminated Veneer Lumber for larger size joists inlieu of timber (hwd or softwood)-more	90 x 43mm 140 x 43mm 190 x 43mm 240 x 43mm 300 x 43mm

		stable and more consistent	
	Joist spacing	450	450
	Flange width	Not applicable	
	Nogging dimensions	Same size as floor joist	Same size as floor joist
	Nogging spacing	Mid span for deep joists	Mid span for deep joists
Ceilings	Rafter dimensions	90 x 35mm 140 x 35mm 190 x 35mm 240 x 35mm 300 x 35mm 90 x 45mm 140 x 45mm 190 x 45mm 240 x 45mm 300 x 45mm Also roof trusses at 600 c-c -most common	90 x 43 x .75bmt mm 140 x 43 x .75bmt mm 190 x 43 x .75bmt mm 240 x 43 x .75bmt mm 300 x 43 x .75bmt mm Also roof trusses at 600 at c-c-most common
	rafter spacing	600-most common Sometimes a 45 x 35 batten used under rafter or truss	600 most common Sometimes a 40 x 20 x .42 bmt batten used under rafter or truss
	Flange width	Not applicable	N/A
	Nogging dimensions	N/A-if nogging is used it is to be same size as joist/rafter	N/A-if nogging is used it is to be same size as joist /rafter
	Nogging spacing	N/A	N/A
Roof elements (roof may be not really thermal bridged as the insulation could be above/below the batten)	Rafter dimensions	90 x 35mm 140 x 35mm 190 x 35mm 240 x 35mm 300 x 35mm	90 x 43 x .75bmt mm 140 x 43 x .75bmt mm 190 x 43 x .75bmt mm 240 x 43 x .75bmt mm 300 x 43 x .75bmt mm

		90 x 45mm 140 x 45mm 190 x 45mm 240 x 45mm 300 x 45mm Also roof trusses at 600 c-c	Also roof trusses at 600 at c-c
	rafter spacing	450 600-most common	450 600-most common
	Flange width	Not applicable	
	batten dimensions	50 x 35	40 x 20 x .42 bmt batten used over rafter or truss
	batten spacing	1200/1500/1800 c-c depending on design	1200/1500/1800 c-c depending on design

Thermal bridging materials

Currently, AccuRate has included **timber (softwood, hardwood), steel, small air gap and concrete** as potential thermal bridging materials. If you know any other potential thermal bridging material, please enter the material name below.

Appendix D.3 Survey responses by Assessor No. 3

Element		Wood	Metal
Walls	Stud dimensions	90 x 45 mm	
	Stud spacing	450 mm	450 mm
	Flange width	Not applicable	0.9 mm for metal thickness
	Nogging dimensions	90 x 45 mm	
	Nogging spacing	1200 mm ctrs	
Floors	Joist dimensions	Varies depending on span. Standard – 90 x 45 in traditional size for 2.8 m span	
	Joist spacing	450 mm	
	Flange width	Not applicable	
	Nogging dimensions	Same size as joist – only used for wide spans as blocking	
	Nogging spacing	Mid span or third span points	
Ceilings	Rafter dimensions	Varies depending on span. We mostly use 150x 45	
	rafter spacing	450 or 600	
	Flange width	Not applicable	
	Nogging dimensions	Same size as joist – only used for wide spans as blocking	
	Nogging spacing	Mid span or third span points	
Roof elements (roof may be not really thermal bridged as the insulation could be above/below the batten)	Rafter dimensions	Varies depending on span. We mostly use 200 x 45 LVL's but we tend to have large spans with cathedral ceilings.	

	rafter spacing	450 or 600	
	Flange width	Not applicable	
	batten dimensions	75 or 50 x 38 for metal roof, 38 x 38 or 38 x 25 for tiles	
	batten spacing	600 or 900 mm for metal roof – can depend on wind load, for concrete and terracotta tiles – relates to length of tile – normally 340 -370 mm	

Thermal bridging materials

Currently, AccuRate has included **timber (softwood, hardwood), steel, small air gap and concrete** as potential thermal bridging materials. If you know any other potential thermal bridging material, please enter the material name below.

Concrete block work – web only	
Brickwork in solid brickwork where it may be a pier within an insulated wall	

Appendix D.4 Survey responses by Assessor (trainer) No. 4

Element		Wood	Metal
Walls	Stud dimensions	90 x 35 mm	78 x 38 / 90 x 38
	Stud spacing	450 mm	450 mm
	Flange width	Not applicable	0.9 mm for metal thickness
	Nogging dimensions	90 x 45 mm	As for walls
	Nogging spacing	Mid height 1350mm	1 row mid height 1350mm
Floors	Joist dimensions	150 x 50	75 x 50 / 100 x 50
	Joist spacing	3m c/s	400 c/s
	Flange width	Not applicable	1.2
	Nogging dimensions	NA	NA
	Nogging spacing	NA	NA
Ceilings	Rafter dimensions	90 x 35	100
	rafter spacing	900 c/s	400
	Flange width	Not applicable	1.2
	Nogging dimensions	Ceiling battens used	NA
	Nogging spacing	NA	NA
Roof elements (roof may be not really thermal bridged as the insulation could be above/below the batten)	Rafter dimensions	90 x 35	?
	rafter spacing	900 c/s	
	Flange width	Not applicable	
	batten dimensions		
	batten spacing		

Thermal bridging materials

Currently, AccuRate has included **timber (softwood, hardwood), steel, small air gap and concrete** as potential thermal bridging materials. If you know any other potential thermal bridging material, please enter the material name below.

Insulbreak 6.5mm (aircell product)	

Appendix D.5 Survey responses by Assessor (trainer) No. 5

Element		Wood	Metal
Walls	Stud dimensions	90 x 45 mm	75 x 31-38mm (worst case, otherwise 90 x 30-35mm)
	Stud spacing	450 mm	450 mm
	Flange width	Not applicable	0.9 mm for metal thickness (ranges from 0.5 to 1.5mm, so guess 0.5mm is worst case?)
	Nogging dimensions	90 x 45 mm	72-75 x 32-40mm (worst case, otherwise 87 x 25-32mm)
	Nogging spacing	Maximum is 1350mm high	
Floors	Joist dimensions	190 x 45mm (common but not worst case)	
	Joist spacing	450mm (or 600mm)	
	Flange width	Not applicable	
	Nogging dimensions	?	
	Nogging spacing	?	
Ceilings	Rafter dimensions	90 x 35mm (bottom chord)	
	Rafter spacing	600mm	
	Flange width	Not applicable	
	Nogging dimensions	?	
	Nogging spacing	?	
Roof elements (roof may be not really thermal bridged as the insulation could be above/below the batten)	Rafter dimensions	Top chord of truss or purlins?	
	Rafter spacing	600mm (same as above)	
	Flange width	Not applicable	

	Batten dimensions	75 x 45mm	40mm high (0.55mm) and 40mm wide where attached to the metal roof sheet
	Batten spacing	1100mm	1200mm(?)

Thermal bridging materials

Currently, AccuRate has included **timber (softwood, hardwood), steel, small air gap and concrete** as potential thermal bridging materials. If you know any other potential thermal bridging material, please enter the material name below.

Appendix D.6 Survey responses by Expert No. 1

Element		Wood	Metal
Walls	Stud dimensions	90 x 45 mm	
	Stud spacing	450 mm	450 mm
	Flange width	Not applicable	0.9 mm for metal thickness
	Nogging dimensions	90 x 45 mm	
	Nogging spacing		
Floors	Joist dimensions	**140x45**	
	Joist spacing	**600**	
	Flange width	Not applicable	
	Nogging dimensions		
	Nogging spacing		
Ceilings	Rafter dimensions	**90x45**	
	rafter spacing	**900**	
	Flange width	Not applicable	
	Nogging dimensions		
	Nogging spacing		
Roof elements (roof may be not really thermal bridged as the insulation could be above/below the batten)	Rafter dimensions	**Trusses, 45mm thick**	
	rafter spacing	**900**	
	Flange width	Not applicable	
	batten dimensions		**50mm tophat**
	batten spacing		**900**

Thermal bridging materials

Currently, AccuRate has included **timber (softwood, hardwood), steel, small air gap and concrete** as potential thermal bridging materials. If you know any other potential thermal bridging material, please enter the material name below.

Brick ties across cavity brick wall types (brick/air gap/brick)	

Appendix D.7 Survey responses by software developer No. 1

Element		Wood	Metal
Walls	Stud dimensions	90 x 45 mm	
	Stud spacing	450 mm	450 mm
	Flange width	Not applicable	0.9 mm for metal thickness
	Nogging dimensions	90 x 45 mm	
	Nogging spacing		
Floors	Joist dimensions		
	Joist spacing	450	
	Flange width	Not applicable	
	Nogging dimensions		
	Nogging spacing		
Ceilings	Ceiling Joist/bottom chord of Truss dimensions ~~Rafter dimensions~~		
	~~Rafter~~/Ceiling joist/Truss spacing	600 mm	
	Flange width	Not applicable	
	Jack ceiling joist/Ceiling trimmer dimensions ~~Nogging dimensions~~		
	Jack ceiling joist/Ceiling trimmer dimensions ~~Nogging spacing~~		
Roof elements (roof may be not really thermal bridged as the insulation could be above/below the batten) **"worst case"- based on (concrete) tiled roof**	Rafter dimensions/top chord of Truss	145 x 35 mm	
	Rafter/truss spacing	450 mm	
	Flange width	Not applicable	
	batten dimensions	38 x 38 mm	

Details may vary as per roof cladding manufacturers specifications	batten spacing	310 mm	

Thermal bridging materials

Currently, AccuRate has included **timber (softwood, hardwood), steel, small air gap and concrete** as potential thermal bridging materials. If you know any other potential thermal bridging material, please enter the material name below.

Sheet bracing: Plywood or OSB panels	OSB is typically - Soft wood Ply can be made from either soft or hard wood, or a combination of bath May be installed to the outside surface of a frame or both side depending on the wind/cyclonic or earthquake rating Typically 4mm, but may vary depending of location/site exposure.
Masonry / Brick ties	Steel – but spaced out points of contact. Not continuous lines of contacts such as battens or framing etc. Spacing may vary depending on frame/stud spacings, openings, control/articulation joints etc. Can join brick or block to steel or timber frame, brick to brick, brick to block, block to block for example.

Appendix E Proposed defaults for information not contained in building plans for cyclonic regions

Element		Wood (both soft and hard wood)	Steel frame
Roof elements – raftered roofs with concealed rafters or horizontal ceilings **Dependent on the design, thermal bridging may not need to be considered for roof elements. The dimensions listed are the defaults if thermal bridging exists.**	Rafter dimensions	140 x 45 mm	200 x 75 mm
	rafter spacing	600 mm	900 mm
	Base Metal Thickness	N/A	1.9
	Flange width	N/A	75 mm
	batten dimensions	N/R	N/R
	batten spacing	N/R	N/R
Walls	Stud dimensions	90 x 45 mm	90 x 40 mm
	Stud spacing	450 mm	600 mm
	Flange width	N/A	40 mm
	Base Metal Thickness	N/A	1.00 mm
	Nogging dimensions	90 x 45 mm	90 x 40 mm
	Nogging spacing	600 mm	1200 mm
Floors	Joist dimensions	140 x 45 mm	100 x 50 mm
	Joist spacing	450 mm	450 mm
	Flange width	N/A	50 mm
	Base Metal Thickness	N/A	1.5 mm
	Nogging dimensions	N/A	N/A
	Nogging spacing	N/A	N/A
Horizontal Ceilings	Ceiling joist dimensions	140 x 45 mm	90 x 40 mm
	Ceiling joist spacing	600 mm	900 mm
	Flange width	N/A	40 mm
	Base Metal Thickness	N/A	1.0 mm
	Nogging dimensions	N/A	N/A
	Nogging spacing	N/A	N/A

Notes: **Consistent to NZ4214:2006, the thermal bridging effect of the ties or nails are not considered.**

N/A: Not applicable

N/R: For thermal bridging calculation, this parameter is not required.

Appendix F AccuBatch modelling results for capital cities

Climate Name	Build Type	Variation	Frame	Thermal Bridge	Standard	Heating MJ/m²	Sensible Cooling MJ/m²	Latent Cooling MJ/m²	Adjusted Heating MJ/m²	Adjusted SCooling MJ/m²	Adjusted LCooling MJ/m²	Adjusted Cooling MJ/m²	Adjusted Energy MJ/m²	Area m²	Stars
Adelaide	House	BV	Dft	NA	ISO	43.2	28.4	2.0	39.7	26.2	1.9	28.0	67.8	148.5	6.8
Adelaide	House	BV	TF	NB	NZ	46.8	30.0	2.1	43.0	27.6	1.9	29.5	72.6	148.5	6.6
Adelaide	House	BV	MF	NB	ISO	51.5	32.5	2.1	47.4	29.9	1.9	31.8	79.2	148.5	6.2
Adelaide	House	BV	MF	NB	NZ	54.9	34.0	2.1	50.5	31.3	2.0	33.3	83.7	148.5	6.0
Adelaide	House	BV	MF	TB	ISO	49.9	31.7	2.1	45.9	29.2	1.9	31.1	77.0	148.5	6.4
Adelaide	House	BV	MF	TB	NZ	51.1	32.4	2.1	47.0	29.8	1.9	31.7	78.7	148.5	6.3
Adelaide	House	BV	MF	TB	NZAdj	46.8	30.0	2.1	43.0	27.6	1.9	29.5	72.5	148.5	6.6
Adelaide	House	LC	Dft	NA	ISO	46.0	31.4	2.1	42.4	28.9	1.9	30.8	73.1	148.5	6.5
Adelaide	House	LC	TF	NB	NZ	50.4	33.4	2.1	46.4	30.7	1.9	32.6	79.0	148.5	6.3
Adelaide	House	LC	MF	NB	ISO	55.9	36.0	2.1	51.4	33.1	1.9	35.0	86.4	148.5	5.9
Adelaide	House	LC	MF	NB	NZ	63.7	39.8	2.2	58.6	36.6	2.0	38.7	97.3	148.5	5.4
Adelaide	House	LC	MF	TB	ISO	54.6	35.9	2.1	50.3	33.0	1.9	34.9	85.2	148.5	5.9
Adelaide	House	LC	MF	TB	NZ	56.4	36.6	2.1	51.9	33.7	1.9	35.6	87.5	148.5	5.9
Adelaide	House	LC	MF	TB	NZAdj	50.2	33.3	2.1	46.2	30.7	1.9	32.6	78.8	148.5	6.3
Adelaide	House	MCSF	Dft	NA	ISO	45.4	35.8	2.2	41.8	32.9	2.0	34.9	76.7	148.5	6.4
Adelaide	House	MCSF	TF	NB	NZ	52.1	38.3	2.2	47.9	35.3	2.0	37.3	85.2	148.5	5.9
Adelaide	House	MCSF	MF	NB	ISO	62.1	38.4	2.2	57.2	35.3	2.0	37.4	94.5	148.5	5.6
Adelaide	House	MCSF	MF	NB	NZ	71.9	41.5	2.3	66.2	38.2	2.1	40.3	106.4	148.5	5.1
Adelaide	House	MCSF	MF	TB	ISO	60.4	37.9	2.2	55.5	34.8	2.0	36.9	92.4	148.5	5.7
Adelaide	House	MCSF	MF	TB	NZ	63.7	38.3	2.2	58.6	35.2	2.0	37.2	95.8	148.5	5.5
Adelaide	House	MCSF	MF	TB	NZAdj	51.9	38.2	2.2	47.7	35.1	2.0	37.2	84.9	148.5	5.9
Adelaide	Apt	Ground	Dft	NA	ISO	36.1	37.4	2.1	32.5	33.7	1.9	35.6	68.1	92.5	6.8
Adelaide	Apt	Ground	TF	NB	NZ	37.0	38.0	2.2	33.3	34.2	2.0	36.1	69.5	92.5	6.7
Adelaide	Apt	Ground	MF	NB	ISO	37.8	38.1	2.2	34.1	34.4	1.9	36.3	70.3	92.5	6.7

Adelaide	Apt	Ground	MF	NB	NZ	39.4	38.7	2.2	35.5	34.9	1.9	36.8	72.4	92.5	6.6
Adelaide	Apt	Ground	MF	TB	ISO	37.3	38.0	2.2	33.6	34.3	2.0	36.2	69.8	92.5	6.7
Adelaide	Apt	Ground	MF	TB	NZ	37.6	38.1	2.2	33.8	34.3	2.0	36.3	70.1	92.5	6.7
Adelaide	Apt	Ground	MF	TB	NZAdj	37.0	38.0	2.2	33.3	34.2	2.0	36.1	69.5	92.5	6.7
Adelaide	Apt	Top	Dft	NA	ISO	34.8	48.6	2.4	31.4	43.8	2.1	45.9	77.3	92.5	6.3
Adelaide	Apt	Top	TF	NB	NZ	37.3	49.4	2.4	33.6	44.5	2.1	46.7	80.3	92.5	6.2
Adelaide	Apt	Top	MF	NB	ISO	45.2	52.8	2.5	40.7	47.5	2.2	49.7	90.4	92.5	5.7
Adelaide	Apt	Top	MF	NB	NZ	47.6	53.7	2.5	42.9	48.3	2.2	50.6	93.5	92.5	5.6
Adelaide	Apt	Top	MF	TB	ISO	42.9	51.7	2.4	38.7	46.5	2.2	48.7	87.4	92.5	5.9
Adelaide	Apt	Top	MF	TB	NZ	42.0	51.3	2.4	37.8	46.2	2.2	48.4	86.2	92.5	5.9
Adelaide	Apt	Top	MF	TB	NZAdj	37.3	49.4	2.4	33.6	44.5	2.1	46.7	80.3	92.5	6.2
Brisbane	House	BV	Dft	NA	ISO	5.2	26.7	15.5	4.9	25.3	14.6	39.9	44.8	148.5	6.9
Brisbane	House	BV	TF	NB	NZ	5.9	27.5	15.6	5.6	26.0	14.8	40.8	46.4	148.5	6.7
Brisbane	House	BV	MF	NB	ISO	7.0	29.1	16.0	6.7	27.5	15.2	42.7	49.3	148.5	6.4
Brisbane	House	BV	MF	NB	NZ	7.9	30.3	16.3	7.5	28.7	15.4	44.1	51.6	148.5	6.1
Brisbane	House	BV	MF	TB	ISO	6.7	28.5	15.9	6.3	27.0	15.0	42.0	48.3	148.5	6.4
Brisbane	House	BV	MF	TB	NZ	7.0	28.7	15.8	6.7	27.1	15.0	42.1	48.7	148.5	6.4
Brisbane	House	BV	MF	TB	NZAdj	5.9	27.4	15.6	5.6	25.9	14.8	40.7	46.3	148.5	6.7
Brisbane	House	LC	Dft	NA	ISO	6.0	28.0	15.7	5.7	26.5	14.8	41.3	47.0	148.5	6.6
Brisbane	House	LC	TF	NB	NZ	7.1	29.6	16.1	6.7	28.0	15.2	43.2	50.0	148.5	6.3
Brisbane	House	LC	MF	NB	ISO	8.5	31.6	16.6	8.0	29.9	15.7	45.6	53.6	148.5	5.9
Brisbane	House	LC	MF	NB	NZ	10.5	33.1	17.1	9.9	31.3	16.2	47.5	57.4	148.5	5.6
Brisbane	House	LC	MF	TB	ISO	8.2	31.6	16.5	7.7	29.9	15.6	45.5	53.3	148.5	5.9
Brisbane	House	LC	MF	TB	NZ	8.6	31.9	16.6	8.2	30.2	15.7	45.8	54.0	148.5	5.9
Brisbane	House	LC	MF	TB	NZAdj	7.0	29.5	16.0	6.7	27.9	15.2	43.1	49.7	148.5	6.3
Brisbane	House	MCSF	Dft	NA	ISO	11.6	29.1	14.7	11.0	27.5	13.9	41.4	52.4	148.5	6.1
Brisbane	House	MCSF	TF	NB	NZ	13.8	30.0	14.8	13.0	28.4	14.0	42.3	55.4	148.5	5.8
Brisbane	House	MCSF	MF	NB	ISO	15.8	30.6	14.9	14.9	28.9	14.1	43.0	58.0	148.5	5.6
Brisbane	House	MCSF	MF	NB	NZ	18.8	31.3	14.9	17.8	29.6	14.1	43.7	61.5	148.5	5.3
Brisbane	House	MCSF	MF	TB	ISO	15.2	30.2	14.9	14.3	28.6	14.1	42.7	57.1	148.5	5.7
Brisbane	House	MCSF	MF	TB	NZ	16.0	30.2	14.7	15.2	28.6	13.9	42.4	57.6	148.5	5.6

Brisbane	House	MCSF	MF	TB	NZAdj	13.7	30.0	14.8	12.9	28.4	14.0	42.4	55.3	148.5	5.8
Brisbane	Apt	Ground	Dft	NA	ISO	1.8	19.4	13.6	1.6	17.7	12.4	30.1	31.7	92.5	8.4
Brisbane	Apt	Ground	TF	NB	NZ	1.9	19.4	13.6	1.7	17.7	12.4	30.1	31.8	92.5	8.4
Brisbane	Apt	Ground	MF	NB	ISO	2.0	19.5	13.6	1.8	17.8	12.4	30.2	32.0	92.5	8.4
Brisbane	Apt	Ground	MF	NB	NZ	2.1	19.5	13.6	1.9	17.8	12.4	30.2	32.1	92.5	8.4
Brisbane	Apt	Ground	MF	TB	ISO	1.9	19.4	13.6	1.7	17.7	12.4	30.1	31.9	92.5	8.4
Brisbane	Apt	Ground	MF	TB	NZ	1.9	19.5	13.6	1.8	17.8	12.4	30.2	32.0	92.5	8.4
Brisbane	Apt	Ground	MF	TB	NZAdj	1.9	19.4	13.6	1.7	17.7	12.4	30.1	31.8	92.5	8.4
Brisbane	Apt	Top	Dft	NA	ISO	8.2	12.3	7.9	7.5	11.3	7.2	18.5	26.0	92.5	9.1
Brisbane	Apt	Top	TF	NB	NZ	9.0	12.7	8.0	8.2	11.6	7.3	19.0	27.2	92.5	8.9
Brisbane	Apt	Top	MF	NB	ISO	11.5	13.1	8.1	10.5	11.9	7.4	19.3	29.8	92.5	8.7
Brisbane	Apt	Top	MF	NB	NZ	12.3	13.1	8.1	11.3	12.0	7.4	19.4	30.6	92.5	8.6
Brisbane	Apt	Top	MF	TB	ISO	10.8	13.1	8.2	9.9	12.0	7.4	19.4	29.3	92.5	8.7
Brisbane	Apt	Top	MF	TB	NZ	10.4	13.0	8.1	9.5	11.9	7.4	19.2	28.8	92.5	8.8
Brisbane	Apt	Top	MF	TB	NZAdj	9.0	12.7	8.0	8.2	11.6	7.3	19.0	27.2	92.5	8.9
Canberra	House	BV	Dft	NA	ISO	143.6	11.5	1.1	131.1	10.5	1.0	11.5	142.6	148.5	6.4
Canberra	House	BV	TF	NB	NZ	152.0	12.5	1.2	138.7	11.4	1.1	12.5	151.3	148.5	6.2
Canberra	House	BV	MF	NB	ISO	163.0	13.7	1.3	148.8	12.5	1.2	13.7	162.4	148.5	5.9
Canberra	House	BV	MF	NB	NZ	170.5	14.6	1.3	155.6	13.3	1.2	14.5	170.1	148.5	5.8
Canberra	House	BV	MF	TB	ISO	159.1	13.4	1.3	145.2	12.3	1.2	13.4	158.6	148.5	6.1
Canberra	House	BV	MF	TB	NZ	161.4	13.7	1.3	147.3	12.5	1.2	13.7	161.1	148.5	5.9
Canberra	House	BV	MF	TB	NZAdj	152.1	12.5	1.2	138.8	11.4	1.1	12.5	151.3	148.5	6.2
Canberra	House	LC	Dft	NA	ISO	149.5	14.0	1.3	136.5	12.8	1.2	14.0	150.5	148.5	6.3
Canberra	House	LC	TF	NB	NZ	159.6	15.3	1.4	145.7	14.0	1.3	15.3	160.9	148.5	6.0
Canberra	House	LC	MF	NB	ISO	172.9	17.0	1.5	157.8	15.5	1.3	16.8	174.6	148.5	5.8
Canberra	House	LC	MF	NB	NZ	191.3	19.1	1.6	174.6	17.4	1.4	18.8	193.4	148.5	5.4
Canberra	House	LC	MF	TB	ISO	169.3	17.0	1.4	154.5	15.5	1.3	16.8	171.3	148.5	5.8
Canberra	House	LC	MF	TB	NZ	173.0	17.4	1.5	157.9	15.9	1.3	17.2	175.1	148.5	5.8
Canberra	House	LC	MF	TB	NZAdj	159.2	15.2	1.4	145.3	13.9	1.3	15.2	160.5	148.5	6.0
Canberra	House	MCSF	Dft	NA	ISO	127.7	17.0	1.5	116.5	15.5	1.4	16.9	133.4	148.5	6.7
Canberra	House	MCSF	TF	NB	NZ	142.4	18.9	1.5	130.0	17.2	1.4	18.6	148.6	148.5	6.3

Canberra	House	MCSF	MF	NB	ISO	170.5	18.5	1.5	155.6	16.9	1.4	18.3	173.9	148.5	5.8
Canberra	House	MCSF	MF	NB	NZ	193.3	20.8	1.6	176.4	19.0	1.4	20.4	196.8	148.5	5.4
Canberra	House	MCSF	MF	TB	ISO	166.0	18.4	1.5	151.5	16.8	1.4	18.1	169.6	148.5	5.9
Canberra	House	MCSF	MF	TB	NZ	174.3	19.0	1.5	159.1	17.3	1.4	18.7	177.8	148.5	5.7
Canberra	House	MCSF	MF	TB	NZAdj	141.9	18.7	1.5	129.6	17.0	1.4	18.4	148.0	148.5	6.3
Canberra	Apt	Ground	Dft	NA	ISO	127.4	10.4	1.1	114.3	9.4	1.0	10.4	124.7	92.5	6.9
Canberra	Apt	Ground	TF	NB	NZ	129.5	10.5	1.1	116.1	9.4	1.0	10.4	126.5	92.5	6.9
Canberra	Apt	Ground	MF	NB	ISO	131.4	10.5	1.1	117.9	9.4	1.0	10.4	128.3	92.5	6.8
Canberra	Apt	Ground	MF	NB	NZ	135.5	10.5	1.1	121.5	9.5	1.0	10.4	131.9	92.5	6.7
Canberra	Apt	Ground	MF	TB	ISO	130.1	10.5	1.1	116.7	9.4	1.0	10.4	127.1	92.5	6.9
Canberra	Apt	Ground	MF	TB	NZ	130.8	10.5	1.1	117.3	9.4	1.0	10.4	127.7	92.5	6.8
Canberra	Apt	Ground	MF	TB	NZAdj	129.5	10.5	1.1	116.1	9.4	1.0	10.4	126.5	92.5	6.9
Canberra	Apt	Top	Dft	NA	ISO	99.4	23.6	1.5	89.2	21.2	1.4	22.6	111.7	92.5	7.3
Canberra	Apt	Top	TF	NB	NZ	104.8	24.1	1.5	94.0	21.6	1.4	23.0	117.1	92.5	7.1
Canberra	Apt	Top	MF	NB	ISO	121.4	25.0	1.6	108.9	22.4	1.4	23.8	132.7	92.5	6.7
Canberra	Apt	Top	MF	NB	NZ	127.2	25.3	1.6	114.1	22.7	1.4	24.1	138.2	92.5	6.6
Canberra	Apt	Top	MF	TB	ISO	116.6	25.1	1.6	104.6	22.5	1.4	23.9	128.5	92.5	6.8
Canberra	Apt	Top	MF	TB	NZ	114.7	24.7	1.6	102.9	22.2	1.4	23.5	126.4	92.5	6.9
Canberra	Apt	Top	MF	TB	NZAdj	104.8	24.0	1.5	94.0	21.6	1.4	22.9	117.0	92.5	7.1
Darwin	House	BV	Dft	NA	ISO	0.0	204.7	107.7	0.0	196.1	103.2	299.2	299.2	148.5	6.9
Darwin	House	BV	TF	NB	NZ	0.0	210.5	108.1	0.0	201.7	103.5	305.2	305.2	148.5	6.8
Darwin	House	BV	MF	NB	ISO	0.0	219.3	108.9	0.0	210.1	104.3	314.4	314.4	148.5	6.6
Darwin	House	BV	MF	NB	NZ	0.0	225.0	109.1	0.0	215.5	104.5	320.1	320.1	148.5	6.4
Darwin	House	BV	MF	TB	ISO	0.0	216.8	108.6	0.0	207.7	104.1	311.7	311.7	148.5	6.7
Darwin	House	BV	MF	TB	NZ	0.0	218.5	108.5	0.0	209.4	103.9	313.3	313.3	148.5	6.6
Darwin	House	BV	MF	TB	NZAdj	0.0	210.4	108.0	0.0	201.5	103.4	305.0	305.0	148.5	6.8
Darwin	House	LC	Dft	NA	ISO	0.0	211.2	107.7	0.0	202.3	103.1	305.5	305.5	148.5	6.8
Darwin	House	LC	TF	NB	NZ	0.0	218.1	108.3	0.0	209.0	103.8	312.8	312.8	148.5	6.6
Darwin	House	LC	MF	NB	ISO	0.0	227.0	109.2	0.0	217.5	104.6	322.1	322.1	148.5	6.4
Darwin	House	LC	MF	NB	NZ	0.0	238.2	110.1	0.0	228.2	105.4	333.6	333.6	148.5	6.2
Darwin	House	LC	MF	TB	ISO	0.0	226.4	108.8	0.0	216.9	104.3	321.2	321.2	148.5	6.4

Darwin	House	LC	MF	TB	NZ	0.0	229.4	109.2	0.0	219.8	104.6	324.5	324.5	148.5	6.4
Darwin	House	LC	MF	TB	NZAdj	0.0	217.7	108.4	0.0	208.6	103.9	312.5	312.5	148.5	6.7
Darwin	House	MCSF	Dft	NA	ISO	0.0	198.6	93.4	0.0	190.2	89.5	279.7	279.7	148.5	7.4
Darwin	House	MCSF	TF	NB	NZ	0.0	208.5	94.4	0.0	199.7	90.4	290.2	290.2	148.5	7.2
Darwin	House	MCSF	MF	NB	ISO	0.0	219.5	95.7	0.0	210.3	91.7	302.0	302.0	148.5	6.9
Darwin	House	MCSF	MF	NB	NZ	0.0	231.6	97.0	0.0	221.9	92.9	314.8	314.8	148.5	6.6
Darwin	House	MCSF	MF	TB	ISO	0.0	218.3	95.4	0.0	209.2	91.4	300.6	300.6	148.5	6.9
Darwin	House	MCSF	MF	TB	NZ	0.0	221.9	96.0	0.0	212.6	92.0	304.6	304.6	148.5	6.8
Darwin	House	MCSF	MF	TB	NZAdj	0.0	207.9	94.4	0.0	199.2	90.5	289.6	289.6	148.5	7.2
Darwin	Apt	Ground	Dft	NA	ISO	0.0	207.3	110.9	0.0	193.0	103.2	296.2	296.2	92.5	7.0
Darwin	Apt	Ground	TF	NB	NZ	0.0	208.0	111.1	0.0	193.6	103.4	297.0	297.0	92.5	7.0
Darwin	Apt	Ground	MF	NB	ISO	0.0	208.0	110.9	0.0	193.6	103.2	296.8	296.8	92.5	7.0
Darwin	Apt	Ground	MF	NB	NZ	0.0	209.5	111.2	0.0	195.0	103.5	298.5	298.5	92.5	6.9
Darwin	Apt	Ground	MF	TB	ISO	0.0	207.9	110.9	0.0	193.5	103.3	296.8	296.8	92.5	7.0
Darwin	Apt	Ground	MF	TB	NZ	0.0	208.1	111.0	0.0	193.7	103.3	297.0	297.0	92.5	7.0
Darwin	Apt	Ground	MF	TB	NZAdj	0.0	207.8	110.9	0.0	193.4	103.2	296.7	296.7	92.5	7.0
Darwin	Apt	Top	Dft	NA	ISO	0.0	178.0	97.5	0.0	165.7	90.8	256.5	256.5	92.5	8.0
Darwin	Apt	Top	TF	NB	NZ	0.0	178.4	97.7	0.0	166.1	91.0	257.0	257.0	92.5	7.9
Darwin	Apt	Top	MF	NB	ISO	0.0	185.0	98.2	0.0	172.2	91.5	263.7	263.7	92.5	7.8
Darwin	Apt	Top	MF	NB	NZ	0.0	186.7	98.4	0.0	173.8	91.6	265.4	265.4	92.5	7.8
Darwin	Apt	Top	MF	TB	ISO	0.0	183.2	97.8	0.0	170.6	91.1	261.6	261.6	92.5	7.9
Darwin	Apt	Top	MF	TB	NZ	0.0	182.7	97.8	0.0	170.1	91.1	261.1	261.1	92.5	7.9
Darwin	Apt	Top	MF	TB	NZAdj	0.0	178.4	97.7	0.0	166.1	91.0	257.1	257.1	92.5	7.9
Hobart	House	BV	Dft	NA	ISO	148.9	1.2	0.1	134.7	1.1	0.1	1.2	135.9	148.5	6.4
Hobart	House	BV	TF	NB	NZ	157.2	1.2	0.2	142.3	1.1	0.1	1.3	143.5	148.5	6.2
Hobart	House	BV	MF	NB	ISO	168.0	1.2	0.1	152.1	1.1	0.1	1.2	153.3	148.5	5.9
Hobart	House	BV	MF	NB	NZ	175.6	1.2	0.1	158.9	1.1	0.1	1.2	160.0	148.5	5.8
Hobart	House	BV	MF	TB	ISO	164.3	1.3	0.1	148.6	1.2	0.1	1.3	149.9	148.5	6.1
Hobart	House	BV	MF	TB	NZ	166.8	1.2	0.1	151.0	1.1	0.1	1.2	152.2	148.5	5.9
Hobart	House	BV	MF	TB	NZAdj	157.3	1.2	0.2	142.3	1.1	0.1	1.3	143.6	148.5	6.2
Hobart	House	LC	Dft	NA	ISO	154.2	1.2	0.1	139.5	1.1	0.1	1.2	140.8	148.5	6.3

Hobart	House	LC	TF	NB	NZ	164.1	1.4	0.2	148.5	1.3	0.1	1.4	149.9	148.5	6.1
Hobart	House	LC	MF	NB	ISO	176.8	1.6	0.2	160.0	1.4	0.2	1.6	161.6	148.5	5.8
Hobart	House	LC	MF	NB	NZ	194.5	1.8	0.2	176.0	1.6	0.2	1.8	177.8	148.5	5.4
Hobart	House	LC	MF	TB	ISO	173.6	1.4	0.1	157.1	1.2	0.1	1.4	158.5	148.5	5.8
Hobart	House	LC	MF	TB	NZ	177.4	1.4	0.1	160.6	1.3	0.1	1.4	162.0	148.5	5.8
Hobart	House	LC	MF	TB	NZAdj	163.8	1.3	0.1	148.2	1.2	0.1	1.3	149.5	148.5	6.1
Hobart	House	MCSF	Dft	NA	ISO	125.9	2.5	0.3	113.9	2.2	0.2	2.5	116.3	148.5	7.0
Hobart	House	MCSF	TF	NB	NZ	140.2	2.7	0.3	126.9	2.4	0.3	2.7	129.5	148.5	6.6
Hobart	House	MCSF	MF	NB	ISO	170.3	2.4	0.2	154.1	2.2	0.2	2.4	156.5	148.5	5.9
Hobart	House	MCSF	MF	NB	NZ	192.4	2.6	0.2	174.1	2.4	0.2	2.6	176.7	148.5	5.4
Hobart	House	MCSF	MF	TB	ISO	166.4	2.4	0.2	150.6	2.2	0.2	2.4	152.9	148.5	5.9
Hobart	House	MCSF	MF	TB	NZ	175.1	2.3	0.2	158.4	2.1	0.2	2.3	160.8	148.5	5.8
Hobart	House	MCSF	MF	TB	NZAdj	139.8	2.6	0.3	126.5	2.3	0.3	2.6	129.1	148.5	6.6
Hobart	Apt	Ground	Dft	NA	ISO	148.5	1.0	0.1	132.5	0.9	0.1	1.0	133.5	92.5	6.5
Hobart	Apt	Ground	TF	NB	NZ	150.5	1.0	0.1	134.3	0.9	0.1	1.0	135.4	92.5	6.4
Hobart	Apt	Ground	MF	NB	ISO	152.5	1.1	0.1	136.1	1.0	0.1	1.1	137.2	92.5	6.4
Hobart	Apt	Ground	MF	NB	NZ	156.5	1.2	0.1	139.7	1.1	0.1	1.2	140.9	92.5	6.3
Hobart	Apt	Ground	MF	TB	ISO	151.1	1.0	0.1	134.9	0.9	0.1	1.0	135.9	92.5	6.4
Hobart	Apt	Ground	MF	TB	NZ	151.8	1.0	0.1	135.6	0.9	0.1	1.0	136.6	92.5	6.4
Hobart	Apt	Ground	MF	TB	NZAdj	150.5	1.0	0.1	134.3	0.9	0.1	1.0	135.4	92.5	6.4
Hobart	Apt	Top	Dft	NA	ISO	107.7	2.7	0.3	96.1	2.4	0.2	2.7	98.8	92.5	7.5
Hobart	Apt	Top	TF	NB	NZ	112.8	2.8	0.3	100.7	2.5	0.2	2.8	103.4	92.5	7.4
Hobart	Apt	Top	MF	NB	ISO	128.3	2.8	0.2	114.6	2.5	0.2	2.8	117.3	92.5	6.9
Hobart	Apt	Top	MF	NB	NZ	133.6	2.8	0.2	119.3	2.5	0.2	2.7	122.0	92.5	6.9
Hobart	Apt	Top	MF	TB	ISO	123.8	2.8	0.2	110.5	2.5	0.2	2.7	113.2	92.5	7.1
Hobart	Apt	Top	MF	TB	NZ	122.0	2.8	0.3	108.9	2.5	0.2	2.8	111.6	92.5	7.1
Hobart	Apt	Top	MF	TB	NZAdj	112.8	2.8	0.3	100.7	2.5	0.2	2.8	103.4	92.5	7.4
Melbourne	House	BV	Dft	NA	ISO	56.8	14.7	1.8	51.7	13.3	1.6	15.0	66.7	148.5	6.7
Melbourne	House	BV	TF	NB	NZ	61.0	15.4	1.9	55.5	14.0	1.7	15.7	71.2	148.5	6.4
Melbourne	House	BV	MF	NB	ISO	66.5	16.8	2.0	60.5	15.3	1.8	17.1	77.6	148.5	6.2
Melbourne	House	BV	MF	NB	NZ	70.4	17.7	2.0	64.0	16.1	1.8	17.9	82.0	148.5	5.9

Melbourne	House	BV	MF	TB	ISO	64.6	16.4	1.9	58.8	14.9	1.7	16.7	75.5	148.5	6.3
Melbourne	House	BV	MF	TB	NZ	66.0	16.9	2.0	60.0	15.3	1.8	17.1	77.2	148.5	6.2
Melbourne	House	BV	MF	TB	NZAdj	61.0	15.4	1.9	55.5	14.0	1.7	15.7	71.2	148.5	6.4
Melbourne	House	LC	Dft	NA	ISO	59.9	16.7	2.0	54.5	15.2	1.8	17.0	71.5	148.5	6.4
Melbourne	House	LC	TF	NB	NZ	64.8	17.8	2.0	59.0	16.2	1.8	18.0	77.0	148.5	6.2
Melbourne	House	LC	MF	NB	ISO	71.3	19.1	2.1	64.8	17.4	1.9	19.3	84.1	148.5	5.9
Melbourne	House	LC	MF	NB	NZ	80.3	20.4	2.1	73.0	18.5	1.9	20.4	93.4	148.5	5.4
Melbourne	House	LC	MF	TB	ISO	69.7	19.0	2.1	63.4	17.3	1.9	19.2	82.6	148.5	5.9
Melbourne	House	LC	MF	TB	NZ	71.7	19.4	2.1	65.3	17.6	1.9	19.5	84.8	148.5	5.8
Melbourne	House	LC	MF	TB	NZAdj	64.7	17.6	2.0	58.9	16.1	1.8	17.9	76.7	148.5	6.2
Melbourne	House	MCSF	Dft	NA	ISO	54.6	19.3	2.0	49.6	17.5	1.8	19.4	69.0	148.5	6.6
Melbourne	House	MCSF	TF	NB	NZ	62.0	20.8	2.1	56.4	18.9	1.9	20.8	77.2	148.5	6.2
Melbourne	House	MCSF	MF	NB	ISO	75.0	20.4	2.0	68.2	18.6	1.8	20.4	88.7	148.5	5.7
Melbourne	House	MCSF	MF	NB	NZ	86.3	22.3	2.1	78.5	20.2	1.9	22.1	100.6	148.5	5.2
Melbourne	House	MCSF	MF	TB	ISO	72.9	20.3	2.0	66.4	18.5	1.8	20.3	86.6	148.5	5.8
Melbourne	House	MCSF	MF	TB	NZ	77.1	20.6	2.0	70.1	18.8	1.8	20.6	90.7	148.5	5.6
Melbourne	House	MCSF	MF	TB	NZAdj	61.8	20.7	2.1	56.2	18.8	1.9	20.7	76.9	148.5	6.2
Melbourne	Apt	Ground	Dft	NA	ISO	45.5	17.5	2.1	40.7	15.7	1.9	17.5	58.2	92.5	7.2
Melbourne	Apt	Ground	TF	NB	NZ	46.4	17.8	2.1	41.5	15.9	1.9	17.8	59.2	92.5	7.1
Melbourne	Apt	Ground	MF	NB	ISO	47.3	17.8	2.1	42.3	15.9	1.9	17.7	60.0	92.5	7.1
Melbourne	Apt	Ground	MF	NB	NZ	49.1	18.1	2.1	43.9	16.1	1.9	18.0	61.9	92.5	7.0
Melbourne	Apt	Ground	MF	TB	ISO	46.8	17.7	2.1	41.8	15.9	1.9	17.7	59.5	92.5	7.1
Melbourne	Apt	Ground	MF	TB	NZ	47.1	17.8	2.1	42.1	15.9	1.9	17.8	59.8	92.5	7.1
Melbourne	Apt	Ground	MF	TB	NZAdj	46.4	17.8	2.1	41.5	15.9	1.9	17.8	59.2	92.5	7.1
Melbourne	Apt	Top	Dft	NA	ISO	40.9	23.3	2.2	36.5	20.9	2.0	22.8	59.4	92.5	7.1
Melbourne	Apt	Top	TF	NB	NZ	43.5	23.8	2.2	38.9	21.3	2.0	23.3	62.1	92.5	6.9
Melbourne	Apt	Top	MF	NB	ISO	51.5	25.1	2.2	46.0	22.4	2.0	24.4	70.4	92.5	6.5
Melbourne	Apt	Top	MF	NB	NZ	54.3	25.1	2.2	48.5	22.4	2.0	24.4	72.9	92.5	6.4
Melbourne	Apt	Top	MF	TB	ISO	49.1	24.8	2.3	43.9	22.2	2.0	24.2	68.0	92.5	6.7
Melbourne	Apt	Top	MF	TB	NZ	48.2	24.5	2.2	43.0	21.9	2.0	23.9	66.9	92.5	6.7
Melbourne	Apt	Top	MF	TB	NZAdj	43.5	23.8	2.2	38.9	21.3	2.0	23.3	62.1	92.5	6.9

Perth	House	BV	Dft	NA	ISO	27.1	31.3	3.3	25.0	28.8	3.0	31.8	56.8	148.5	7.3
Perth	House	BV	TF	NB	NZ	29.8	32.7	3.3	27.5	30.2	3.1	33.2	60.7	148.5	7.0
Perth	House	BV	MF	NB	ISO	33.3	35.3	3.4	30.7	32.5	3.1	35.6	66.3	148.5	6.7
Perth	House	BV	MF	NB	NZ	36.0	37.2	3.5	33.1	34.3	3.2	37.5	70.6	148.5	6.4
Perth	House	BV	MF	TB	ISO	32.1	34.6	3.4	29.6	31.9	3.1	35.0	64.6	148.5	6.8
Perth	House	BV	MF	TB	NZ	33.1	35.3	3.4	30.5	32.5	3.1	35.7	66.2	148.5	6.7
Perth	House	BV	MF	TB	NZAdj	29.8	32.8	3.3	27.4	30.2	3.1	33.3	60.7	148.5	7.0
Perth	House	LC	Dft	NA	ISO	29.4	35.3	3.4	27.1	32.5	3.1	35.6	62.7	148.5	6.9
Perth	House	LC	TF	NB	NZ	32.8	37.8	3.5	30.2	34.8	3.2	38.1	68.2	148.5	6.6
Perth	House	LC	MF	NB	ISO	37.0	40.8	3.7	34.1	37.6	3.4	41.0	75.1	148.5	6.2
Perth	House	LC	MF	NB	NZ	43.1	44.3	3.8	39.7	40.8	3.5	44.3	84.0	148.5	5.7
Perth	House	LC	MF	TB	ISO	36.0	40.5	3.6	33.2	37.3	3.4	40.6	73.8	148.5	6.3
Perth	House	LC	MF	TB	NZ	37.4	41.1	3.7	34.4	37.9	3.4	41.3	75.7	148.5	6.2
Perth	House	LC	MF	TB	NZAdj	32.6	37.6	3.5	30.1	34.6	3.2	37.8	67.9	148.5	6.6
Perth	House	MCSF	Dft	NA	ISO	35.3	39.1	3.6	32.5	36.0	3.3	39.3	71.9	148.5	6.4
Perth	House	MCSF	TF	NB	NZ	40.6	41.8	3.7	37.4	38.5	3.4	41.9	79.2	148.5	5.9
Perth	House	MCSF	MF	NB	ISO	47.6	43.7	3.7	43.9	40.3	3.4	43.7	87.6	148.5	5.4
Perth	House	MCSF	MF	NB	NZ	55.3	47.4	3.8	51.0	43.6	3.5	47.1	98.1	148.5	4.9
Perth	House	MCSF	MF	TB	ISO	46.1	42.9	3.7	42.5	39.5	3.4	42.9	85.4	148.5	5.6
Perth	House	MCSF	MF	TB	NZ	48.6	43.9	3.7	44.8	40.4	3.4	43.8	88.6	148.5	5.4
Perth	House	MCSF	MF	TB	NZAdj	40.3	41.6	3.6	37.1	38.3	3.3	41.6	78.8	148.5	6.0
Perth	Apt	Ground	Dft	NA	ISO	19.9	33.7	3.0	18.0	30.3	2.7	33.0	51.0	92.5	7.6
Perth	Apt	Ground	TF	NB	NZ	20.5	34.2	3.0	18.5	30.8	2.7	33.5	52.0	92.5	7.6
Perth	Apt	Ground	MF	NB	ISO	21.1	34.3	3.0	19.0	30.9	2.7	33.6	52.6	92.5	7.5
Perth	Apt	Ground	MF	NB	NZ	22.2	34.9	3.0	20.0	31.5	2.7	34.2	54.2	92.5	7.4
Perth	Apt	Ground	MF	TB	ISO	20.7	34.3	3.0	18.6	30.9	2.7	33.7	52.3	92.5	7.5
Perth	Apt	Ground	MF	TB	NZ	20.9	34.3	3.0	18.8	30.8	2.7	33.6	52.4	92.5	7.5
Perth	Apt	Ground	MF	TB	NZAdj	20.5	34.2	3.1	18.5	30.8	2.7	33.5	52.0	92.5	7.5
Perth	Apt	Top	Dft	NA	ISO	28.1	49.9	3.2	25.3	44.9	2.9	47.8	73.1	92.5	6.3
Perth	Apt	Top	TF	NB	NZ	30.1	50.6	3.2	27.1	45.6	2.9	48.4	75.5	92.5	6.2
Perth	Apt	Top	MF	NB	ISO	36.3	53.0	3.2	32.7	47.7	2.9	50.6	83.3	92.5	5.7

Perth	Apt	Top	MF	NB	NZ	38.4	53.5	3.2	34.6	48.2	2.9	51.1	85.7	92.5	5.6
Perth	Apt	Top	MF	TB	ISO	34.5	52.3	3.2	31.1	47.1	2.9	49.9	81.0	92.5	5.9
Perth	Apt	Top	MF	TB	NZ	33.7	51.8	3.2	30.4	46.7	2.9	49.6	79.9	92.5	5.9
Perth	Apt	Top	MF	TB	NZAdj	30.1	50.6	3.2	27.1	45.6	2.9	48.5	75.5	92.5	6.2
Sydney	House	BV	Dft	NA	ISO	21.2	8.3	3.1	19.4	7.5	2.9	10.4	29.8	148.5	7.0
Sydney	House	BV	TF	NB	NZ	23.2	8.6	3.3	21.2	7.9	3.0	10.9	32.1	148.5	6.8
Sydney	House	BV	MF	NB	ISO	25.9	9.7	3.5	23.6	8.8	3.2	12.0	35.7	148.5	6.4
Sydney	House	BV	MF	NB	NZ	28.0	10.2	3.6	25.6	9.3	3.3	12.6	38.2	148.5	6.1
Sydney	House	BV	MF	TB	ISO	25.0	9.4	3.5	22.9	8.6	3.2	11.8	34.7	148.5	6.5
Sydney	House	BV	MF	TB	NZ	25.9	9.6	3.5	23.6	8.8	3.2	12.0	35.6	148.5	6.4
Sydney	House	BV	MF	TB	NZAdj	23.2	8.6	3.3	21.2	7.9	3.0	10.8	32.1	148.5	6.8
Sydney	House	LC	Dft	NA	ISO	22.8	9.6	3.4	20.8	8.8	3.1	11.9	32.7	148.5	6.7
Sydney	House	LC	TF	NB	NZ	25.3	10.3	3.5	23.1	9.4	3.2	12.6	35.7	148.5	6.4
Sydney	House	LC	MF	NB	ISO	28.3	11.2	3.7	25.9	10.3	3.4	13.7	39.5	148.5	5.9
Sydney	House	LC	MF	NB	NZ	32.7	12.2	4.0	29.9	11.1	3.6	14.8	44.7	148.5	5.4
Sydney	House	LC	MF	TB	ISO	27.7	11.2	3.7	25.3	10.3	3.4	13.6	38.9	148.5	6.0
Sydney	House	LC	MF	TB	NZ	28.7	11.5	3.7	26.2	10.5	3.4	13.9	40.1	148.5	5.9
Sydney	House	LC	MF	TB	NZAdj	25.2	10.3	3.5	23.0	9.4	3.2	12.6	35.7	148.5	6.4
Sydney	House	MCSF	Dft	NA	ISO	24.9	11.2	3.3	22.8	10.3	3.0	13.2	36.0	148.5	6.4
Sydney	House	MCSF	TF	NB	NZ	28.7	12.1	3.3	26.2	11.0	3.1	14.1	40.3	148.5	5.9
Sydney	House	MCSF	MF	NB	ISO	34.0	11.6	3.1	31.1	10.6	2.8	13.4	44.5	148.5	5.4
Sydney	House	MCSF	MF	NB	NZ	39.6	12.5	3.2	36.2	11.4	2.9	14.3	50.5	148.5	4.9
Sydney	House	MCSF	MF	TB	ISO	33.0	11.4	3.0	30.2	10.5	2.8	13.2	43.4	148.5	5.6
Sydney	House	MCSF	MF	TB	NZ	34.9	11.6	3.1	31.9	10.6	2.8	13.4	45.3	148.5	5.4
Sydney	House	MCSF	MF	TB	NZAdj	28.6	11.7	3.2	26.1	10.7	3.0	13.7	39.8	148.5	5.9
Sydney	Apt	Ground	Dft	NA	ISO	15.3	7.0	3.4	13.7	6.3	3.0	9.3	23.0	92.5	7.9
Sydney	Apt	Ground	TF	NB	NZ	15.6	7.1	3.4	14.0	6.3	3.0	9.4	23.4	92.5	7.8
Sydney	Apt	Ground	MF	NB	ISO	16.0	7.1	3.4	14.4	6.3	3.0	9.4	23.7	92.5	7.8
Sydney	Apt	Ground	MF	NB	NZ	16.8	7.2	3.3	15.1	6.4	3.0	9.4	24.5	92.5	7.7
Sydney	Apt	Ground	MF	TB	ISO	15.8	7.1	3.4	14.1	6.3	3.0	9.3	23.5	92.5	7.8
Sydney	Apt	Ground	MF	TB	NZ	15.9	7.1	3.4	14.3	6.3	3.0	9.4	23.6	92.5	7.8

Sydney	Apt	Ground	MF	TB	NZAdj	15.6	7.1	3.4	14.0	6.3	3.0	9.4	23.4	92.5	7.8
Sydney	Apt	Top	Dft	NA	ISO	19.1	11.1	2.8	17.1	10.0	2.5	12.4	29.5	92.5	7.1
Sydney	Apt	Top	TF	NB	NZ	20.4	11.3	2.8	18.3	10.2	2.5	12.7	30.9	92.5	6.9
Sydney	Apt	Top	MF	NB	ISO	24.5	11.7	2.7	21.9	10.5	2.4	12.9	34.9	92.5	6.5
Sydney	Apt	Top	MF	NB	NZ	25.9	11.8	2.7	23.2	10.6	2.4	13.0	36.2	92.5	6.3
Sydney	Apt	Top	MF	TB	ISO	23.3	11.7	2.7	20.9	10.5	2.5	13.0	33.9	92.5	6.6
Sydney	Apt	Top	MF	TB	NZ	22.8	11.9	2.8	20.4	10.7	2.5	13.2	33.6	92.5	6.6
Sydney	Apt	Top	MF	TB	NZAdj	20.4	11.3	2.8	18.3	10.2	2.5	12.7	30.9	92.5	6.9

Note: The “Dft” (Default) case is the current NatHERS rating practice which does not include thermal bridging effect. NB (no thermal break) cases have included thermal bridging effect, but without thermal break. TB (with thermal break) cases have included thermal bridging effect, with thermal break.

BV brick veneer
Dft Default
MCSF metal cladding with suspended floor
MF metal frame
NA thermal bridging not applied
NB no thermal break
TB with thermal break
TF timber frame
ISO ISO 6946: 1996 thermal bridging calculations applied
NZ NZS 4214: 2006 thermal bridging calculations applied
NZAdj Adjusted NZS 4214: 2006 thermal bridging calculations applied

References

Australian/New Zealand Standard AS/NZS 4859.2:2018: Thermal insulation materials for buildings. Part 2: Design. 2018.

Chen D, Ren Z, Ambrose M and James M, Thermal Bridging for Residential Building Energy Rating - Defaults, modelling guidance and impact on residential building energy ratings, Report for Department of Industry, Science, Energy and Resources, August 2020.

Doran S and Gorgolewski M, U-values for light steel-frame construction, BRE and Department of Transport, Local Governemnt And Regions, Digest No. 465, 2002, pp1 – 12.

Gorgolewski, M., Developing a simplified method of calculating U-values in light steel framing, Building and Environment, 2007, 42, 230–236.

ISO 6946: 1996. Building components and building elements—thermal resistance and thermal transmittance—calculation method, Switzerland, ISO 1996.

ISO 6946: 2017. Building components and building elements—thermal resistance and thermal transmittance—calculation method, Switzerland, ISO 2017.

Kelly, M., Private communications, the National Association of Steel-framed Housing Inc. (NASH), July 2020.

Kingspan, Air-cell Insulbreak, Thermal break solution. Kingspan Insulation Pty Ltd, 2019.

NASH, Technical Note 2, Energy Efficiency Measures for Houses, National Association of Steel-framed Housing Inc. (NASH), May 2015.

New Zealand Standard NZS4214: 2006: Methods of Determining the total Thermal Resistance of Parts of Buildings.

As Australia's national science agency and innovation catalyst, CSIRO is solving the greatest challenges through innovative science and technology.

CSIRO. Unlocking a better future for everyone.

Contact us

1300 363 400
+61 3 9545 2176
csiroenquiries@csiro.au
csiro.au

For further information

CSIRO Energy
Dong Chen
+61 3 9545 2856
Dong.Chen@csiro.au
csiro.au/Energy