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Evaluating the impact of thermal bridging on energy savings predicted for the NCC 2022 RIS

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1 Executive Summary

This report summarises the research on the impacts of thermal bridging mitigation (TBM) undertaken to allow the regulatory proposal to be evaluated by the RIS. It also provides a case study of costs and benefits for one house in various climate zones to identify the specific impacts of thermal bridging mitigation.

Steel frames without TBM can result in a loss of performance of between 0.4 and 1.5 NatHERS stars more than the impact of timber frames. Impacts are highest in cooler climates. Timber-frames, by contrast, only cause a reduction in NatHERS ratings of between 0.1 to 0.6 stars. There is, therefore, a solid case for investigating the use of TBM in NCC 2022.

The TBM proposed in NCC 2022 only applies to steel-framed dwellings. The mitigation measures have been designed to ensure that the performance of dwellings with steel frames achieve similar performance to timber-framed dwellings.

Addressing TBM in NCC 2022 would produce more energy savings than the improvement in performance at 7-stars by itself. Because TBM is not considered in NCC 2019, the energy demand of steel-framed homes at 6-stars is higher than previously modelled.

The reduction in heating and cooling loads due to TBM are presented in this report for the 12 climates modelled for the RIS. This information will be used to develop industry-wide costs and benefits for NCC 2022 as a whole.

The extent of loss of performance due to thermal bridging in Class 2 dwellings is much less than in Class 1 dwellings due to the lower overall area of each unit exposed to the outside. Further, this lower external surface area means that not all walls or floors would need to be insulated to achieve compliance. The costs and benefits for the Class 2 building modelled for this project are relatively small compared to Class 1 dwellings.

Improved energy efficiency is not the only benefit of TBM; however, it is the only benefit evaluated in this report. Mitigating thermal bridging reduces condensation. Condensation can lead to structural problems, damage to linings, and cause mould growth, leading to adverse health outcomes. The benefits of TBM may therefore be significantly larger than those shown in this report.

To allow the impacts of TBM to be more easily identified, this report, therefore, presents a case study of the effects of TBM for one of the Class 1 dwellings modelled in 8 climates representing each of the NCC Climate Zones. This modelling evaluated the Net Present Value of costs and benefits at a 7% real discount rate as required by the Office of Best Practice Regulation. In addition, two other types of benefits were modelled to show the impact of the regulation on the households affected by the regulation: an alternative investment scenario and the impact on annual cash flow (energy savings versus mortgage increase.

NPV at a 7% discount rate was only positive in Alpine areas and the Melbourne climate, where central heating is the most common heater type. From a household perspective, however, TBM has a positive impact on households except in the Brisbane climate. The benefits from a householder perspective and the other benefits not modelled may be sufficient to justify the implementation of TBM in NCC 2022.

Note that TBM is relatively new to Australia. There has therefore been a low demand for the products that provide TBM. Higher demand may bring economies of scale and the development of innovative products that allow TBM to be achieved for a lower cost. A breakeven analysis is shown to show the extent of price reduction that would be needed to make TBM cost-effective in all climates.

2 Introduction

Typical timber and steel framing members have lower R-values than the insulation installed between them, e.g. a 90mm softwood wall stud has a thermal resistance of around 0.9. In contrast, a 90 x 40 C-section metal stud with a base thickness of 0.75 mm has a thermal resistance of around 0.16, including contact resistances on either side of the stud. Neither of the current (NCC 2019) elemental Deemed to Satisfy or NatHERS methods accounts for the additional heat flows through framing members.

Part of the brief for the development of NCC 2022 was to allow for the additional heat flows through framing members and propose thermal bridging mitigation measures. The method for calculating this thermal bridging is the method reference in NCC 2022 shown in this report and calculated using NZS 4214. The NZS method is cited in the Australian standard for AS 4858.1 "Materials for the thermal insulation of buildings: General criteria and technical provisions" which is a reference standard in the NCC.

Modifications to the NZS 4214 method

NZS 4214 was developed primarily for thermal bridging in elements like walls, cathedral ceilings, and floors over unenclosed subfloor spaces. Roofs with attic spaces and floors over enclosed subfloor spaces contain a thermal zone where the effect of this thermal zone on heat flow from inside to outside air is dynamic, i.e. it varies over time.

Initially, NZS 4214 was applied to the element between thermal zones, e.g. the ceiling plane between the inside and the attic space thermal zone. However, it was not clear whether this initial approach was consistent with NZS 4214. Therefore, the University of Wollongong was engaged to undertake additional thermal performance simulations that modelled the three-dimensional heat flow through framing members and adjacent structure and modelled air flows in attic spaces using Computational Fluid Dynamics (CFD)[1]. This research proposed amendments to the NZS 4214 to more accurately calculate the thermal bridging effects of framing for horizontal ceilings under pitched roofs. These amendments have been used to calculate thermal bridging in this report.

Thermal bridging mitigation for steel frames seeks to improve their performance to that of timber frames

The thermal bridging mitigation measures proposed for NCC 2022 do not seek to eliminate thermal bridging by framing. Instead, it is proposed to reduce the thermal bridging of steel framing so that the total R-value of an element with steel frames is

- no less than 95% of that for a timber-framed element for insulation R-values of R3.0 or less and
- no less than 90% of that for a timber-framed element total R-values for insulation levels above R3.0.

This differential approach reflects the diminishing returns of insulation at higher R-values.

Standard frame ratios based on industry feedback and framing layouts are proposed

The impact of thermal bridging depends on the area of framing within a building element. Strictly speaking, this area varies from dwelling to dwelling, which would imply that thermal bridging effects need to be calculated on a case by case basis. Such an approach would require detailed thermal bridging calculations, which would be time-consuming and costly and would exceed the skills of many building practitioners involved in the regulatory certification process. A standard framed area for walls, floors, roofs and ceilings was therefore developed. Based on feedback from the steel industry, slightly lower framed areas were assumed for steel-framed buildings based on standard construction practices such as truss spacings.

The framed areas used in this report are not based on the theoretical minimum derived from simple frame spacing. The framing layout may need to have closer spacing in some areas than this theoretical minimum

[1] Green A et al (2021) Thermal Bridging of Horizontal Ceilings under pitched roofs: A report for the Australian Building Codes Board by the University of Wollongong, Wollongong

based on the building's dimensions. For example, additional studs may be required based on the wall length, and truss spacings may be less than the theoretical maximum based on whether the building's dimensions are a multiple of the truss spacing. Further, additional framing to walls is required around windows, and the complexity of the roof design can require additional framing. The frame ratios used in this report are therefore based on a framing layout developed for dwelling SBH04.

Table 1 Frame ratios for various building elements

Building element	Timber frame ratio	Steel frame ratio
Brick Veneer Wall	15.0%	12.0%
Lightweight clad framed wall	15.0%	12.0%
Concrete block/precast concrete wall	12.0%	12.0%
Brick Cavity wall	0.0%	0.0%
Cathedral/Skillion/Flat roofs	8.4%	8.4%
Ceilings below attic spaces	8.4%	6.0%
Framed floors	10.8%	10.8%

Multiple forms of thermal bridging mitigation measures are proposed in NCC 2022

There are several ways in which thermal bridging can be mitigated that are proposed in NCC 2022:

- Increase the R-value of installed insulation (only practical at lower R-values),
- Provide an additional continuous layer of insulation over the frame, and
- Provide extra insulation attached to the frame.

Lower-cost alternatives to continuous insulation mitigation may become available

The costs for thermal bridging mitigation shown in this report are based on installing an extra layer of continuous insulation.

There are products available that attach to steel frames using an adhesive backing, such as Fletcher's "Thermatape" or Hardie's "HardieBreak". These products are designed to provide a thermal break where two layers of steel construction contact each other. Both products have an R-value of R0.2, and this is less than the minimum required for thermal bridging mitigation. Products like this cover only a fraction of the area of a continuous insulation layer. Development of similar products with higher R-values may mean that the cost of installing these types of insulation may be significantly less than the installation of a continuous layer.

Other benefits of thermal bridging mitigation not modelled

Improved energy efficiency is the only benefit modelled in this report. Mitigating thermal bridging reduces condensation. Condensation can lead to structural problems, damage to linings, and cause mould growth, leading to adverse health outcomes.

Purpose of this report

The purpose of this report is twofold:

- To define the impacts of thermal bridging to allow benefits and costs across new housing stock for the Regulatory Impact Statement (RIS), and
- To provide a case study of costs and benefits of thermal bridging mitigation in isolation of other proposed regulation impacts for one house.

3 Calculating the impact of thermal bridging mitigation for the RIS Class 1 dwellings

The Thermal Bridging mitigation measures proposed for NCC provide energy savings in two ways:

- Reduced heat flows in building elements for the 7-star equivalent NCC 2022, and
- Additional energy savings over NCC 2019 because thermal bridging in steel-framed dwellings is not taken into account. Dwellings constructed with steel frames under NCC 2019 at 6-stars, therefore, have a higher energy use.

The HIA provided data to the ABCB on the proportion of dwellings constructed using steel frames. It is estimated that 13% of dwellings are built using steel frames. Therefore, the impact of steel frame thermal bridging mitigation in the RIS only applies to this 13% of dwellings.

Note that the application of the University of Wollongong's recommendations for the calculation of thermal bridging of Horizontal Ceilings under Pitched Roofs has led to some small reductions in the R-values required to mitigate thermal bridging for these ceilings. These reductions affect both the cost and benefit for TBM but do not alter the cost benefit ratio.

3.1 Class 1 Star Rating Impacts

Table 2 below shows the impact of thermal bridging on the star rating of the SBH05 dwelling when constructed on a timber floor in the 12 NatHERS climate zones evaluated for this project. Note that the rating impacts for timber floors show the maximum impact of thermal bridging because slab on ground floors have no thermal bridging. The impacts on slab and timbers floors on energy loads are shown separately in later tables.

Table 2 Impact of thermal bridging on star ratings of timber floored dwellings

NatHERS Climate Zone		Star Rating	Star Rating	Star Rating
		Without Thermal Bridging	Accounting for Thermal Bridging	
			Steel Frame	Timber Frame
Darwin	1	7.0	6.6	6.9
Cairns	1	7.1	6.9	7
Brisbane	2	6.9	6.3	6.5
Longreach	3	6.9	6.4	6.8
Mildura	4	6.9	5.8	6.5
West Sydney	5	6.9	5.9	6.4
Perth	5	6.9	6.4	6.6
Adelaide	5	6.9	6.1	6.6
Melbourne	6	6.9	5.9	6.7
Hobart	7	7.1	5.8	6.7
Canberra	7	6.9	5.9	6.6
Thredbo	8	7.2	5.2	6.7

Table 2 shows that thermal bridging impacts are most significant in cooler climates. Timber frames result in a loss of rating of between 0.1 and 0.6 stars. In cooler climates, the loss of rating performance for steel-framed dwellings is between 0.4 and 1.5 stars greater than the impact of timber frames. The significant effect of steel frames on star ratings provides a clear rationale for addressing thermal bridging for this frame type.

Note that in the initial implementation of thermal bridging requirements in NatHERS, it is anticipated that ratings will not show the effect of timber frames, only the differential impact between timber and steel frames. Showing the impact of timber frames in NatHERS would require recalculation of star bands. Later implementations of NatHERS could show the effects of timber frames as well as steel frames once the issue of star bands has been resolved.

3.2 Class 1 Impact of steel frames on energy demand at 6-stars

The energy loads of 6-star dwellings constructed with steel frames will be larger than the energy demand predicted using the current NatHERS tool. The energy rating files for 6-star houses were modified to take into account the lower effective insulation levels due to timber and steel framing. The difference in the energy demand between the two frame types was then added to the simulated energy demand to allow for the higher energy demand in steel-framed dwellings. The table below shows the percentage impact on energy loads of steel frames (over the effect of timber frames) in the twelve climate zones evaluated.

Table 3 Impact on heating and cooling energy demand on 6-star Class 1 dwellings in various climate zones for slab and timber floor construction

Climate Zone	% saving through installing thermal bridging mitigation			
	Ceiling Wall and Floor (suspended floor)		Ceiling Wall (slab floor)	
	Cooling	Heating	Cooling	Heating
Darwin	2.5%	0.0%	2.5%	0.0%
Cairns	0.9%	0.0%	0.9%	0.0%
Brisbane	1.1%	32.0%	1.1%	32.0%
Longreach	1.9%	9.6%	1.9%	9.6%
Mildura	4.6%	18.8%	4.6%	18.8%
West Sydney	3.3%	22.3%	3.3%	22.3%
Perth	2.7%	9.9%	2.7%	9.9%
Adelaide	9.1%	27.4%	9.1%	27.4%
Melbourne	4.7%	12.6%	1.3%	26.5%
Hobart	-14.7%	11.7%	-15.7%	20.5%
Canberra	-3.2%	15.3%	-5.3%	25.1%
Thredbo	24.5%	21.1%	10.7%	30.6%

Expressing impacts in percentage terms, while convenient for RIS modelling, may give the wrong impression of the effects of thermal bridging, e.g. 24.5% of cooling loads in Thredbo is a much lower amount of energy than 2.5% of cooling loads in Darwin. In some climates, it is also clear that addressing thermal bridging sometimes has a negative impact, e.g. slightly higher cooling loads in Hobart and Canberra. The higher cooling loads in cool climates are due to the lower R-value of bridged frames allowing dwellings to cool down more quickly, where this effect can exceed the benefits of reducing heat gain during the day. This impact is not observed in Thredbo due to its unique climatic conditions and construction. Dwellings in Thredbo are assumed to have lightweight walls with minimal or no overhangs and darker colours to minimise heating. Consequently, thermal bridging in walls makes a more significant contribution to cooling loads. In all these cool climates, the energy-saving for heating far outweighs any increase in cooling energy demand.

Note that impacts of thermal bridging for slab and suspended floor dwellings are identical for climates from Darwin to Adelaide in the table above. The DTS elemental provisions do not require floor insulation in these climates. While some of the dwellings modelled in these climates did use floor insulation in NatHERS, there were other alternatives to obtaining 7-stars than using floor insulation. Consequently, thermal bridging impacts for floors has been ignored in these climates.

3.3 Class 1 Impact of steel frames on energy demand at 7-stars

The effect on energy loads at 7-stars is shown in the table below:

Table 4 Impact on heating and cooling energy demand on 7-star Class 1 dwellings in various climate zones for slab and timber floor construction

Climate Zone	% saving through installing thermal bridging mitigation			
	Ceiling Wall and Floor (suspended floor)		Ceiling Wall (slab floor))	
	Cooling	Heating	Cooling	Heating
Darwin	4.5%	0.0%	4.5%	0.0%
Cairns	4.3%	0.0%	4.3%	0.0%
Brisbane	3.3%	13.8%	3.3%	13.8%
Longreach	10.7%	22.9%	10.7%	22.9%
Mildura	12.4%	23.2%	12.4%	23.2%
West Sydney	7.4%	20.3%	7.4%	20.3%
Perth	5.2%	15.2%	5.2%	15.2%
Adelaide	7.4%	20.1%	7.4%	20.1%
Melbourne	0.6%	27.0%	2.0%	12.9%
Hobart	-4.8%	26.1%	-5.1%	14.8%
Canberra	1.8%	26.5%	4.9%	16.2%
Thredbo	7.5%	35.6%	17.2%	24.5%

3.4 Class 1 Element by element impact at 7-stars

The initial assumptions about frame ratios and the application of the NZS standard to the ceiling plane only, before the University of Wollongong's modifications, saw that energy savings due to mitigating thermal bridging in ceilings were much higher. After the implementation of the University of Wollongong's new method, walls and floors now have around the same energy-saving impact as ceilings. The table below shows the percentage energy savings at 7-stars for walls, floors and ceilings in each of the climate zones modelled. Note that the percentage savings for mitigating thermal bridging for only one element will be higher than shown in the table below.

Table 5 Thermal bridging mitigation energy savings by type of construction element in each climate

Climate Zone	% saving through installing thermal bridging mitigation					
	Ceiling		Wall		Floor	
	Cooling	Heating	Cooling	Heating	Cooling	Heating
Darwin	1.0%	0.0%	3.6%	0.0%	0.0%	0.0%
Cairns	1.0%	0.0%	3.3%	0.0%	0.0%	0.0%
Brisbane	1.1%	5.8%	2.2%	8.0%	0.0%	0.0%
Longreach	2.7%	12.0%	8.0%	10.9%	0.0%	0.0%
Mildura	5.6%	10.1%	6.8%	13.1%	0.0%	0.0%
West Sydney	4.7%	12.1%	2.7%	8.2%	0.0%	0.0%
Perth	5.2%	15.2%	0.0%	0.0%	0.0%	0.0%
Adelaide	4.5%	12.1%	2.9%	8.0%	0.0%	0.0%
Melbourne	1.8%	7.6%	0.2%	5.3%	-1.4%	14.1%
Hobart	-2.8%	6.3%	-2.4%	8.5%	0.4%	11.2%
Canberra	1.9%	6.9%	3.1%	9.3%	-3.1%	10.3%
Thredbo	-2.6%	5.5%	19.8%	19.1%	-9.7%	11.0%

3.5 Class 1 Costs of thermal bridging mitigation

The cost of thermal bridging mitigation required in the proposed DTS elemental provisions for continuous insulation is shown in the table below. Note that in some climates, not all walls or floors needed to be insulated to achieve 7-stars, so only those parts of the elements which are insulated have thermal bridging mitigation applied. The cost per square metre used is for the insulation product is assumed to be the same as that for continuous polystyrene board insulation installed in a Brick Cavity wall while installation costs were assumed to be slightly higher.

Table 6 Average cost of thermal bridging mitigation per Class 1 dwelling – Timber floor

Climate Zone	Total Cost: Continuous thermal bridging mitigation using polystyrene board			
	Ceiling	Wall	Floor	Total
Darwin	$881	$179	$-	$1,060
Cairns	$872	$67	$-	$939
Brisbane	$875	$638	$-	$1,514
Longreach	$827	$48	$-	$875
Mildura	$923	$759	$-	$1,682
West Sydney	$908	$761	$-	$1,669
Perth	$879	$-	$-	$879
Adelaide	$1,002	$745	$-	$1,747
Melbourne	$901	$770	$589	$2,259
Hobart	$923	$759	$781	$2,462
Canberra	$926	$763	$855	$2,544
Thredbo	$928	$752	$855	$2,536

Table 7 Average cost of thermal bridging mitigation per Class 1 dwelling – Slab on ground

Climate Zone	Total Cost: Continuous thermal bridging mitigation using polystyrene board			
	Ceiling	Wall	Floor	Total
Darwin	$881	$179	$-	$1,060
Cairns	$872	$67	$-	$939
Brisbane	$875	$638	$-	$1,514
Longreach	$827	$48	$-	$875
Mildura	$923	$759	$-	$1,682
West Sydney	$908	$761	$-	$1,669
Perth	$879	$-	$-	$879
Adelaide	$1,002	$745	$-	$1,747
Melbourne	$901	$770	$-	$1,670
Hobart	$923	$759	$-	$1,681
Canberra	$926	$763	$-	$1,689
Thredbo	$928	$752	$-	$1,680

4 Calculating the impact of thermal bridging mitigation for the RIS Class 2 dwellings

Energy Savings due to thermal bridging mitigation in Class 2 dwellings are very different to those found in Class one for the following reasons:

- Only a portion of the units have ceilings and floors exposed to the outside,
- The construction methods used have less thermal bridging:
    - Concrete roofs with suspended ceilings below have no frames to break the insulation layer. Only around 10% of Class 2 dwellings in the NatHERS portal have metal or tiled roofs, with the remainder having concrete roofs.
    - Concrete floors similarly have minimal thermal bridging, and over 99% of Class 2 dwellings report using concrete floors in the CSIRO Australian Housing Data portal. When floor insulation is required (at low R-values), insulation can be placed under the floor surface, eliminating any thermal bridging. Alternatively, if insulation wraps around beams or is placed on suspended ceilings, there is no thermal bridging.
- Externally exposed wall areas are low.

These construction differences mean that both the benefit and cost of thermal bridging is much lower in Class 2 dwellings. The impacts of thermal bridging mitigation shown below are based on the energy savings in the corner and middle unit with the average rating and average heating loads proportion in each climate. Because there was assumed to be no thermal bridging in floors and ceilings, the impacts only relate to walls. Impacts are more significant in units with larger wall areas.

4.1 Class 2 Star Rating Impacts

Because wall areas of Class 2 dwellings are small, the impact of thermal bridging mitigation is small. Star rating changes due to steel frames were a maximum of a 0.2-star in corner units in the coldest climates.

4.2 Class 1 Impact of steel frames on energy demand at 6-stars

The table below shows the percentage increase in heating and cooling loads at 6-stars when steel frames are used without thermal bridging mitigation. Note that not all walls were required to be insulated to achieve 6-stars in each climate, so the overall impact of steel frames will be less than the individual unit figures shown.

Table 8Impact of steel frame thermal bridging at 6-stars in various climates

Climate Name	NatHERS Climate Number	ABCB Climate Zone	Heating increase due to thermal bridging	Cooling increase due to thermal bridging
Darwin	1	1	0.00%	0.45%
Longreach	3	3	4.70%	0.91%
Brisbane	10	2	8.00%	0.63%
Perth	13	5	0.65%	0.45%
Adelaide	16	5	4.24%	0.91%
Melbourne	21	6	2.00%	0.91%
Canberra	24	7	2.17%	0.91%
Hobart	26	7	3.53%	-1.19%
Mildura	27	4	3.05%	0.91%
Cairns	32	1	0.00%	0.64%
Sydney	56	5	5.61%	0.57%

4.3 Class 1 Impact of steel frames on energy demand at 7-stars

The table below shows the percentage reduction in heating and cooling loads at 7-stars when thermal bridging mitigation measures are applied to steel frame walls.

Table 9 Impact of steel frame thermal bridging at 7-stars in various climates

Climate Name	Climate Number	ABCB Climate Zone	Heating Saving	Cooling Saving
Darwin	1	1	0.0%	0.8%
Longreach	3	3	0.0%	4.4%
Brisbane	10	2	3.4%	1.9%
Perth	13	5	1.6%	2.6%
Adelaide	16	5	5.2%	2.5%
Melbourne	21	6	1.8%	2.0%
Canberra	24	7	3.3%	1.8%
Hobart	26	7	2.6%	-1.0%
Mildura	27	4	1.5%	1.4%
Cairns	32	1	0.0%	0.2%
Sydney	56	5	3.6%	-0.5%

4.4 Class 1 Costs of thermal bridging mitigation

The table below shows the average cost per unit of installing thermal bridging mitigation measures to the representative Class 2 dwelling. Costs are for walls only.

Table 10 Proportion of elements insulated and average per unit costs for thermal bridging mitigation in walls

Climate	% ceiling insulated in Class 2 (of units with external roofs)	% walls insulated in Class 2	% floors insulated in Class 2 (of units with external floors)	Cost (wall only)
Darwin	100%	77%	24%	$141.10
Longreach	100%	65%	62%	$118.46
Brisbane	100%	54%	100%	$99.20
Perth	101%	73%	100%	$133.39
Adelaide	100%	85%	95%	$156.03
Melbourne	100%	69%	100%	$125.69
Canberra	100%	88%	100%	$159.88
Hobart	100%	60%	100%	$110.28
Mildura	100%	75%	88%	$137.25
Cairns	100%	71%	0%	$129.54
Sydney	100%	88%	100%	$159.88
Thredbo	100%	60%	100%	$110.28

5 Case study of thermal bridging mitigation costs and benefits for Class 1 dwelling SBH05

5.1 Benefits not modelled

In some climate zones, the energy befits of thermal bridging mitigation may not exceed costs. There are other benefits of mitigating thermal bridging which were not costed:

- Where thermal bridging occurs, moisture can damage the structure and adjacent structures of framing and the internal lining.
- Because thermally bridged structure will experience condensation on the internal surface, this can cause mould growth. Mould growth is linked to a variety of adverse health impacts.

The uncosted benefits may be sufficient to warrant their inclusion.

The Australian Government's *Best practice regulation handbook* gives direction on the nature of the analysis required for a RIS where not all the benefits are easily monetised:

Some costs and benefits are difficult to quantify. These impacts still need to be considered; the challenge is to assess the unquantified effects adequately. For example, suppose a regulation is proposed that would have quantifiable costs and benefits in addition to unquantifiable benefits. It may be possible for you to assess the net effect of the quantified impacts and compare this to a qualitative assessment of the remaining (unquantified) benefits; you may be able to make a persuasive argument that these benefits are worth paying the costs. (Australian Government 2010, p. 40[2])

5.2 Variety of cost-benefit perspectives assessed

The evaluation of recurrent benefits against initial costs is assessed by comparing the Present Value (PV) of recurrent benefits against the initial cost to derive a Net Present Value (NPV). The PV discounts the value of future benefits. The Office of Best Practice Regulation sets the rate at which future benefits are discounted to evaluate building regulatory policy used in this project.

The Office of Best Practice Regulation ensures all major decisions of Government are supported by the best possible evidence and analysis. Accordingly, it has set the discount rate for the study of energy-efficiency regulations for NCC 2022 to 7% real, i.e. over the rate of inflation. A 7% discount rate means that the future value of 40 years of energy savings is worth around 13 years of savings at today's value. NPV allows the costs and benefits of this policy to be compared directly with other policies.

The way households experience the benefits and costs of improving building fabric performance from 6 to 7-stats can be evaluated in various ways. Providing further analysis from the householder perspective provides important additional information to help inform policy decisions. After all, it is not the Government that is paying for the higher efficiency standard; it is the household. If an increase in building standards is to be implemented, it will be important that householders can see that they benefit. How the policy affects households is also important to the building industry. They want to make sure that their clients will derive benefit from the policy.

[2] Australian Government (2010) *Best Practice Regulation Handbook*, Canberra

Two further ways of evaluating costs and benefits are therefore reported:

The impact on householder cash flow.

This compares the annual energy savings delivered by the improved building fabric with the yearly increase in mortgage payments (at 4% interest rate, i.e. higher than current rates, which are artificially low due to COVID) needed to construct a dwelling to this standard. Cash flow is far more relevant to households than more arcane concepts like NPV. If the improvement to building fabric means that households have more money in their pocket from day 1, households are more likely to feel comfortable about the policy change.

Cash flow is also far more relevant to consumers than payback periods. An energy efficiency measure may have a long payback period, which suggests that the consumer will need to wait many years to derive a benefit, and the household may have sold the house before the payback period is finished. If cash flow is improved, regardless of the payback period, then benefits accrue from Day 1.

Alternative investment

Households will also want to see whether they would have been better off using the money spent to improve building performance in other ways. To assist householders to better understand the benefits/disbenefits of improved building fabric, this project compared the annual energy bill savings with the return from an alternative investment. For example, will a household make more money by investing the money that they would have spent on upgrading from 6 to 7 stars on, for example, the stock market?

Russell Investments & the ASX[3] evaluated long term investment returns from a variety of investments. This report showed that a variety of asset classes had earned from 2.1% (cash) to 6.3% (Australian shares) above the inflation rate before tax (excluding investment property returns). After-tax, this reduced to a return of between -0.1% and 3.5%. The return depends on the tax rate of the individual and the type of investment.

Unlike alternative investments, savings from energy efficiency are tax-free. Further, if residential energy tariffs increase above the inflation rate, then the future value of energy savings will also increase. AEMO's retail energy price forecasts showed a modest rise above inflation to 2040[4].

The alternative investment scenario compares energy savings to an investment with a 3% after-tax return, which is at the higher end of long-term investment returns reported by Russell Investments and the ASX.

Both alternative ways of evaluating the benefits of improved energy efficiency assume that the households are economically rational. It can be very 'rational' from a householder's perspective to make decisions which value short term over long term gain. The recent withdrawals from Superannuation to help households cope with reduced financial circumstances brought about by the COVID pandemic is one example where short-term gain is favoured over the long term. Nevertheless, providing information for householders and the building industry about impacts on the individual in addition to the societal cost metric can provide a level of reassurance that the policy selected is the right decision.

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[3] Russell Investments & ASX (2018). *2018 long-term investing report: The journey matters as much as the destination*, https://russellinvestments.com/-/media/files/au/insights/2018-russell-investmentsasx-long-term-investing-report.pdf?la=en-au&hash=18B8B58D5FD13A599B577128C453D9E8463A3129 (viewed 18 May 2020).

[4] AEMO (Australian Energy Market Operator) (2015). *Electricity market forecasts: 2015*, report prepared by Frontier Economics for AEMO, April **2015**, Canberra.

5.3 Cost-Benefit Evaluation Findings

The table below shows the costs and benefits of implementing thermal bridging mitigation from the three perspectives discussed in the previous section:

1. Net Present Value at 7% discount (policy perspective),
2. Net Present Value at 3% discount rate (alternative investment) and
3. Impact on annual cash flow (household perspective.

Costs and benefits vary depending on the type of heating and cooling appliances used and the extent of the house heated and cooled with these appliances. Two appliance combinations are shown:

- Whole-house heating and cooling using the most common devices in the Climate Zone, and
- Partial house heating and cooling in living areas only using the most common devices in the Climate Zone.

Two occupancies were modelled, and the energy savings were weighted to reflect actual home occupancy as found by the ABS (as consistent with the RIS): all day and workday (house vacant during 9 to 5).

Table 11 Costs and benefits of implementing thermal bridging mitigation

Climate Zone	Heating and Cooling Appliances	Financial Analysis		
		Net Present Value @ 7%	Alternative Investment	Cash Flow: Annual Savings - Mortgage Increase
CZ01 (Darwin)	HP Ducted whole House	$554	$1,908	$64
	HP Living areas only	-$436	$191	-$10
CZ02 (Brisbane)	HP Ducted whole House	-$938	-$672	-$47
	HP Heat and Cool Living only	-$967	-$721	-$49
CZ03 (Longreach)	HP Ducted whole House	$410	$1,360	$46
	HP Heat and Cool Living only	-$316	$101	-$8
CZ04 (Mildura)	HP Ducted whole House	$357	$1,565	$50
	HP Heat and Cool Living only	-$272	$474	$2
CZ05 (West Sydney)	HP Ducted whole House	-$234	$557	$6
	HP Heat and Cool Living only	-$591	-$62	-$21
CZ06 (Melbourne: Tullamarine)	Gas Duct Heat + Living HP Cool	$1,417	$4,029	$144
	HP Heat and Cool Living only	-$607	$520	-$8
CZ07 (Hobart)	Wood Heat + Living HP Cool	$739	$2,864	$94
	HP Heat and Cool Living only	-$661	$437	-$11
CZ08 (Thredbo)	Wood Heat + Living HP Cool	$1,584	$4,316	$122
	HP Heat and Cool Living only	$372	$2,213	$122

From a policy analysis perspective, thermal bridging mitigation is only cost-effective regardless of the area of the house conditioned in Thredbo. Darwin, Longreach, Mildura, Melbourne and Hobart are cost-effective for whole-house conditioning options only. Whole house conditioning is only commonly used in Melbourne. From an alternative investment perspective, Net Present Values are positive in all climates except Brisbane and for space conditioning in West Sydney, with a similar finding for cash flow.

Thermal Bridging Mitigation is a relatively new concept in Australia. The market is yet to experience significant demand for thermal bridging mitigation products, so current prices do not reflect any benefits of economies of scale. The cost of board products may fall with higher levels of production. Further, applying insulation to the frame only reduces the area of insulation needed by 87% in walls, 94% in ceilings and 89% in floors. Installation costs would be higher for products applied to frames only. Despite this higher installation cost, it is possible alternative products could be developed in response to demand that would be cheaper to install than predicted above. The two existing thermal break products: HardieBreak and ThermaTape, could be modified to meet the R-values required.

A breakeven analysis was conducted to determine how much the price of thermal bridging insulation products would need to fall to provide a positive cost-benefit analysis. The table below shows the results of this analysis. If the breakeven result is above 100%, the price could rise and still produce a breakeven outcome. If the breakeven result is below 100%, the outcome shows what the cost of thermal bridging mitigation would need to be relative to current prices to break even, e.g., in Brisbane, prices would need to be 29% of current costs for NPV to breakeven at 7% discount rate.

Table 12 Breakeven analysis for thermal bridging mitigation in the 8 ABCB climate zones

Climate Zone	Heating and Cooling Appliances	Breakeven Analysis: Cost change for thermal bridging to give 0 NPV or 0 cashflow		
		Net Present Value @ 7%	Net Present Value @ 3%	Cash Flow: Annual Savings - Mortgage Increase
		% change to thermal bridging costs		
CZ01	HP Ducted whole House	143%	244%	180%
	HP Living areas only	63%	111%	85%
CZ02	HP Ducted whole House	29%	48%	40%
	HP Heat and Cool Living only	25%	43%	30%
CZ03	HP Ducted whole House	100%	100%	180%
	HP Heat and Cool Living only	51%	87%	80%
CZ04	HP Ducted whole House	143%	222%	160%
	HP Heat and Cool Living only	77%	133%	105%
CZ05	HP Ducted whole House	80%	80%	105%
	HP Heat and Cool Living only	54%	53%	70%
CZ06	Gas Duct Heat + Living HP Cool	167%	286%	210%
	HP Heat and Cool Living only	71%	125%	90%
CZ07	Wood Heat + Living HP Cool	133%	233%	190%
	HP Heat and Cool Living only	67%	118%	90%
CZ08	Wood Heat + Living HP Cool	172%	303%	230%
	HP Heat and Cool Living only	118%	200%	155%

The breakeven analysis shows that the price of thermal bridging mitigation would need to fall substantially to ever be cost-effective in Brisbane and for space conditioned homes in West Sydney from the less stringent household and alternative investment perspectives.

5.4 Conclusion

Thermal Bridging Mitigation for the Class 1 dwelling evaluated in this case study does not produce a positive Net Present Value (NPV) of benefits and costs at a 7% discount rate except in the Alpine Climate or where central heating and cooling used. Note that as the most common heating appliance used in Melbourne is Gas Central Heating, the overall thermal bridging mitigation NPV may well be positive in Melbourne. Brisbane and Sydney have negative NPV at a 7% discount rate for central heating and cooling.

Simply because the NPV is negative at 7% does not necessarily mean that thermal bridging mitigation should not be pursued. Impacts from a householder and alternative investment perspective are positive or close to 0 in all climate zones except Brisbane. Furthermore, the benefits which have not evaluated in this project:

- Where thermal bridging occurs, moisture can damage the structure and adjacent structures of framing and the internal lining.
- Because thermally bridged structure will experience condensation on the internal surface, this can cause mould growth. Mould growth is linked to a variety of adverse health impacts.

These uncosted benefits may be sufficient to warrant the inclusion of thermal bridging mitigation in NCC 2022 by themselves. When the positive impacts on householders from the cash flow and alternative investment perspectives in all but one climate zone are considered, there may be a strong case for the inclusion of thermal bridging mitigation in NCC 2022.