Final report:

Cost-optimal insulation levels for Australian and New Zealand houses

transport | community | industrial & mining | carbon & energy

pitt&sherry

Prepared for: Knauf Insulation

Date: July 2016

Our reference: HB14534

in partnership

Association of WALL & CEILING INDUSTRIES Australia & New Zealand

KNAUF INSULATION it's time to save energy

AUSTRALIAN ALLIANCE FOR ENERGY PRODUCTIVITY

Doing more. Using less.

sustainable*thinking*®

Table of contents

Prepared by: Phil McLeod July 2016

Reviewed by: Phil Harrington July 2016

Authorised by: Phil Harrington July 2016

Glossary of key terms

ABCB	Australian Building Codes Board
AGO	Australian Greenhouse Office
BASIX	Building Sustainability Index (New South Wales)
BCA	Building Code of Australia
Cost optimal	The R-value of additional insulation where the present value of energy cost savings it provides equals or offsets its installed costs.
Deemed-to-satisfy (DTS) provisions	The provisions contained in the National Construction Code (NCC) which are deemed to comply with the Performance Provisions of the Code.
Discount rate	The rate used to discount future cash flows to the present value.
NCC	National Construction Code
Net Present Value	NPV is defined as the sum of the present values (PVs) of incoming and outgoing cash flows over a period of time. Incoming and outgoing cash flows can also be described as benefit and cost cash flows, respectively.
NZBC	New Zealand Building Code
R-value	R-values describe the resistance to heat flow, including conduction, convection and radiation. The thermal resistance (m^2.K/W) of a component is calculated by dividing its thickness by its thermal conductivity.
SHGC	Solar heat gain coefficient.
The Nationwide House Energy Rating Scheme (NatHERS)	A performance based rating system that describes the thermal performance of a home. It is based on a star rating scale of 0–10. Theoretically, the higher the star rating, the less energy is required to make it thermally comfortable.
U-value	1/R value

Executive summary

The primary purpose of this study is to identify the cost-optimal insulation levels for Australian and New Zealand homes by climate zone, and to identify the gap, if any, between mandatory minimum insulation levels, as specified in deemed-to-satisfy (DTS) provisions of the Construction Codes for both Australia and New Zealand, and the cost-optimal level. Cost-optimal in this context is when the benefits (savings from using less energy) from installing additional insulation equal or outweigh the additional installed insulation costs. The benefits of insulation should last the life of the building with only the initial cost of installation being incurred, unlike equipment which needs to be maintained and eventually replaced.

For the purposes of the DTS energy efficiency provisions of the Construction Codes, NZ and Australia comprise 3 and 8 climate zones respectively (ranging from 'Alpine' to 'Hot-humid' climates) for which there are minimum insulation requirements. However, generally these climate zones cover a considerable area within which there is a range of sub-climates. This means that there can be a significant variation in the heating and cooling requirements for houses in the same climate zone (see section 1.7 for further explanation). This presents a significant challenge in achieving consistent energy efficiency regulations across each country.

Figures 1 to 3 show the front elevations of the three dwellings used in the study.

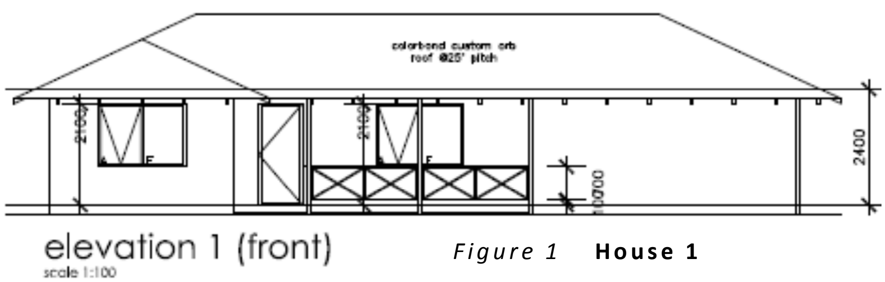


Figure 1 **House 1**

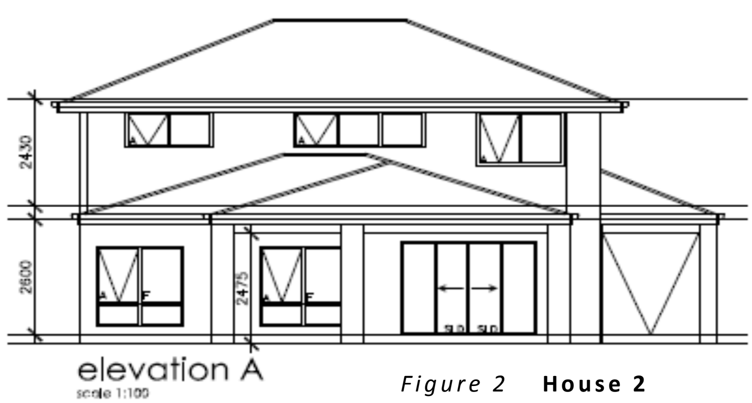


Figure 2 **House 2**

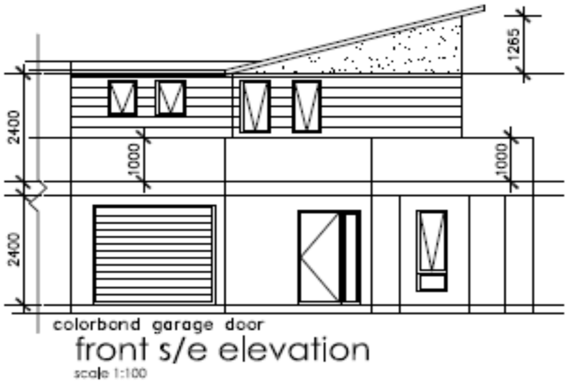


Figure 3 **House 3 (semi-detached)**

Overview

The key finding of this study is that for most owners of typical homes in Australia and New Zealand, insulation levels above the minimum code requirements are cost effective. Topping up ceiling insulation to existing dwellings that have relatively low levels of insulation is extremely cost effective, as is adding floor insulation to dwellings in cool climates which have none. It should be noted that if energy prices increase above the forecast prices used in this study, additional insulation would become even more cost effective, shortening its payback period.

Generally, ceiling insulation levels of R6.0 and wall insulation of around R2.5 are cost effective in all Australian climate zones studied, although the individual house results show that R3.0 wall insulation is cost effective in some cases. That represents levels around 50% higher on average than the DTS R-value for ceilings, and up to 35% higher R-values on average than DTS for walls. In some climate zones where there is significant heating load, the installation of additional floor insulation (to R3.5 in total) proves to be very cost effective when combined with increases in wall and ceiling insulation.

In New Zealand, only one house design was modelled for which the cladding, floor type and climate zone was varied. It was found that in Auckland, Wellington and Christchurch, higher insulation levels were cost effective for all the construction type variations. Even higher insulation levels are likely to be cost effective; however, the upper limits of wall and ceiling insulation modelled was constrained by the highest R-value batts available (R6.3 ceiling and R3.2 wall).

Results by climate zone

The key data for each climate zone is shown in Figures 4 to 16. Figures 4 to 13 cover Australian climate zones, while Figures 14 to 16 cover New Zealand climate zones.

Figures 4 to 13 show, first, the DTS requirements of the Building Code of Australia (BCA) for ceiling and wall insulation (shades of green), and then the cost optimal ceiling (blue) and wall (red) insulation levels for each of three housing types (small detached, large detached and small semi-detached). 'Cost optimal' is defined as the R-value of insulation where the present value of the additional energy cost savings equals or offsets the additional (installed) costs of the extra insulation. Note that for each house type and climate zone, the optimums shown are the weighted averages of a range of results obtained for different flooring and cladding types, with the weightings based on the shares of flooring /cladding types of the actual stock in that climate zone.

Figures 14 to 16 show the minimum requirements for insulation for ceiling and wall insulation (shades of green) in New Zealand, and then the cost optimal ceiling insulation levels (blue) and wall (red) for different flooring and cladding types of the one house design. The results are unweighted because we do not have data on the composition of the residential building stock by construction type in New Zealand.

Results for individual building types as well as for retrofitting insulation are presented in Sections 4 and 5. The graphs below do not include floor insulation, results for which are also presented in Sections 4 and 5.

Australia

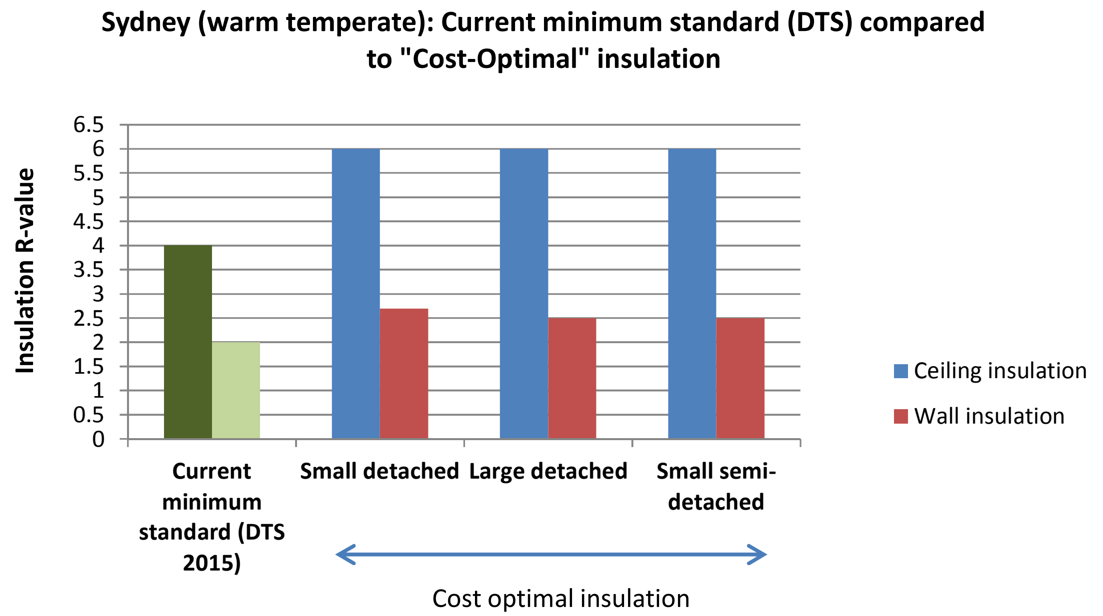


Figure 4 **Sydney weighted average results**

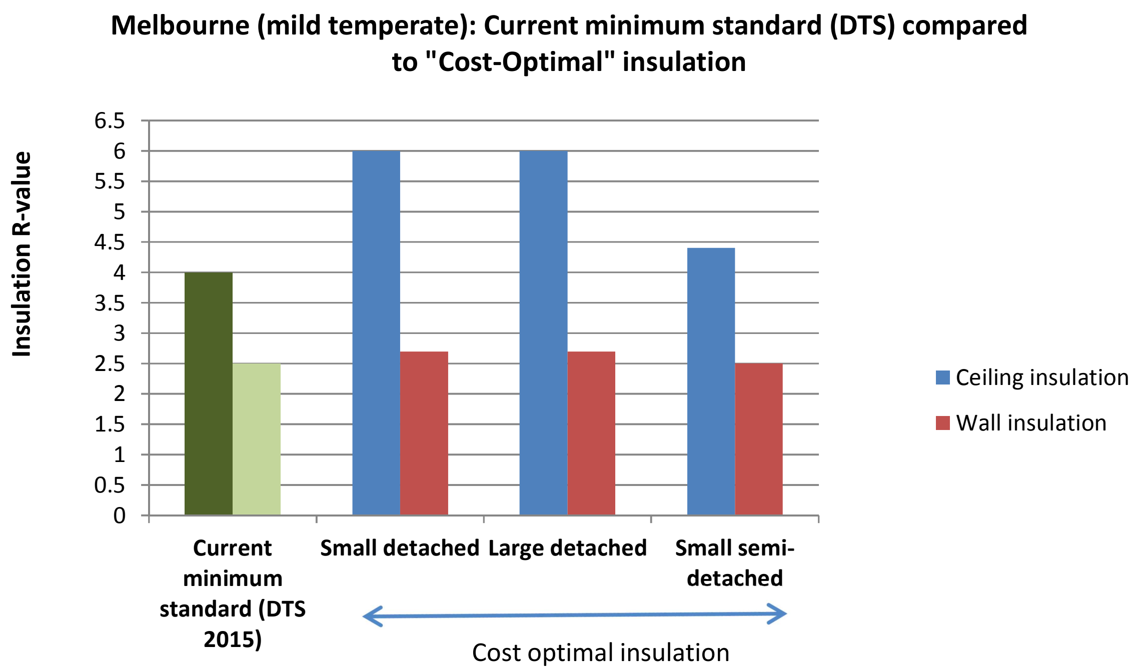


Figure 5 **Melbourne weighted average results**

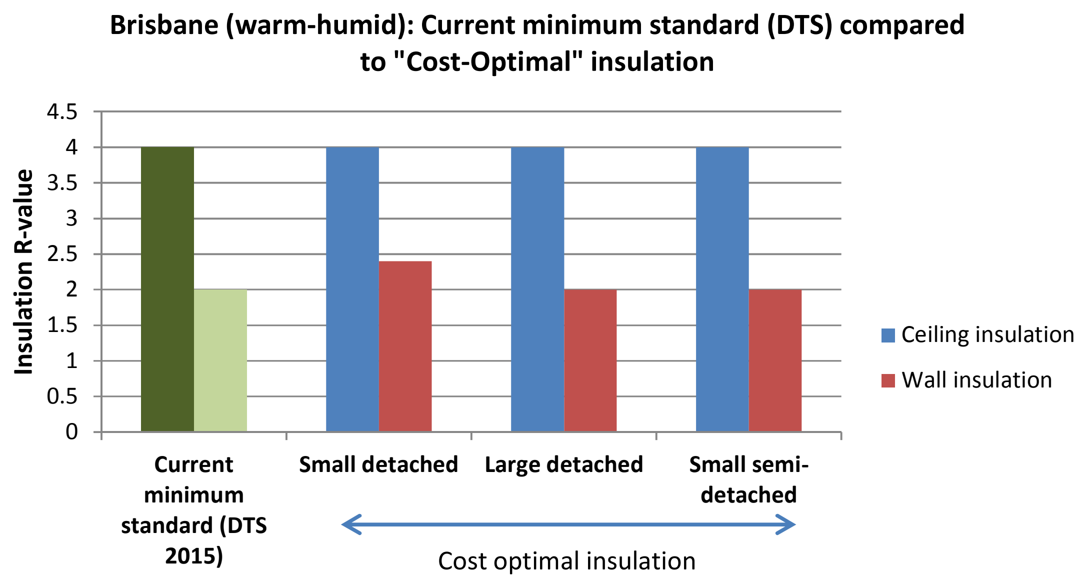


Figure 6 **Brisbane weighted average results**

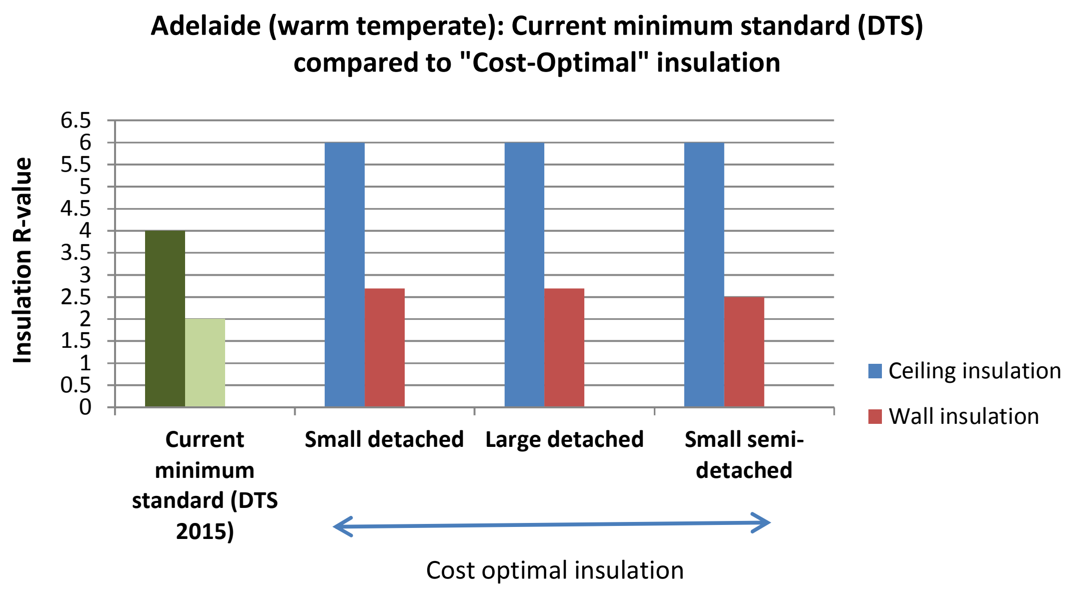


Figure 7 **Adelaide weighted average results**

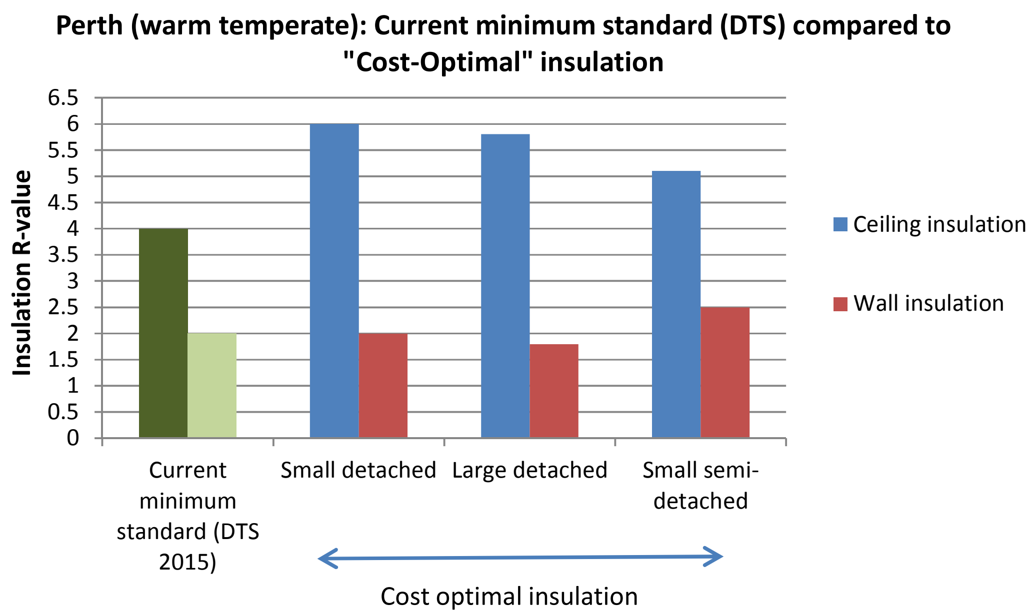


Figure 8 **Perth weighted average results**

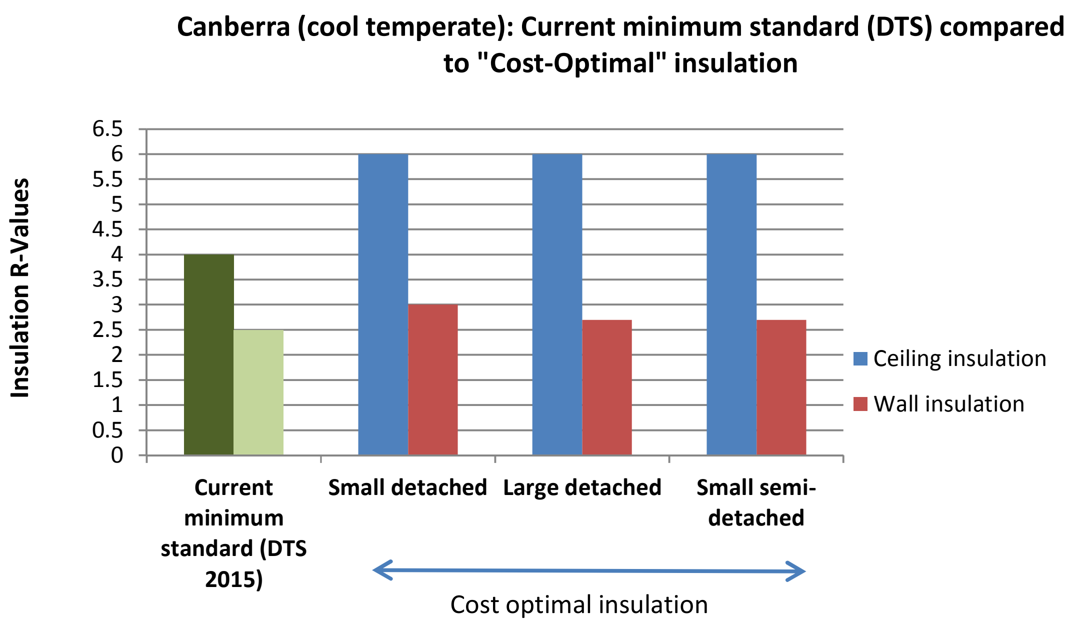


Figure 9 **Canberra weighted average**

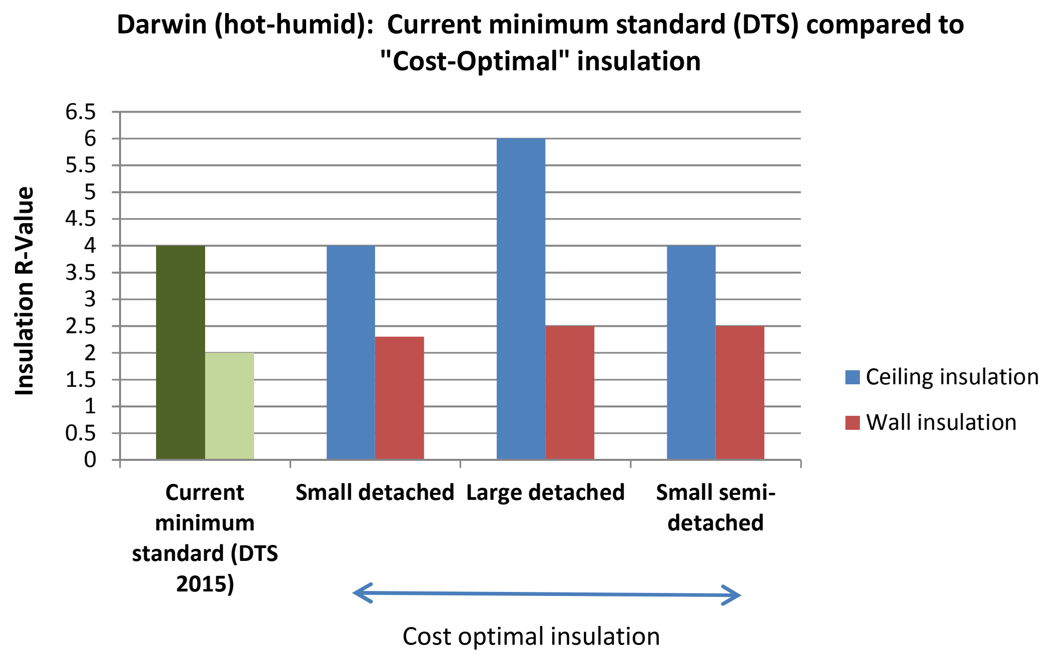


Figure 10 **Darwin weighted average results**

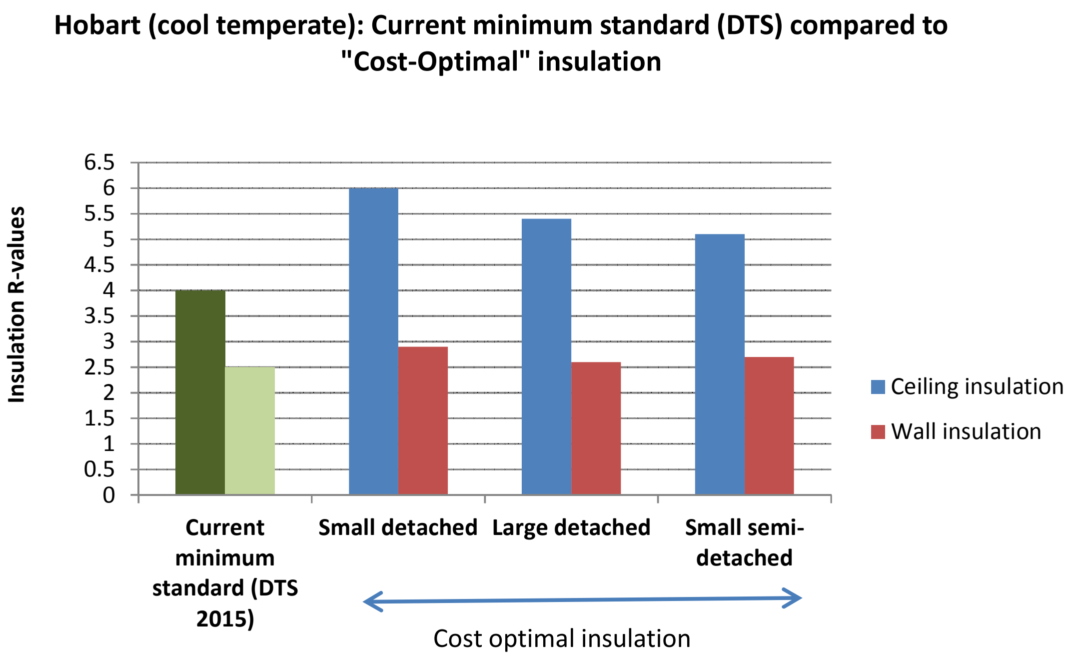


Figure 11 **Hobart weighted average results**

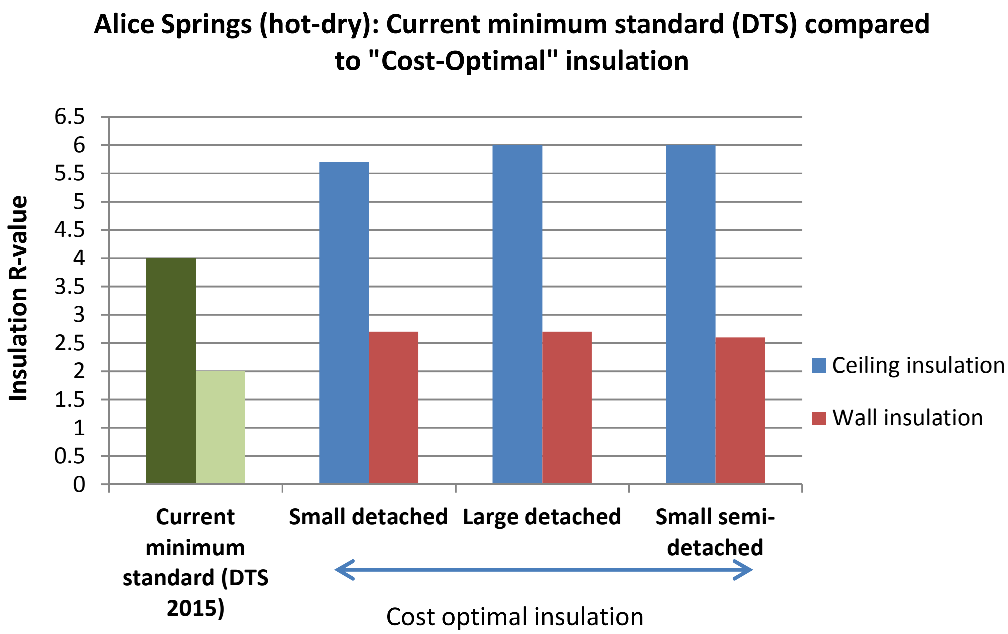


Figure 12 **Alice Springs weighted average results**

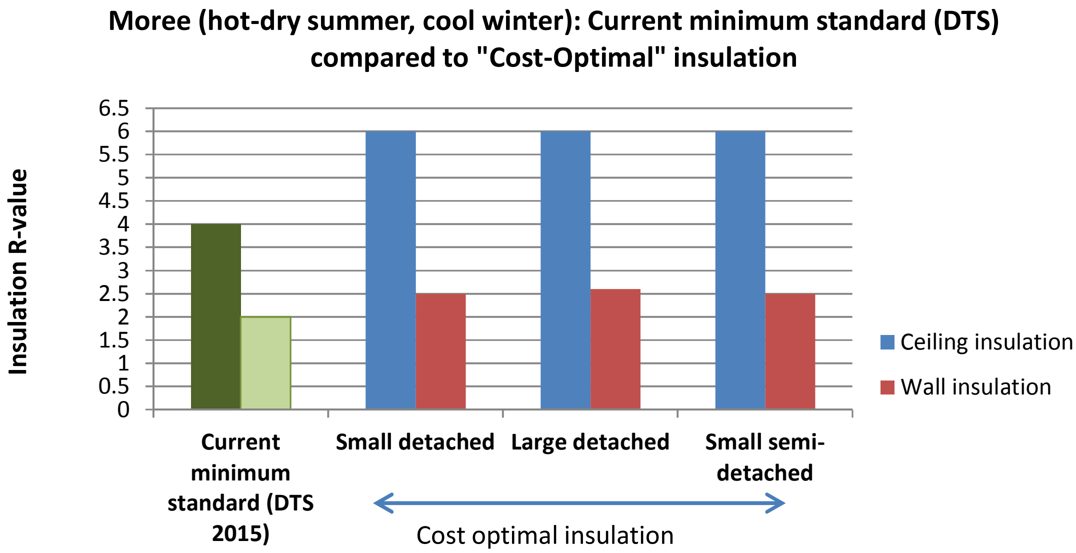


Figure 13 **Moree weighted average results**

New Zealand

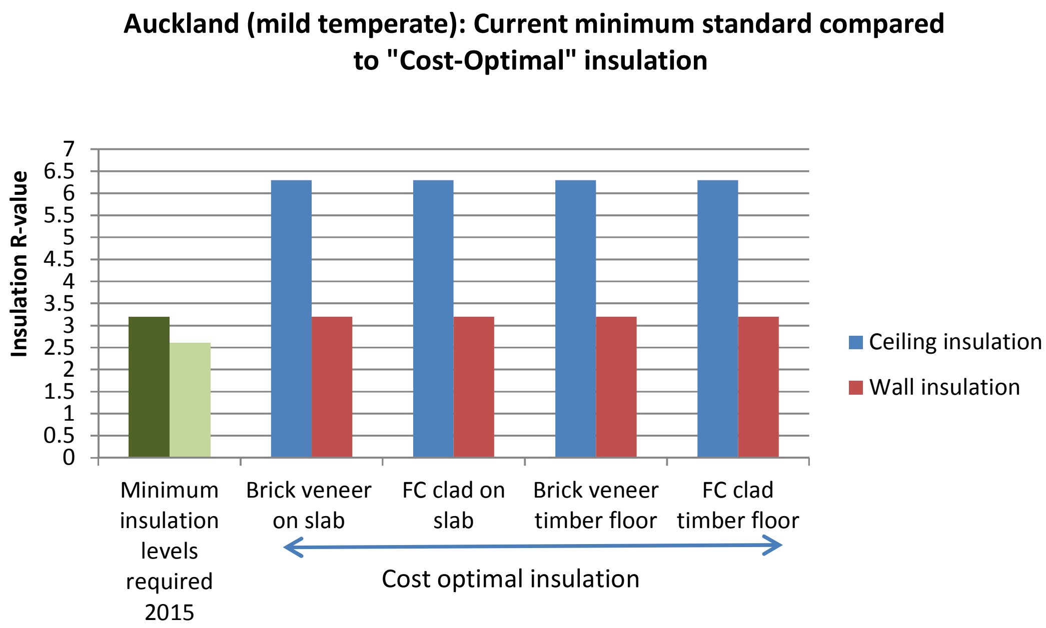


Figure 14 **Auckland average**

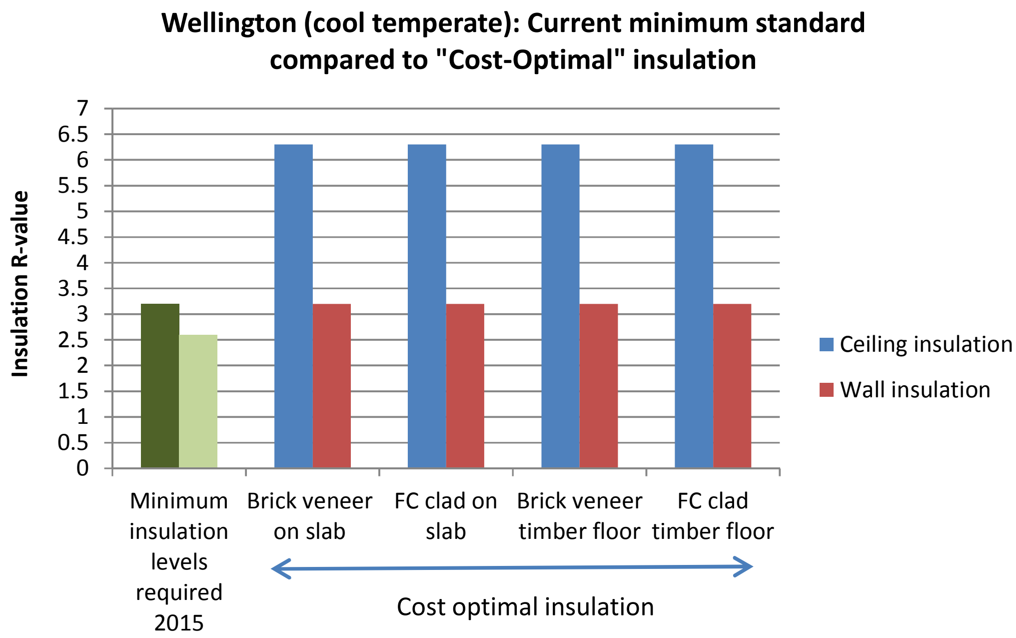


Figure 15 **Wellington average**

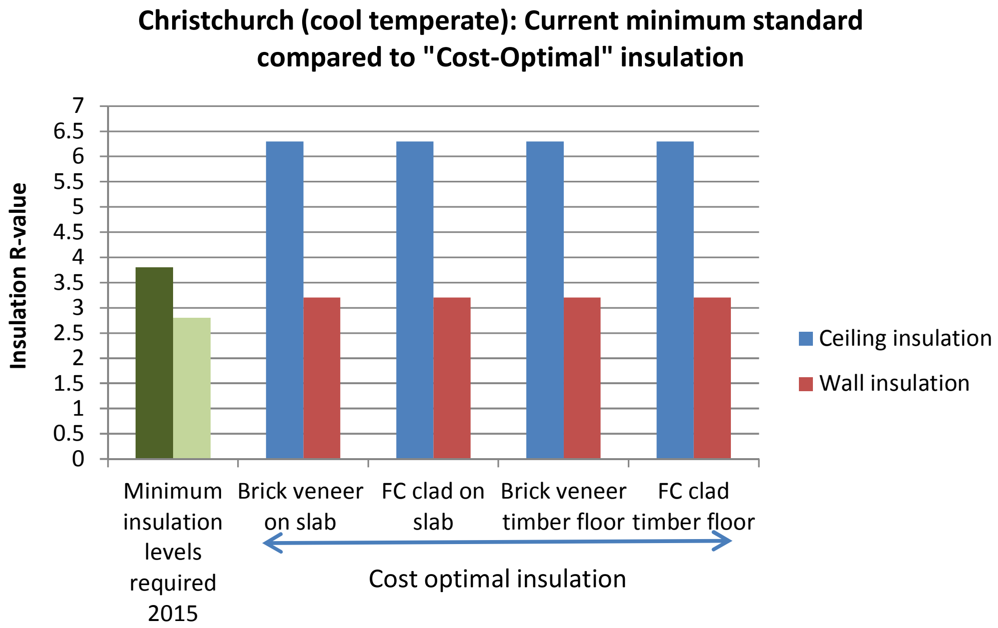


Figure 16 **Christchurch average**

Table 1 **Summary of results – optimal insulation levels (Australia)**[1]

	DTS insulation levels		Optimum insulation levels (small detached)		Optimum insulation levels (large detached)		Optimum insulation levels (small semi-detached)	
	Ceiling	Wall	Ceiling	Wall	Ceiling	Wall	Ceiling	Wall
Sydney	R4.0	R2.0	R6.0	R2.7	R6.0	R2.5	R6.0	R2.5
Melbourne	R4.0	R2.5	R6.0	R2.7	R6.0	R2.7	R4.4	R2.5
Brisbane	R4.0	R2.0	R4.0	R2.4	R4.0	R2.0	R4.0	R2.0
Adelaide	R4.0	R2.0	R6.0	R2.7	R6.0	R2.7	R6.0	R2.5
Perth	R4.0	R2.0	R4.0	R2.3	R6.0	R2.5	R4.0	R2.5
Canberra	R4.0	R2.5	R6.0	R3.0	R6.0	R2.7	R6.0	R2.7
Darwin	R4.0	R2.0	R4.0	R2.3	R6.0	R2.5	R4.0	R2.5
Hobart	R4.0	R2.5	R6.0	R2.9	R5.4	R2.6	R5.2	R2.7
Alice Springs	R4.0	R2.0	R5.7	R2.7	R6.0	R2.7	R6.0	R2.6
Moree	R4.0	R2.0	R6.0	R2.5	R6.0	R2.6	R6.0	R2.5
Thredbo	R6.0	R3.5	R8.0	R4.0	R8.0	R4.0	R8.0	R4.0

Table 2 **Summary of results – optimal insulation levels (New Zealand)**

	Minimum insulation levels		Optimum insulation levels (brick veneer on slab)		Optimum insulation levels (fibre-cement clad on slab)		Optimum insulation levels (brick veneer timber floor)		Optimum insulation levels (fibre-cement clad timber floor)	
	Ceiling	Wall	Ceiling	Wall	Ceiling	Wall	Ceiling	Wall	Ceiling	Wall
Auckland	R3.2	R2.6	R4.1	R3.2	R3.2	R2.6	R3.2	R2.6	R3.2	R2.6
Wellington	R3.2	R2.6	R6.3	R3.2	R6.3	R3.2	R5.2	R3.2	R3.2	R2.6
Christchurch	R3.8	R2.8	R3.8	R2.8	R3.8	R2.8	R6.3	R3.2	R6.3	R3.2

[1] The optimum insulation levels shown in Tables 1 and 2 relate to the R-value of the insulation, not the total R-value of the system in which it is installed (e.g. the whole wall or ceiling system). In New Zealand, to get the total minimum R-value of the system the insulation is installed in, the R-value of the insulation needs to be higher than the R-value of the system itself. This is to compensate for the thermal bridging (heat transfer) through uninsulated sections of the system (e.g. through wall studs) which reduces the system's R-value.

1. Introduction

1.1 Background and scope of study

The primary purpose of this study is to identify the cost-optimal insulation levels for Australian and New Zealand homes by climate zone, and to identify the gap, if any, between mandatory minimum insulation levels as specified in DTS provisions of the Construction Codes for each country. Identifying the cost versus benefits of retrofitting insulation to existing homes is also a study aim.

In Australia, as an alternative to the DTS method, the thermal performance requirement can also be met by using an approved thermal simulation modelling software. A history of the progressive increases in the minimum star-rating requirement under the modelling approach and the corresponding DTS elemental construction approach is shown in section 1.5. It should be noted that the insulation levels of a dwelling that meets the performance requirement via modelling will not necessarily correspond to the insulation levels required under the DTS approach. This is because under the modelling method there is greater scope to influence a design's thermal performance (at least its theoretical performance) by changing factors other than insulation (e.g. shading, orientation and internal zoning) that also affect the space-conditioning requirement.

It is well documented that insulation has a measurable impact on the amount of energy used by space-conditioning equipment in residential buildings. Recognising this, in Australia and New Zealand there are minimum insulation R-values required for new residential buildings, which vary across climate zones.

In Australia, each past increase in the minimum level of thermal performance (measured by star rating) has been accompanied by a debate about whether or not it is cost effective.

One could define the three options for the thermal performance of houses as:

- Option 1: legal requirements (minimum energy performance)
- Option 2: economic optimum (best practice range)
- Option 3: maximum energy performance (state-of-the-art).

There may be a perception among householders, or those within the design/construction community, that option 1 is best (or near best) practice in terms of environmental and/or economic outcomes. This study aims to make recommendations for R-values for the building components: wall, roof and (ground) floor for residential buildings on the level of economic optimum (option 2). Option 3, while probably not the economic optimum, would deliver even better environmental benefits.

The analysis looks at optimising the insulation R-value between the floor (where applicable), wall and ceiling of house designs so that the value of energy savings exceeds the incremental costs (above the minimum required) of its installation.

1.2 Study assumptions and shortcomings

The results are based on:

- the economic optimum, representing the best practice values for floor, wall and ceiling construction, recognising that there are interdependencies between them with respect to thermal performance;
- the latest insulation costs (sourced from large hardware retailers) and current labour costs (sourced from Rawlinson's Cost Guide);
- a range of construction types, typical to each Australian state and territory, and to New Zealand;

- the latest residential energy price forecasts for each Australian state and territory. These projections were based on the generation (wholesale) cost results contained in the Treasury modelling for the *Clean Energy Future* package, Treasury (2011). They also assumed a modest but steady increase in the network (transmission and distribution) cost component in each state and territory for some years into the future. For New Zealand price projections were based on historical increases (around 1% p.a);
- savings and costs calculated over a 30-year period (30 years is the timeframe commonly used in similar cost-benefit analysis);
- NPV of savings and costs calculated using a discount rate of 7%;
- residential buildings using commonly used heating and cooling appliances.

Requirements for better R-values driven by other building physical conditions like condensation risks or acoustical requirements are not covered. The results are based on modelling that uses the thermal simulation software, AccuRate, a NatHERS approved software. There are a number of assumptions in the software that do not accurately reflect user behaviour. These have been accounted for to reflect space-conditioning use that matches reality more closely (see Section 2.7). However, it is recognised that user behaviour and occupancy patterns can vary greatly between households so the results may not hold true in every case.

1.3 The role of insulation and how it works

Thermal insulation is provided by any material that reduces the flow of heat energy from hot to cold regions – inward flows in summer and outward flows in winter. The rate of heat transfer is directly linked to the temperature difference – higher temperature differences result in faster rates of heat transfer. The resulting comfort improvements inside buildings mean that less energy (heating or cooling energy) is required to condition the inside of buildings to deliver required comfort levels for occupants.

In a temperate climate during winter, an uninsulated home loses more heat through the ceiling and roof than any other part of the house, making the roof the top priority for insulation. About 22% of heat from an average uninsulated home is lost through the walls and around 14% of heat is typically lost through the floor. In summer there are corresponding levels of heat gain (New Zealand Department of Building and Housing 2015). Figure 1.1 shows the direction of heat flows in and out of a house for hot, moderate and cool climates.

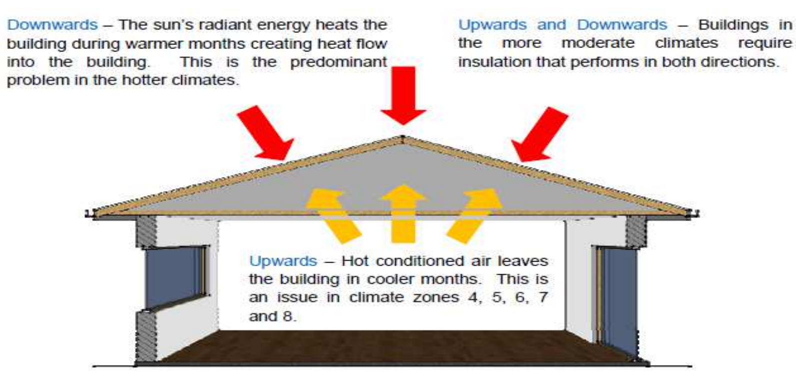


Figure 1.1

Inward and outward heat flows

Bulk insulation performance is directly related to its thickness and its thermal conductivity (K, measured in W/mK) which are combined to give a value for Thermal Resistance, known as the R-value, where W is the instantaneous heat flow measured in watts (1 W = 1 joule/second) and K is the temperature difference. This is known as a **Material R-value.**

R = Thickness (m)/K (W/mK)

The heat loss from a building element is then given by the following simple equation, where U = 1/R (W/m^2*K) is the heat transmission coefficient, and A is the area.

H = Area (m2) * U * K (W)

Heat loss

Heat transfer occurs via the three separate routes discussed below, and the choice of insulation material is determined by the heat transfer mechanism.

Conduction occurs between objects in physical contact with each other, and is addressed by common insulation products by inserting materials with low thermal conductivity such as bulk insulation products between outside surfaces and inside air spaces. The problem is addressed in common construction methods by providing thermal breaks to reduce heat transfer (e.g. non-conducting timber between the outer and inner parts of aluminium window frames and isolation of metal structural frames).

Convection occurs when warm air rises and cool air falls within a room or wall/ceiling space, and allows transfer of heat from one surface to another. Again bulk insulation products are used to reduce temperature differences between different surfaces and reduce convection. This is why ceiling insulation is critically important in residential dwellings, as the ceiling is the warmest part of a room and insulation reduces heat loss in winter and, conversely, in the summer can reduce the flow of heat from an hot attic space to a room.

Radiation heat transfer occurs when electromagnetic radiation (especially infrared wavelengths) is absorbed by surfaces. All materials absorb a wide range of radiation to some degree, and ultimately energy may be transferred into dwellings as infrared energy. Foil insulation products can reduce radiative heat transfer. Conduction and convection heat transfers are addressed by the use of bulk insulation, generally *consisting of materials which trap a very large number of separate air spaces (or other specific gases)* which have low conduction and the bulk material provides an unventilated space which reduces internal convection.

In Australia and New Zealand material R-values of insulation products are typically in the range R-0.5 to R-6.0 and, as defined above, are measured in SI (the International System of Units) units of area (measured in metres squared) times temperature difference (measured in degrees Celsius) divided by the instantaneous heat flow (measured in watts). In the much colder northern hemisphere countries, maximum R-values are typically higher due to the larger temperature differences experienced in winter.

Apart from reducing space-conditioning energy there are also health benefits that can result from insulating homes. Low indoor temperatures have been shown to be associated with poor health, excess winter mortality, as well as contributing to mould and damp. Temperatures lower than 16°C can affect respiratory function; below 12°C place strain on the cardiovascular system, and below 6°C increase the risk of hypothermia. For the elderly and sick, these effects are exacerbated. The temperatures found in many New Zealand houses are below the level recommended by the World Health Organisation. Survey results indicate that only about 50% of New Zealand households consistently achieve comfortable temperatures during the winter (Stoecklein *et al.* 2001).

1.4 Energy use in Australian and New Zealand households

Figures 1.2 and 1.3 show how energy is used in the average Australian and New Zealand home. In both Australia and New Zealand, space-conditioning energy makes up about one-third of a home's total energy use. That means there is the potential to save a considerable amount of energy by insulating homes well. It should be noted, however, that the actual amount of space-conditioning in a home varies by climate zone. In Tasmania, for example, space-conditioning energy comprises about half of an average household's total energy use, whereas in Brisbane it is only about 15% on average.

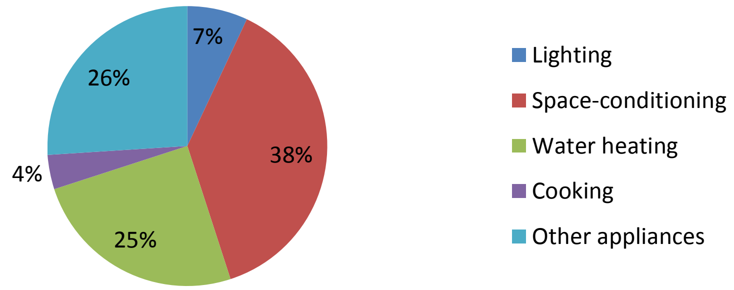


Figure 1.2

Energy end-use in an average Australian household

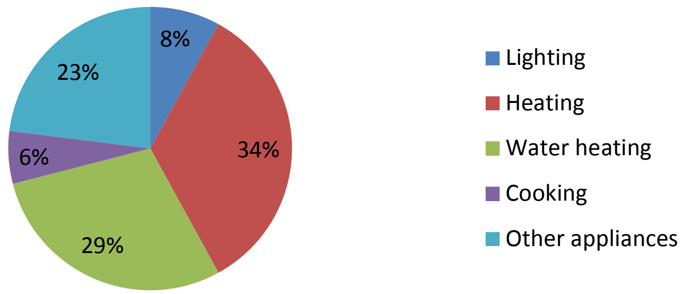


Figure 1.3

Energy end-use in an average New Zealand household

1.5 Housing energy performance requirements in the Australian and New Zealand Building Codes

Australia

From the mid-2000s the Australian Greenhouse Office (AGO) worked with the Australian Building Codes Board (ABCB) to develop energy performance requirements for the Building Code of Australia (BCA). The initial residential energy standard was established at NatHERS 4-Star level or the corresponding DTS elemental construction approach, for which minimum insulation requirements were developed on a climate zone basis. The AGO also managed the development (2003–2006) of AccuRate, a second generation NatHERS modelling tool, which is now used as one of the tools to meet the performance requirements in the BCA. The corresponding DTS insulation requirements for each of the eight BCA climates zones are covered in the BCA.

The progressive increase in stringency of BCA energy standards is shown below.

- 2003 residential 4-star
- 2005 multi-residential provisions
- 2006 residential 5-star
- 2010 residential 6-star
- 2010 multi-residential Provisions (stringency increased).

Table 1.1 shows the corresponding increase in the minimum DTS levels of roof and wall insulation from increased energy standards in the BCA.

Table 1.1 **Increases in insulation levels**

Regulation	Insulation	Climate zone 1 & 2	Climate zone 3	Climate zone 4	Climate zone 5	Climate zone 6	Climate zone 7	Climate zone 8
2003	Roof (metal)	R2.0	R2.0	R2.5	R2.0	R2.5	R3.0	R4.0
	Wall (brick veneer)	R1.0	R1.0	R1.5	R1.0	R1.5	R1.5	R2.5
2006	Roof (dark)	R2.0	R2.5	R3.5	R3.0	R3.5	R4.0	R4.5
	Wall (brick veneer)	R1.5	R1.5	R2.0	R1.5	R2.0	R2.0	R3.0
2010	Roof	R4.0	R4.0	R4.0	R4.0	R4.0	R4.0	R6.0
	Wall	R2.0	R2.0	R2.0	R2.0	R2.5	R2.5	R3.5

Since 2010 there have been no significant changes to the requirements in the BCA. Plumbing requirements have been added to the coverage of the BCA, and the combined volumes are now collectively named the National Construction Code (NCC) of which the BCA makes up the first two of three volumes.

The NCC does not create any legal requirement in isolation. Rather the NCC provisions become requirements via building acts and regulations in each individual state and territory that call up the code.

Under this reasonably complex suite of acts and regulations there are several 'additions and variations' to the NCC provisions. For instance New South Wales does not use the code provisions that apply to residential buildings but uses the separate BASIX requirements. In the Northern Territory only a 4-star performance is required for residential buildings. In Queensland there is a minimum 6-star requirement; however, there are concessions that allow for a lower than 6-star rating. In climate zones 1 and 2, if the dwelling has an outdoor living area that is covered and/or has a ceiling fan, the minimum star rating required is reduced by up to 1 star.

New Zealand

Since 1978, New Zealand has required that new buildings must be thermally insulated. In 1993 a performance-based New Zealand Building Code (NZBC) was implemented which converted insulation requirements for residential buildings into the energy efficiency clause of the new code. Non-residential requirements were also introduced. In 2004 the code was revised to align with the new Building Act.

Changes to the energy efficiency clause of the NZBC (Clause H1) occurred from October 2007. The revisions include performance requirements that result in most new houses having higher levels of both roof and wall insulation.

1.6 The potential to insulate existing homes

The energy efficiency provisions of the building codes concern new dwellings not the existing dwelling stock (apart from additions/renovations to existing stock). In 2011, around 28% (or around 2.5 million) of Australian dwellings had no insulation (ABS 2011). In addition to those dwellings these would also be a large number of under-insulated households in Australia. In New Zealand, The New Zealand House Condition Survey (BRANZ 2005) found that many houses were under-insulated. 21% of New Zealand houses had less than 50% of the ceiling insulated, 66% less than half of the walls and 79% less than half the floor insulated. These figures show that there is clearly an enormous potential to both insulate and to top up existing levels of insulation of existing dwellings in both Australia and New Zealand.

1.7 Australian and New Zealand climate zones

The minimum R-values of insulation required for new homes in Australia and New Zealand depends on the climate zone in which the house is built. Figure 1.4 shows the eight NCC climate zones in Australia and Figure 1.5 shows the three climate zones that are relevant to minimum insulation requirements in New Zealand.

The climate of the eight zones can be characterised as:

- climate zone 1 – high humidity summer, warm winter
- climate zone 2 – warm humid summer, mild winter
- climate zone 3 – hot dry summer, warm winter
- climate zone 4 – hot dry summer, cool winter
- climate zone 5 – warm temperate
- climate zone 6 – mild temperate
- climate zone 7 – cool temperate
- climate zone 8 – alpine.

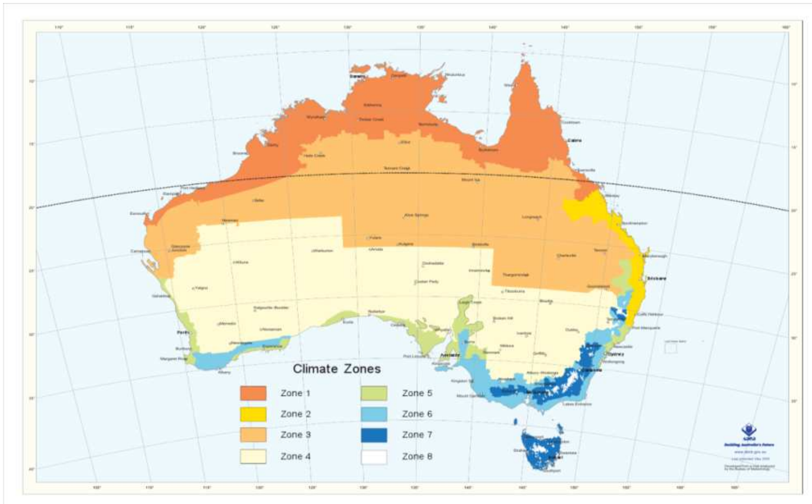


Figure 1.4

The eight NCC climate zones

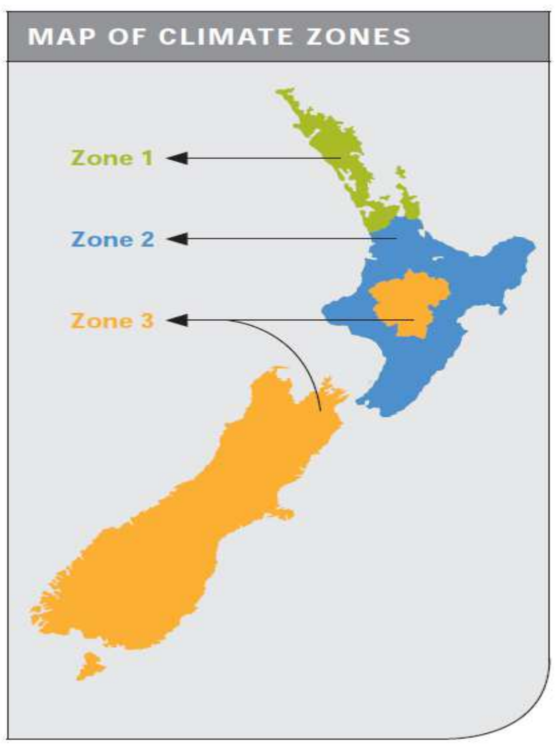


Figure 1.5

New Zealand climate zones

It is clear from the above figures that each climate zone covers a considerable area. In Australia (and in all likelihood New Zealand, too) there is a significant range in space-conditioning demand for houses of a certain star band in the NatHERS climate zones that are within the eight NCC climate zones. There are 69 NatHERS climate zones within Australia.

Figure 1.6 shows the variation in space-conditioning demand for a 5-star house as an example. (Each trough to peak line in the graph represents the range within each NCC climate zone, from climate zone 1 on the left across to climate zone 8 on the right).

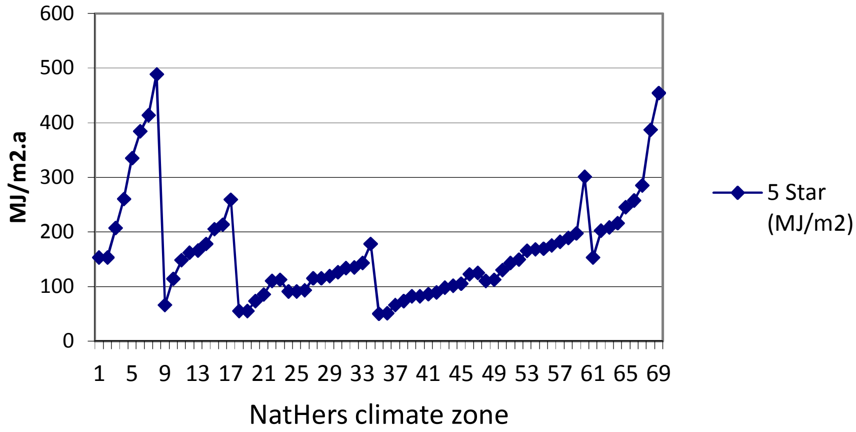


Figure 1.6

NatHers climate zone – 5-star house variation

Figure 1.7 further illustrates this variation for a 6-star house. Each of the four West Australian locations below is located in BCA climate zone 5, yet both their total space-conditioning demand as well as the proportions of heating and cooling energy that make up that demand, vary. Despite this variation, the 6-star DTS insulation requirements are the same in each of the four locations.

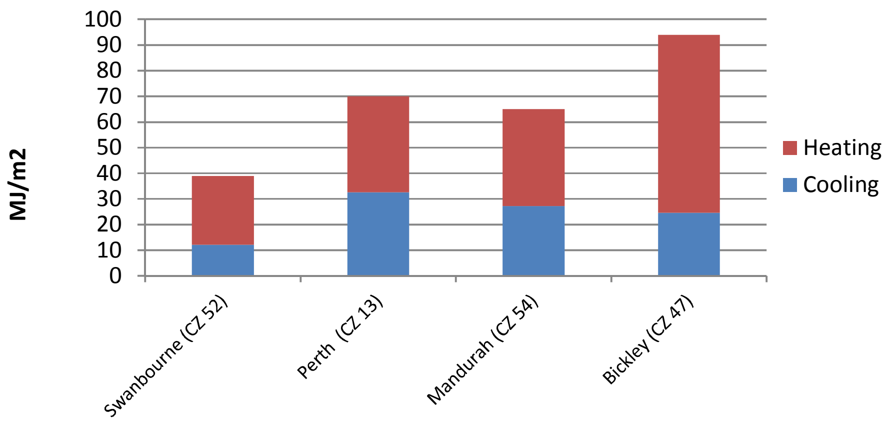


Figure 1.7

Variations in space-conditioning demand for a 6-star house in BCA climate zone 5

1.8 The relationship between increasing thermal performance and space-conditioning demand

Houses in the different climate zones have widely differing requirements for space-conditioning energy, as a function of the severity of the winter and/or summer climates they experience. Brisbane and Perth, for example, are mild climates, with Darwin and Canberra more severe. Generally, since milder climates are using less energy for space conditioning, it is more difficult to identify cost-effective opportunities for space conditioning energy savings (i.e., higher star ratings) in those climates.

Table 1.2 shows that as star ratings increase, the space-conditioning energy demand (in all climates) falls in a non-linear fashion. That is, as higher star ratings are reached, the residual space-conditioning energy demand rapidly declines. Since there is less energy left to save, the cost of achieving those savings climbs (indeed, it climbs more rapidly with increasing star ratings), and cost effectiveness is likely to decline as higher and higher star bands (or thermal performance levels) are tested.

Table 1.2 **Increase in star rating and space-conditioning demand (MJ/m2.a)**

City	5-star	6-star	7-star	8-star	9-star	10-star
Sydney	112	87	66	44	23	7
Melbourne	165	125	91	58	27	1
Brisbane	55	43	34	25	17	10
Adelaide	125	96	70	46	22	3
Perth	89	70	52	34	17	4
Canberra	216	165	120	77	35	2
Darwin	413	349	285	22	140	119
Hobart	202	155	113	71	31	0

2. Methodology – Australian houses

This section outlines the methodology used to determine cost effective levels of insulation in new homes as well that used to determine the cost and benefits of installing additional insulation (retrofitting) in existing homes.

2.1 House designs

Class 1a dwellings (detached and attached single homes) that are generally representative of Australian dwellings were modelled. Figures 2.1 to 2.4 show the floor plans for the single-storey, double-storey and semi-detached dwellings used in the study.

House 1 – single-storey design

The single-storey design is typical of that built throughout Australia in terms of size, window to floor area ratio and glazing distribution. It is also characterised by quite evenly distributed glazing throughout which is typical of designs by high-volume builders in Australia. The result is that the dwelling's thermal performance is largely insensitive to orientation.

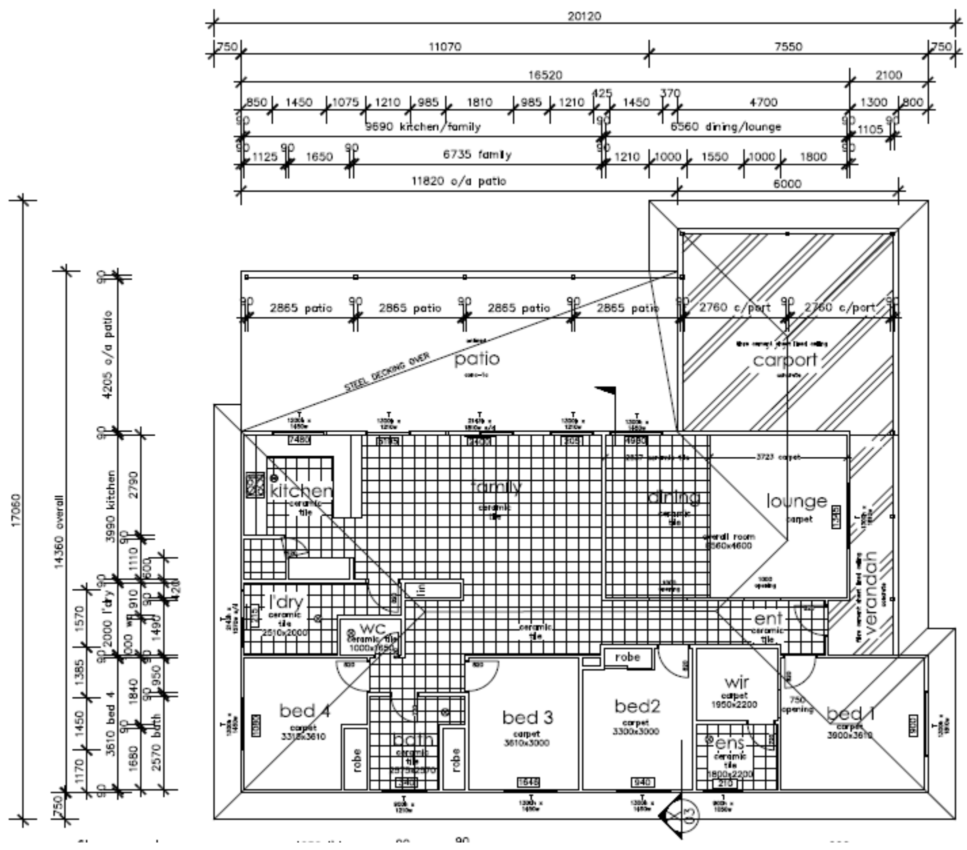


Figure 2.1

House 1

House 2 – double-storey design

The double storey design has a floor area of around 260 m² and is typical of large project home designs throughout Australia. Glazing is relatively evenly distributed and the house has an attached garage.

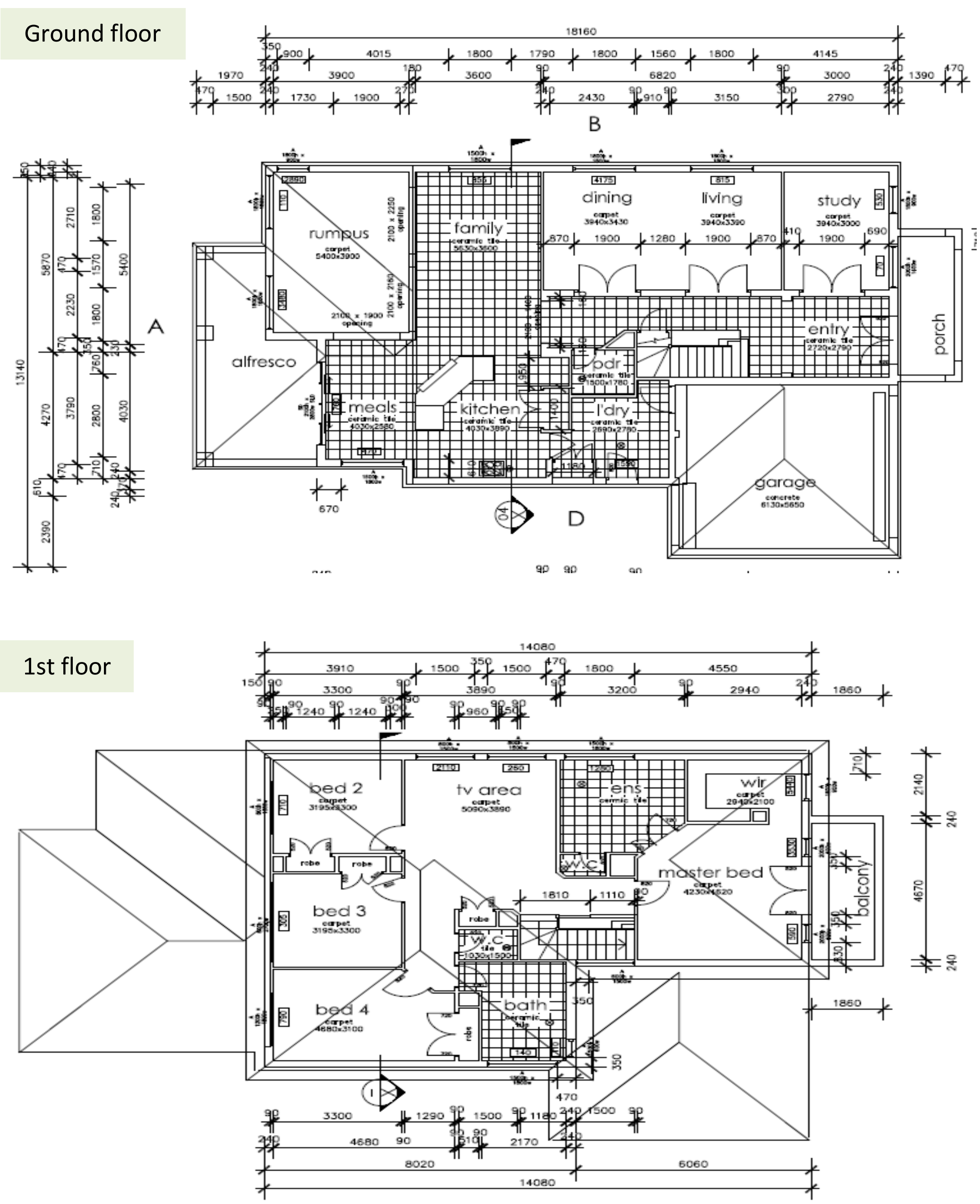


Figure 2.2

House 2

House 3 – semi-detached design

1st floor

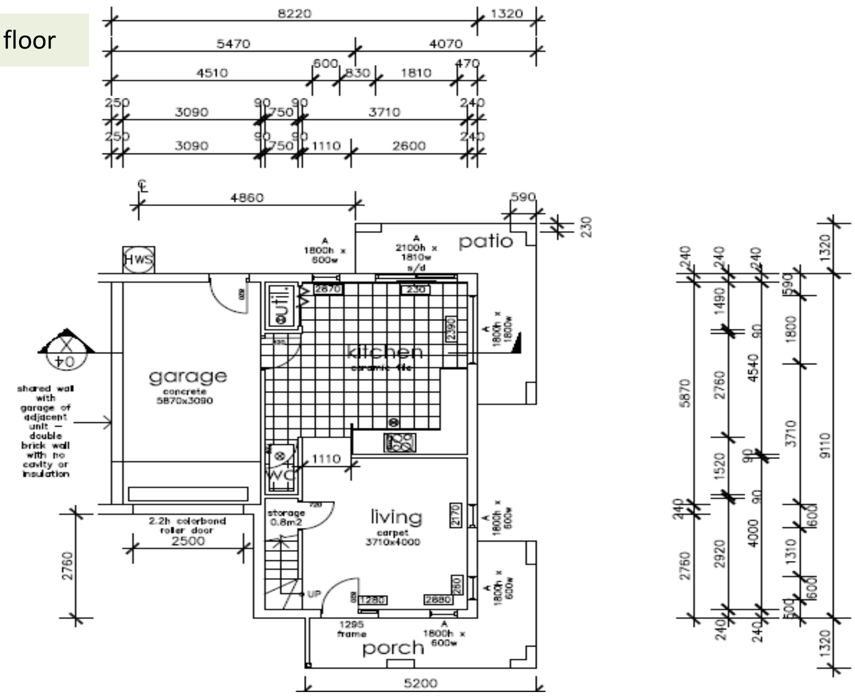


Figure 2.3

House 3

Ground

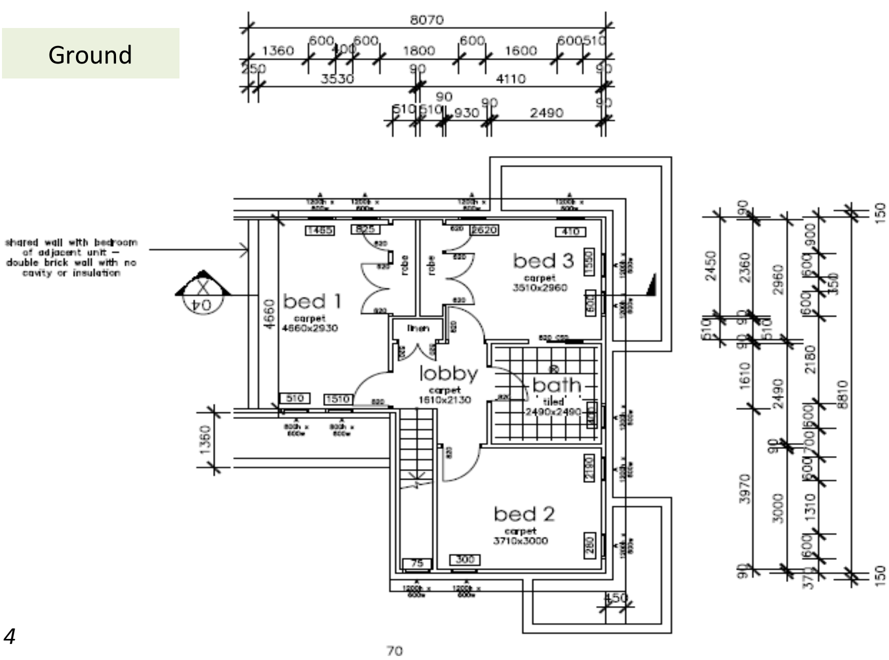


Figure 2.4

House 3

While the floor plans above show brick veneer construction, the construction types modelled are shown below. These reflect the type typically used by high volume builders in each capital city climate zones.

Table 2.1 **House design construction type**

House no.	Capital city climate zone	Construction type
1, 2, 3	All cities	Brick veneer and fibre-cement sheet (lightweight) external walls with concrete slab on ground floor
1, 2, 3	Sydney, Perth	Cavity brick external walls with concrete slab on ground floor
1, 2, 3	All cities	Brick veneer and fibre-cement sheet (lightweight) external walls with raised timber floor

2.2 Climate zones

Noting the significant variation of space-conditioning demand (even within BCA climate zones as mentioned), but also to provide good coverage of the major population centres, we modelled each house in representative climate zones within each capital city, plus other representative locations to cover the BCA climate zones that contain no capital cities, namely:

- BCA CZ 1 (Darwin)
- BCA CZ 2 (Alice Springs)
- BCA CZ 3 (Brisbane)
- BCA CZ 4 (Moree)
- BCA CZ 5 (Sydney)
- BCA CZ 5 (Adelaide)
- BCA CZ 5 (Perth)
- BCA CZ 6 (Melbourne)
- BCA CZ 7 (Canberra)
- BCA CZ 7 (Hobart)
- BCA CZ 8 (Thredbo).

2.3 Starting point insulation levels

Table 2.2 shows the minimum R-values of insulation required in each part of the building envelope (for various constructions types) to meet the DTS requirements of the NCC. These were the starting point insulation levels used in the modelling. There are also DTS requirements for the U-value and solar heat gain coefficient (SHGC) of glazing. These were calculated using the NCC glazing calculator. A window type within AccuRate was then selected that matched those specifications as closely as possible.

It should be noted that when DTS insulation and glazing requirements are met, a 6-star rating was not necessarily achieved when modelled in AccuRate. There is variation around 6 stars (some more, and some less than 6 stars) in each climate zone depending on the wall and floor type modelled for each house type. For the purposes of modelling, minimum insulation levels required were rounded up to the nearest commonly used R-value batt – for example, where minimum insulation required in ceiling is 3.71, an R4.0 batt was modelled.

Table 2.2 **DTS levels of insulation by NCC climate zone**

	Minimum R-value of insulation						
Climate Zone	Roof/ceiling	Wall (brick veneer)	Wall (weatherboard)	Wall (fibre-cement)	Wall (double brick)	Suspended Floor (unenclosed)	Suspended Floor (enclosed)
Climate zone 1	3.56	1.84	1.92	1.98	1.71	1.11	0.74
Climate zone 2 (less than 300m)	3.56	1.84	1.92	1.98	1.71	0.61	0.24
Climate zone 2 (300m or more)	3.71	1.84	1.92	1.98	1.71	0.61	0.24
Climate zone 3	3.71	1.84	1.92	1.98	1.71	1.11	0.74
Climate zone 4	3.71	1.84	1.92	1.98	1.71	1.74	1.36
Climate zone 5	3.71	1.84	1.92	1.98	1.71	0.49	0.11
Climate zone 6	3.71	2.24	2.32	2.38	2.11	1.74	1.36
Climate zone 7	3.71	2.24	2.32	2.38	2.11	2.24	1.86
Climate zone 8	5.91	3.24	3.32	3.38	3.11	2.74	2.36

Note: The minimum ceiling insulation is for a pitched metal roof with a flat ceiling. The minimum wall insulation is for a standard eaves width. Both were assumptions used in the modelled houses.

2.4 Starting point space-conditioning loads

Table 2.3 shows the heating and cooling loads for a house at around 6 stars in each of the climate zones modelled in this study. It can be seen that there is considerable variation across climate zones in the total space-conditioning energy, as well as the proportions of heating and cooling demand that make up the total. Darwin for example has a high total space-conditioning load that is all cooling demand, whereas Brisbane has the lowest total space-conditioning demand of which heating makes up 33%.

Table 2.3 **Space-conditioning loads at 6 stars**

City/climate zone	Approx. heating load at 6 stars (MJ/m^2.a)	Approx. cooling load at 6 stars (MJ/m^2.a)	Approx. total space-conditioning load at 6 stars (MJ/m^2.a)
Sydney	81	19	100
Melbourne	151	3	154
Brisbane	16	32	48
Adelaide	87	19	106
Perth	54	25	79
Canberra	160	13	173
Darwin	0	360	360
Hobart	162	4	166
Alice Springs	49	70	119
Moree	70	30	100
Thredbo	330	2	332

Note: The total space-conditioning requirement for 6 stars in a given climate zone is about the same irrespective of the building fabric. However, fabric can influence the proportions of heating and cooling that make up the total load.

2.5 Capital costs

Increases in the insulation levels were limited to commonly available batts. As such, each step up in insulation level is not necessarily linear. The current costs of insulation ($\$/m^2$) were obtained from a hardware retailer's website. These costs were discounted by 15% to reflect a typical trade discount rate offered to builders (noting that volume builders are probably getting even higher discounts). A labour allowance ($\$/m^2$) was then added to get a total installed cost estimate.

It was assumed that the modelled houses used 90 mm wall studs which would accommodate the DTS wall insulation levels in each climate zone (except Thredbo), and up to an R2.7 wall batt. Where modelled wall insulation levels exceeded R2.7, incremental costs took into account the cost of a deeper (120 mm) wall stud needed for accommodate the thicker insulation.

2.6 Energy prices

Energy price forecasts are from a recent (2013) updated energy prices series **pitt&sherry** did for the Australian Government. (For New Zealand we have used an average residential electricity tariff in 2015 and have assumed it increases by 1% per annum in line with historical trends.)

2.7 Adjustment of space-conditioning demand

AccuRate calculates the theoretical reduction in a dwelling's space-conditioning requirement from higher insulation levels. This is based on a number of assumptions in the software. These include the following.

Occupancy hours

A standard occupancy pattern is applied to represent a reasonable expectation of how a room (or space) is used (its function). Each space is allocated one or more functions and a period of time during which the space is likely to be used and required to be kept at a comfortable thermal range. For living spaces, thermal comfort is maintained from 7 am to midnight. For sleeping spaces, thermal comfort is maintained from 4 pm to 9 am.

Thermal comfort

NatHERS software considers whether spaces can achieve thermal comfort through three means:

- by natural means (e.g. open windows)
- cooling via mechanical air movement (e.g. ceiling fans)
- by adding or extracting an amount of energy to that space via heating and cooling appliances and equipment.

All external openings (e.g. windows) are considered to be operable at all hours, although a factor has been incorporated to limit the number of operations to one per each three-hour period.

Heating thermostat settings

The heating thermostat setting varies according to the function of the space and the expected clothing level in that space during a particular time period. For example, a lower minimum heating thermostat setting is used during sleeping hours to reflect the likelihood of bedding (sheets, blankets, quilts, etc.) being used.

- For sleeping spaces (including bedrooms and other spaces closely associated with bedrooms), a minimum heating thermostat setting of 18 degrees Celsius is used from 7 am to 9 am and from 4 pm to midnight; and a heating setting of 15 degrees Celsius from midnight to 7 am.
- For living spaces (including kitchens and other spaces typically used during waking hours): a minimum heating thermostat setting of 20 degrees Celsius is applied.

Cooling thermostat settings

The cooling methodology is based on the effective temperature method of calculating thermal comfort. The cooling thermostat setting varies according to the climate zone to account for the acclimatisation of local residents. It also varies from room to room from the summer neutral cooling temperature of that climate zone to take into account the effect of air movement, air temperature and humidity level in that space on the occupants' perception of thermal comfort.

Adjustments made

However, these assumptions typically do not reflect actual user behaviour and it is likely that the space-conditioning energy requirement is overestimated. In order to calculate actual energy savings (metered energy) an adjustment was made to the space-conditioning requirement to better reflect typical user behaviour. It was assumed across all climate zones that the actual space-conditioning demand was 50% of that calculated by AccuRate, a reduction factor similar to that which has been used in previous analyses.

It was assumed that space-conditioning demand was met by reverse cycle air-conditioning with an efficiency of 350%. Gas heating was also modelled in two of the cooler climate zones (Canberra and Hobart).

2.8 Economic optimum

The aim of this study was to find the optimal level of insulation in terms of cost effectiveness. In this case a cost-effective level of insulation is one where the value of energy savings (over a 30-year period) equals or exceeds the additional incremental cost of the insulation to achieve them. The starting point for the analysis was the required minimum insulation levels as described above. Insulation levels were increased incrementally until the break-even point (savings equal costs) was reached.

It was recognised that the cost-optimal insulation level for one part of the building envelope is not independent of the insulation levels of the other parts. As such the optimal balance of ceiling, wall and floor insulation (where relevant) in each climate zone that is practical and reasonable, was sought.

2.9 Retrofit

The study also looked at the costs and benefits of installing top-up insulation in existing homes. The starting point was assumed to be a home with R2.0 ceiling insulation and no wall or floor insulation – that is, a home built before NCC thermal performance regulations were introduced. In each climate the benefits and costs of additional R2.0 ceiling insulation were modelled. For cooler climates (Melbourne, Canberra, Hobart) the benefits and costs of retrofitting R2.0 floor insulation were also modelled. Retail costs of insulation were used for the retrofit modelling rather than wholesale costs as in many cases top-ups a likely to done by the home-owner.

3. Methodology – New Zealand houses

3.1 House designs

Only House 1 was modelled – its size and layout closely reflect a typical New Zealand house built today. The house was modelled as brick veneer and timber clad with a raised timber floor, and brick veneer and timber clad on concrete slab.

Variations on the house design were modelled in NatHERS climate zones which closely match the climates of Auckland, Wellington and Christchurch, as follows:

- Christchurch = Canberra
- Wellington = Lowhead (Tasmania)
- Auckland = Albany (West Australia).

3.2 Starting point insulation levels

Table 3.1 shows the minimum R-values of insulation required in each part of the building envelope (for various constructions types) by climate zone. These were the starting point insulation levels used in the modelling. As previously noted, these insulation R-values exceed the minimum required system R value to account for heat losses/gains from thermal bridging through uninsulated framing elements.

Table 3.1 **Deemed-to-satisfy levels of insulation**

City/climate zone	Zones 1 & 2 (Auckland, Wellington)	Zone 3 (Christchurch)
Wall insulation R-values		
Brick veneer	2.6	2.8
Weatherboard / fibre-cement sheet	2.6	2.8
Ceiling insulation R-values (for non-solid construction)		
Colorbond pitched roof	3.2	3.8
Minimum window U-value	3.84	3.84

3.3 Adjustment of space-conditioning demand

It was assumed that heating demand in the living spaces and bedrooms was met through reverse cycle heat pump. As for the Australian houses, the total energy requirement calculated by AccuRate was adjusted (down by 50%) to reflect more realistic occupancy patterns.

The New Zealand analysis was limited to Auckland, Wellington and Christchurch. These cities are located in climate zones where, as in Australia, there is likely to be a significant variation in the heating/cooling demand. An analysis of houses outside the main cities may show that cost effectiveness of higher insulation levels varies significantly within the three main climate zones of New Zealand.

3.4 Retrofit

As for Australia, the starting point was assumed to be a home with R2.0 ceiling insulation and no wall or floor insulation. In each climate the benefits and costs of additional R1.8 ceiling insulation (a batt available in New Zealand) were modelled. Retail costs of insulation rather than wholesale costs were used in the modelling.

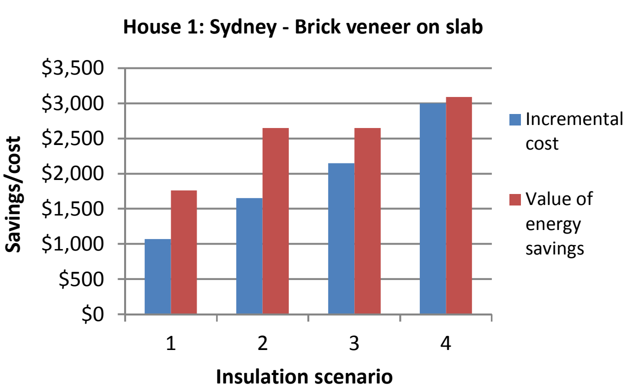
4. Results – Australia

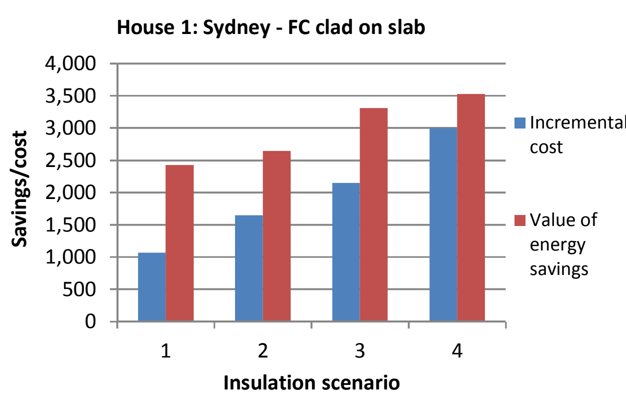
This section outlines the results of the study for the houses modelled in Australia. The graphs below show the incremental cost of each insulation scenario and the value of energy savings that each scenario provides. Incremental costs and value of energy savings are relative to the DTS insulation levels specified in the NCC. Where additional incremental costs exceed the additional value of energy savings, the scenario is not cost effective.

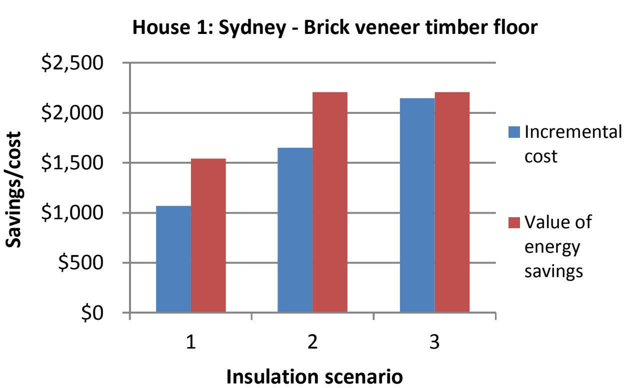
4.1 Sydney

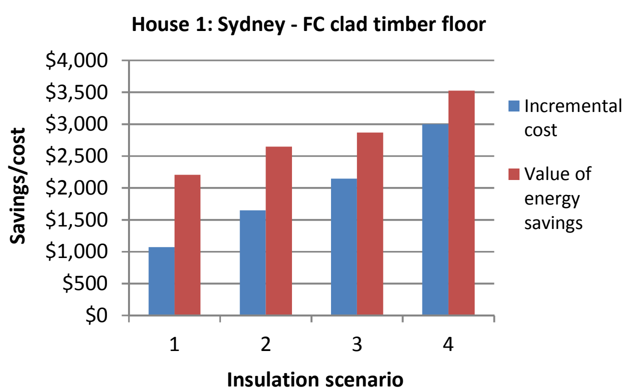
Table 4.1 **Insulation scenarios**

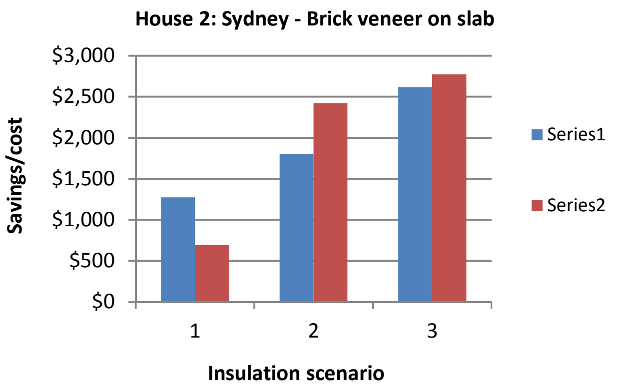
DTS insulation	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Roof – R4.0	Roof – R5.0	Roof – R6.0	Roof – R6.0	Roof – R6.0
Wall – R2.0	Wall – R2.5	Wall – R2.5	Wall – R2.7	Wall – R3.0

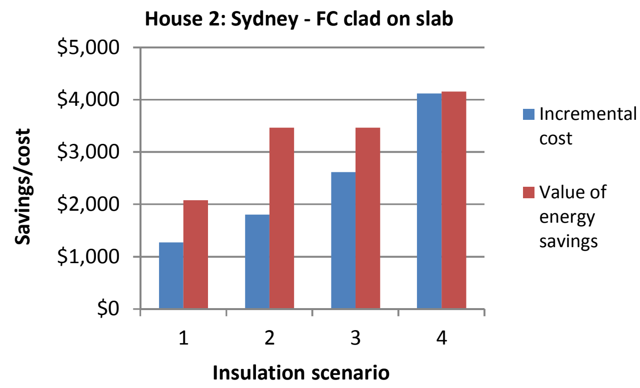


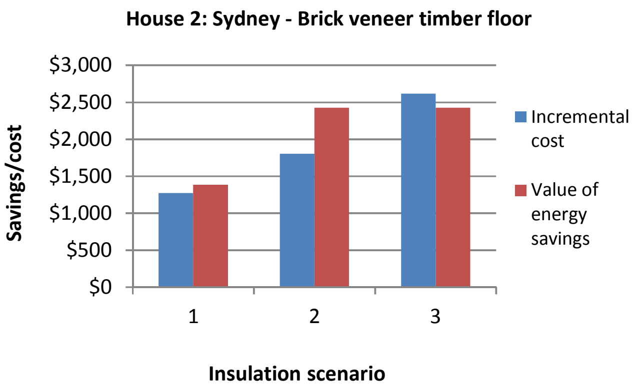


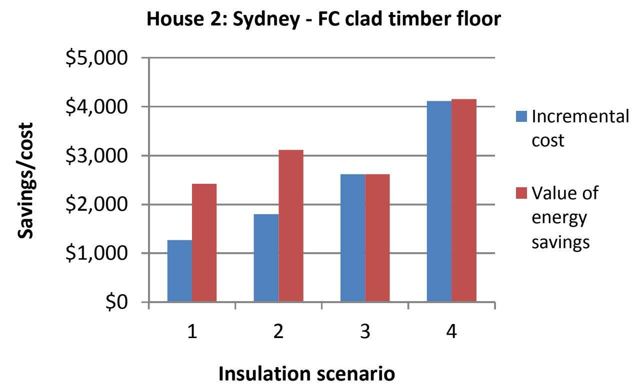


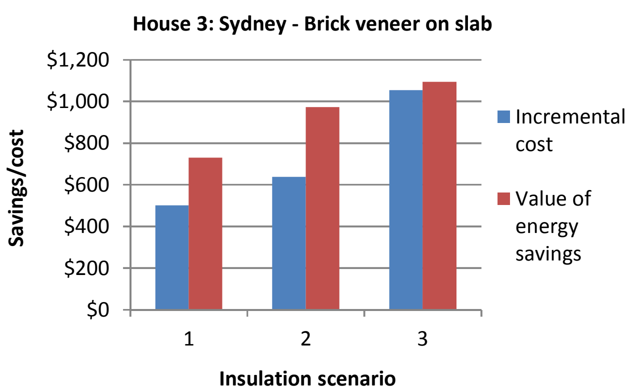


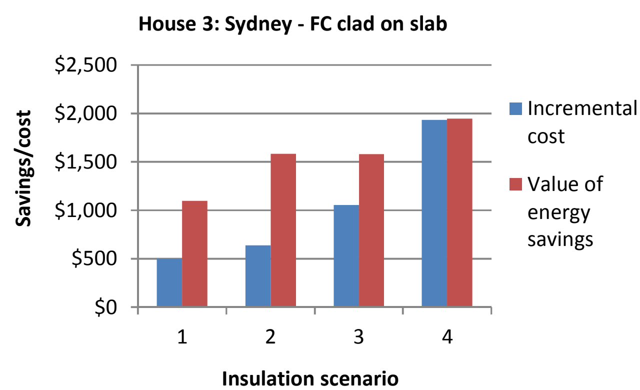

House 2: Sydney - Brick veneer on slab
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
Savings/cost
1
2
3
Insulation scenario
Series1
Series2

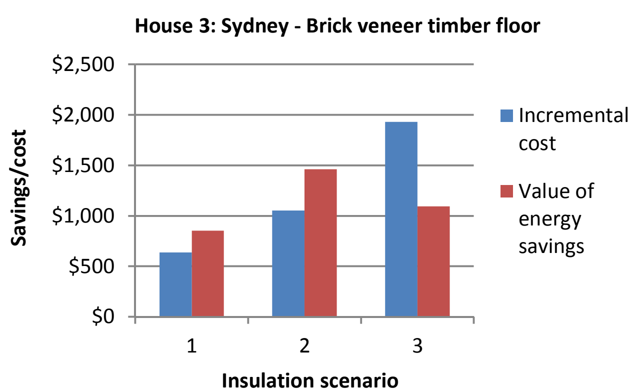

House 2: Sydney - FC clad on slab
$5,000
$4,000
$3,000
$2,000
$1,000
$0
Savings/cost
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings

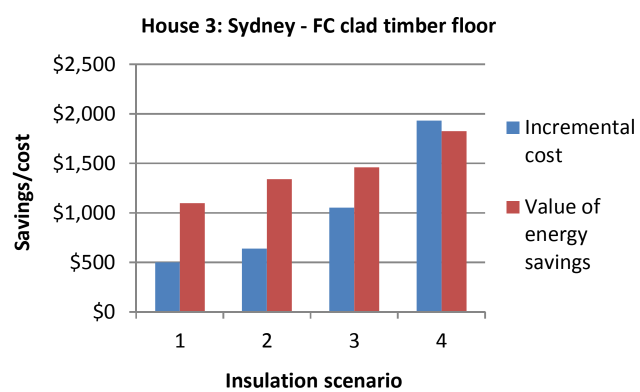

House 2: Sydney - Brick veneer timber floor
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
Savings/cost
1
2
3
Insulation scenario
Incremental cost
Value of energy savings


House 2: Sydney - FC clad timber floor
$5,000
$4,000
$3,000
$2,000
$1,000
$0
Savings/cost
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings


House 3: Sydney - Brick veneer on slab
$1,200
$1,000
$800
$600
$400
$200
$0
Savings/cost
1
2
3
Insulation scenario
Incremental cost
Value of energy savings


House 3: Sydney - FC clad on slab
$2,500
$2,000
$1,500
$1,000
$500
$0
Savings/cost
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings


House 3: Sydney - Brick veneer timber floor
$2,500
$2,000
$1,500
$1,000
$500
$0
Savings/cost
1
2
3
Insulation scenario
Incremental cost
Value of energy savings


House 3: Sydney - FC clad timber floor
$2,500
$2,000
$1,500
$1,000
$500
$0
Savings/cost
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings

In Sydney, higher insulation levels are cost effective for all houses. R6.0 ceiling insulation is cost effective in all cases, and for House 1, R3.0 wall insulation is cost effective for the fibre-cement clad designs. Table 4.2 shows the cost-effective levels of insulation for each house and construction type. The figure in red shows how much higher the cost-effective level of insulation is than the DTS level.

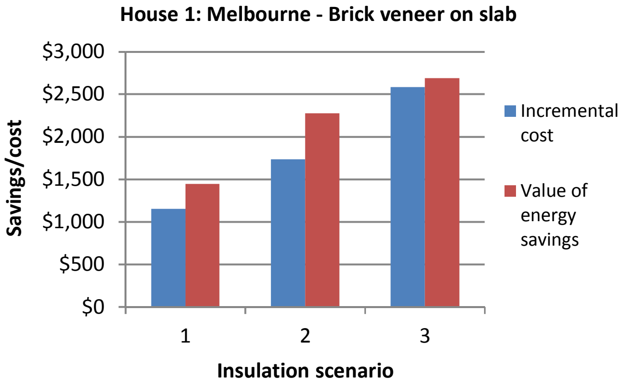
Table 4.2 **Sydney**

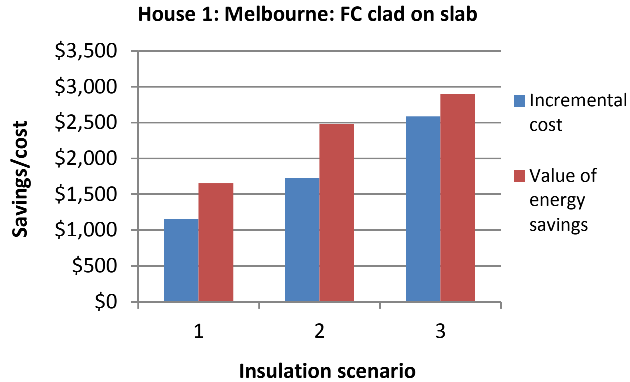
House fabric	House 1	House 2	House 3
Brick veneer on slab	Ceiling R6.0 (+2.0) Wall R2.7 (+0.7)	Ceiling R6.0 (+2.0) Wall R2.5 (+0.5)	Ceiling R6.0 (+2.0) Wall R2.5 (+0.5)
Fibre-cement clad on slab	Ceiling R6.0 (+2.0) Wall R3.0 (+1.0)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.7)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.7)
Brick veneer timber floor	Ceiling R6.0 (+2.0) Wall R2.5 (+0.5)	Ceiling R6.0 (+2.0) Wall R2.5 (+0.5)	Ceiling R6.0 (+2.0) Wall R2.5 (+0.5)
Fibre-cement clad timber floor	Ceiling R6.0 (+2.0) Wall R3.0 (+1.0)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.7)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.7)

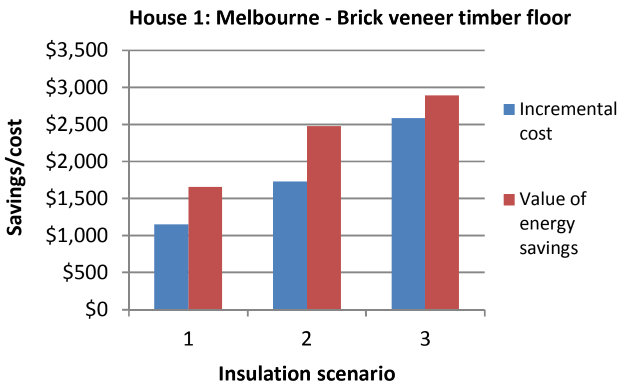
4.2 Melbourne

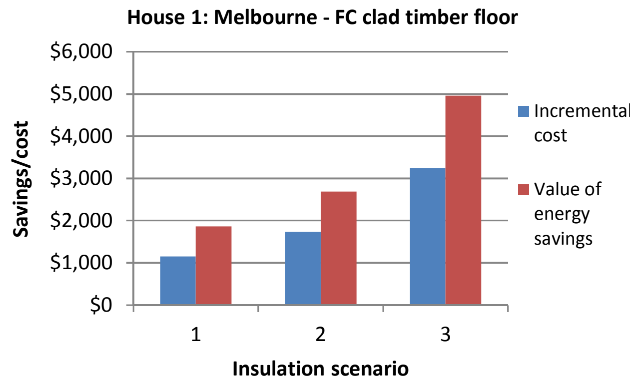
Table 4.3 **Insulation scenarios**

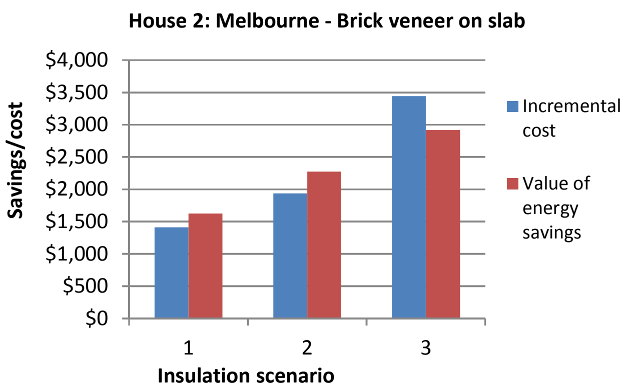
DTS insulation	Scenario 1	Scenario 2	Scenario 3	Scenario 4 (timber floor houses)
Roof – R4.0	Roof – R5.0	Roof – R6.0	Roof – R6.0	Roof – R6.0
Wall – R2.5	Wall – R2.7	Wall – R2.7	Wall – R3.0	Wall – R3.0
Enclosed floor – R1.5	Enclosed floor – R1.5	Enclosed floor – R1.5	Enclosed floor – R1.5	Floor – R3.5

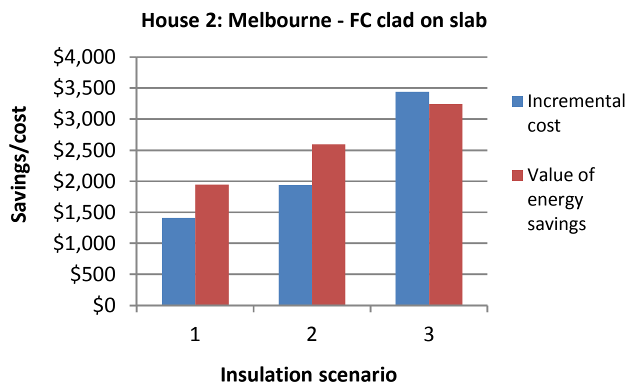

House 1: Melbourne - Brick veneer on slab
Savings/cost
$0
$500
$1,000
$1,500
$2,000
$2,500
$3,000
1
2
3
Insulation scenario
Incremental cost
Value of energy savings

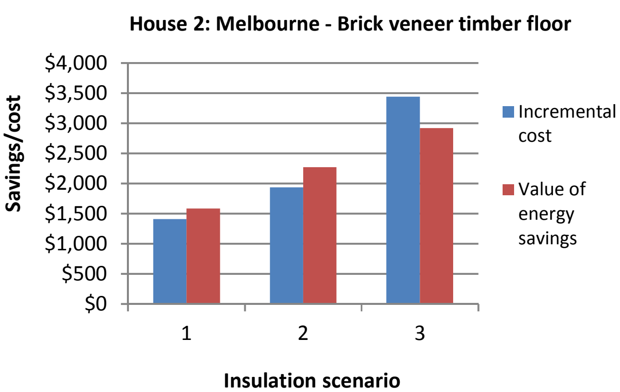

House 1: Melbourne: FC clad on slab
Savings/cost
$0
$500
$1,000
$1,500
$2,000
$2,500
$3,000
$3,500
1
2
3
Insulation scenario
Incremental cost
Value of energy savings

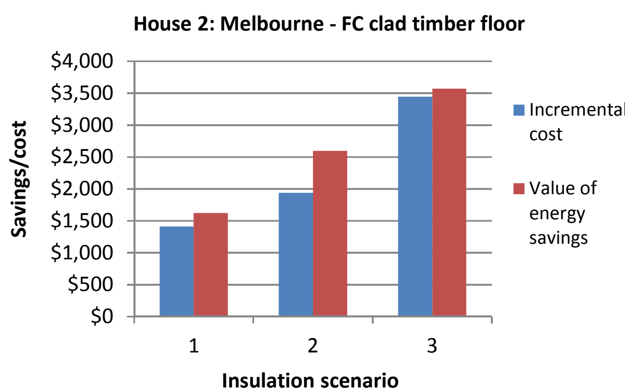

House 1: Melbourne - Brick veneer timber floor
Savings/cost
$0
$500
$1,000
$1,500
$2,000
$2,500
$3,000
$3,500
1
2
3
Insulation scenario
Incremental cost
Value of energy savings

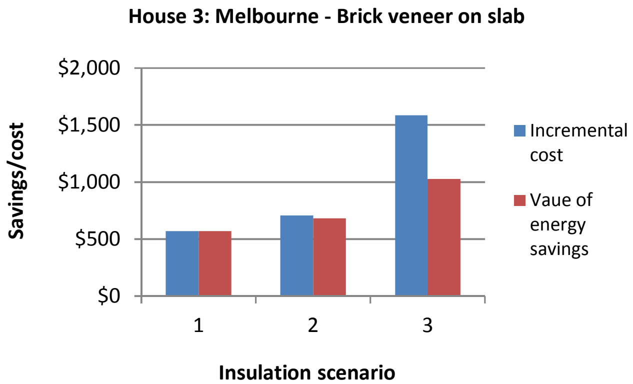

House 1: Melbourne - FC clad timber floor
Savings/cost
$0
$1,000
$2,000
$3,000
$4,000
$5,000
$6,000
1
2
3
Insulation scenario
Incremental cost
Value of energy savings

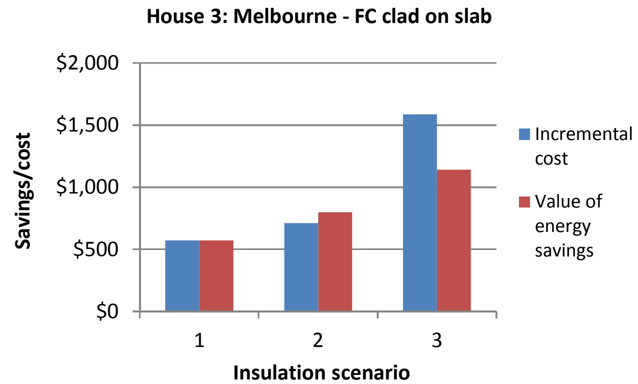

House 2: Melbourne - Brick veneer on slab
Savings/cost
$0
$500
$1,000
$1,500
$2,000
$2,500
$3,000
$3,500
$4,000
1
2
3
Insulation scenario
Incremental cost
Value of energy savings

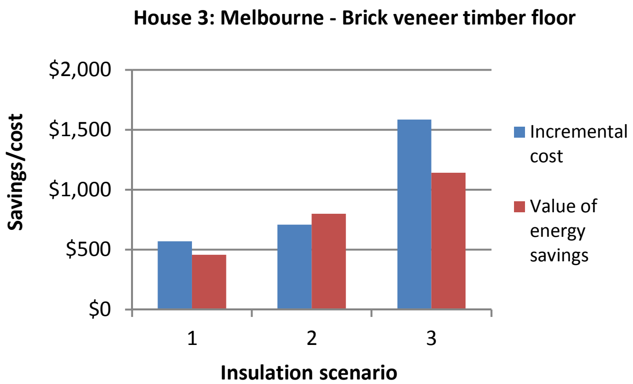

House 2: Melbourne - FC clad on slab
Savings/cost
$0
$500
$1,000
$1,500
$2,000
$2,500
$3,000
$3,500
$4,000
1
2
3
Insulation scenario
Incremental cost
Value of energy savings

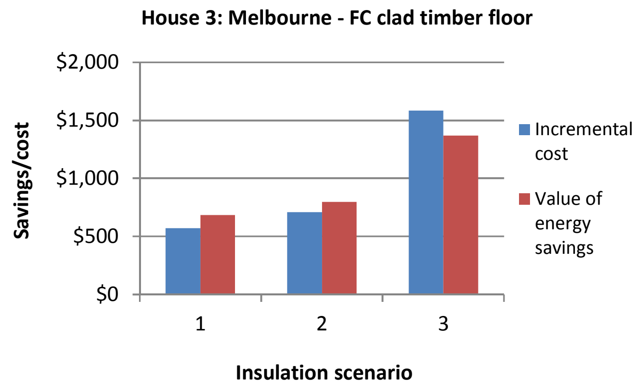

House 2: Melbourne - Brick veneer timber floor
Savings/cost
$0
$500
$1,000
$1,500
$2,000
$2,500
$3,000
$3,500
$4,000
1
2
3
Insulation scenario
Incremental cost
Value of energy savings


House 2: Melbourne - FC clad timber floor
Savings/cost
$0
$500
$1,000
$1,500
$2,000
$2,500
$3,000
$3,500
$4,000
1
2
3
Insulation scenario
Incremental cost
Value of energy savings









R6.0 ceiling and R2.7 wall insulation is cost effective in all cases except for House 3 (brick veneer on slab). Combined with extra ceiling and floor insulation, R3.5 floor insulation is also cost effective for the timber floor designs of House 1.

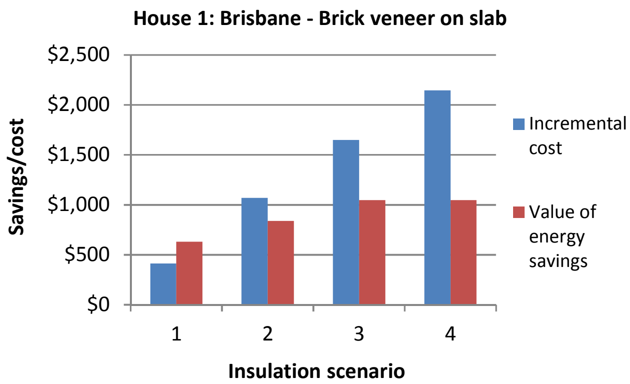
Table 4.4 **Melbourne**

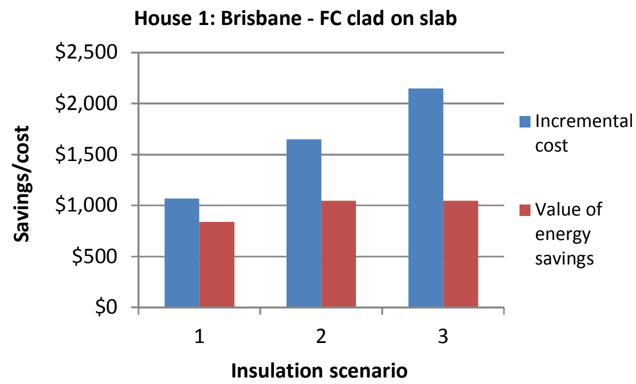
House fabric	House 1	House 2	House 3
Brick veneer on slab	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)	Ceiling R4.0 Wall R2.5
Fibre-cement clad on slab	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)
Brick veneer timber floor	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2) Floor R3.5 (+2.0)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)	Ceiling R6.0 Wall R2.7 (+0.2)
Fibre-cement clad timber floor	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2) Floor R3.5 (+2.0)	Ceiling R6.0 Wall R2.7 (+0.2)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)

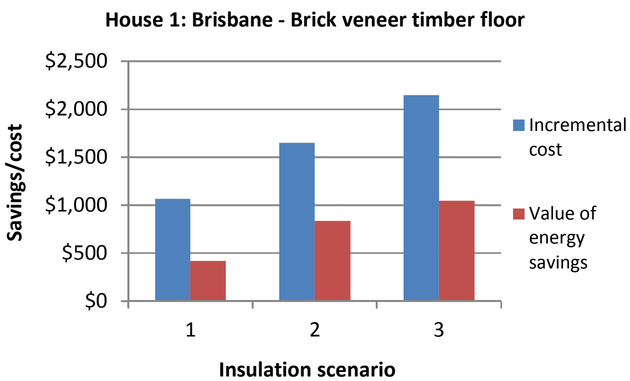
4.3 Brisbane

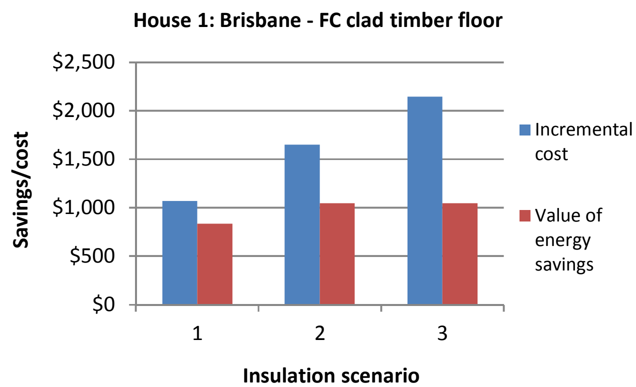
Table 4.5 **Insulation scenarios**

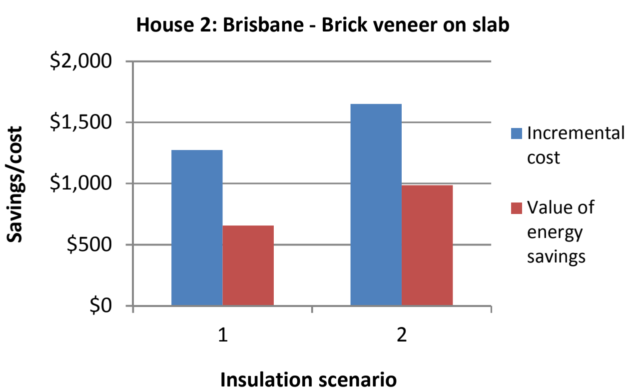
DTS insulation	Scenario 1	Scenario 2	Scenario 3
Roof – R4.0	–	Roof – R5.0	Roof – R6.0
Wall – R2.0	Wall – R2.5	Wall – R2.5	Wall – R2.5

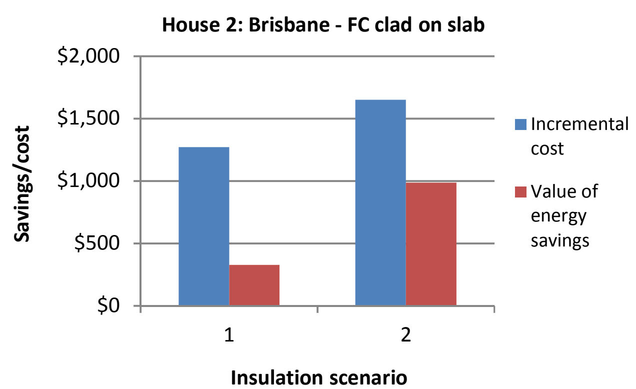


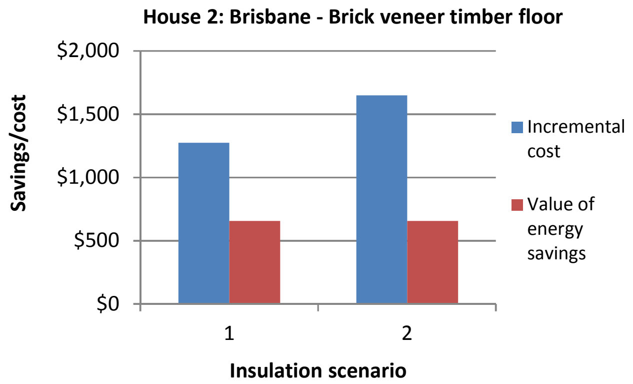


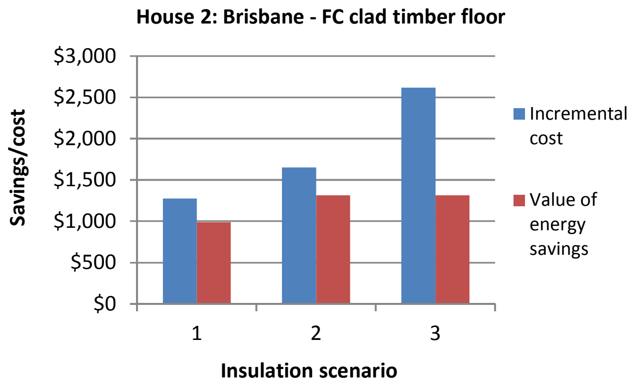


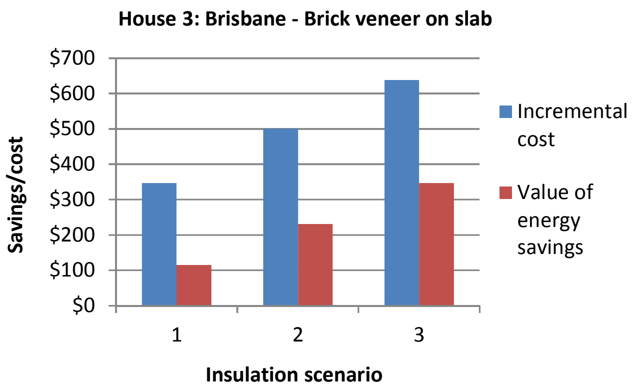


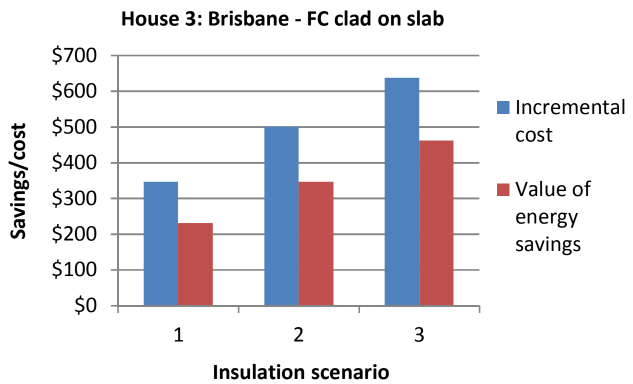


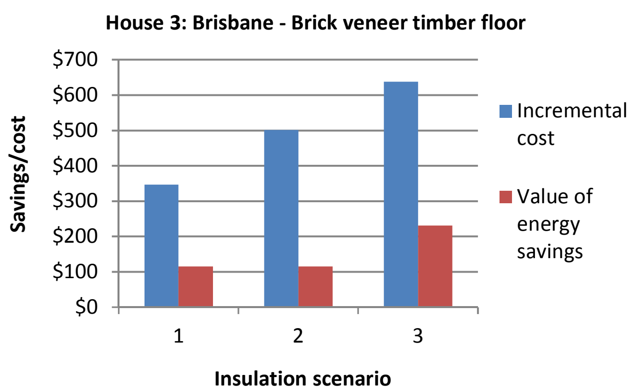


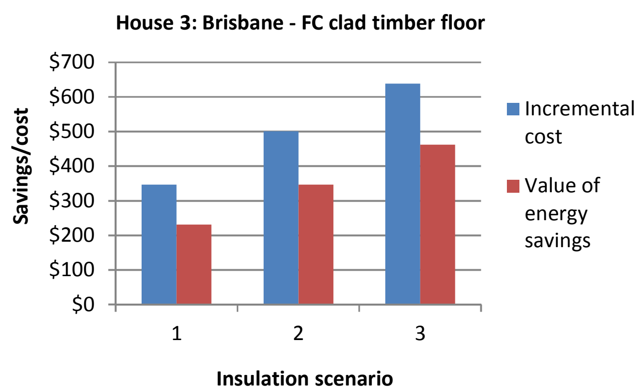












Brisbane, except in the case of House 1 (brick veneer slab), none of the insulation scenarios is cost effective. The primary reason for this is because beyond 6 stars there is very little space-conditioning left to be saved (refer to Table 1.2 to see how Brisbane compares with other locations in terms of space-conditioning demand at 6 stars. It is significantly lower than everywhere else). In Brisbane, space-conditioning energy only accounts for about 15% of total household energy, compared to the national average of 38%.

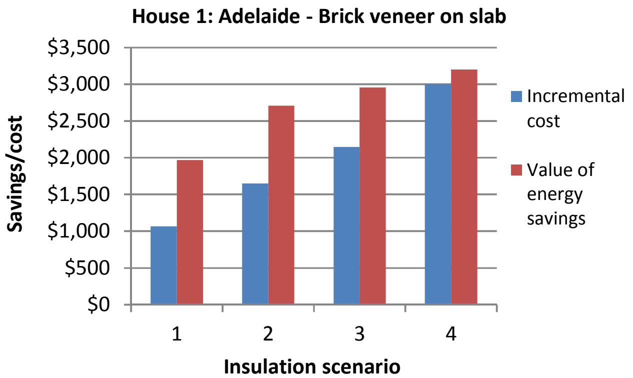
Table 4.6 **Brisbane**

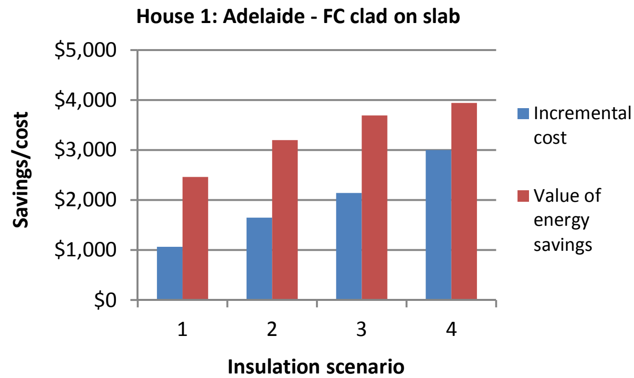
House fabric	House 1	House 2	House 3
Brick veneer on slab	Ceiling R4.0 Wall R2.5 (0.5)	Ceiling R4.0 Wall R2.0	Ceiling R4.0 Wall R2.0
Fibre-cement clad on slab	Ceiling R4.0 Wall R2.0	Ceiling R4.0 Wall R2.0	Ceiling R4.0 Wall R2.0
Brick veneer timber floor	Ceiling R4.0 Wall R2.0	Ceiling R4.0 Wall R2.0	Ceiling R4.0 Wall R2.0
Fibre-cement clad timber floor	Ceiling R4.0 Wall R2.0	Ceiling R4.0 Wall R2.0	Ceiling R4.0 Wall R2.0

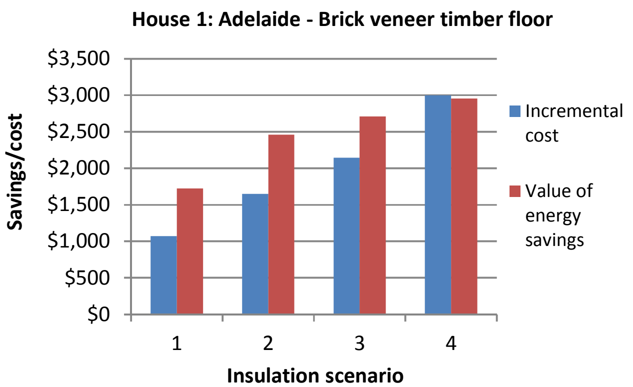
4.4 Adelaide

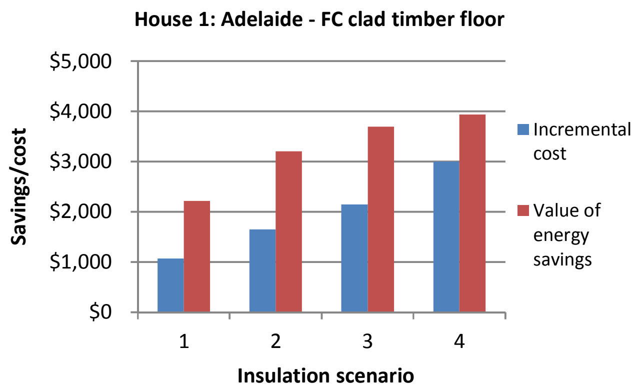
Table 4.7 **Insulation scenarios**

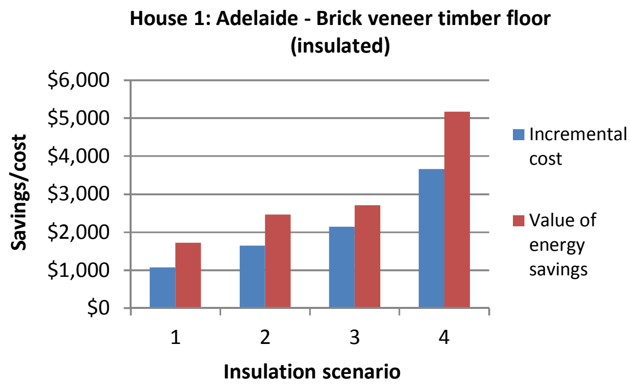
DTS insulation	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Roof – R4.0	Roof – R5.0	Roof – R6.0	Roof – R6.0	Roof – R6.0
Wall – R2.0	Wall – R2.5	Wall – R2.5	Wall – R2.7	Wall – R3.0

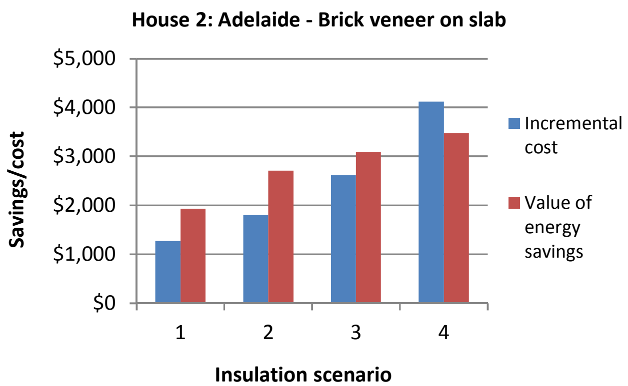


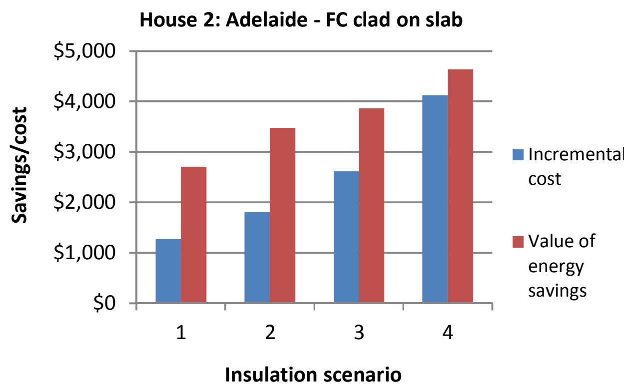


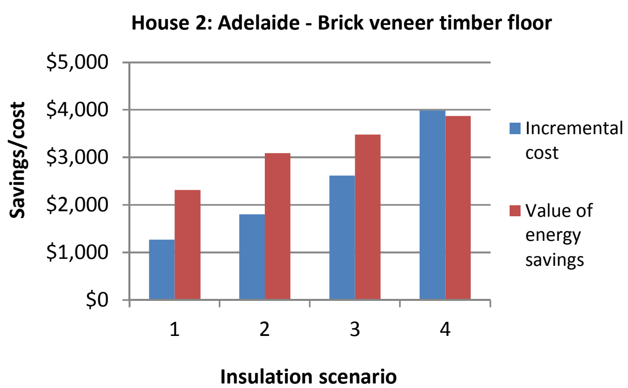


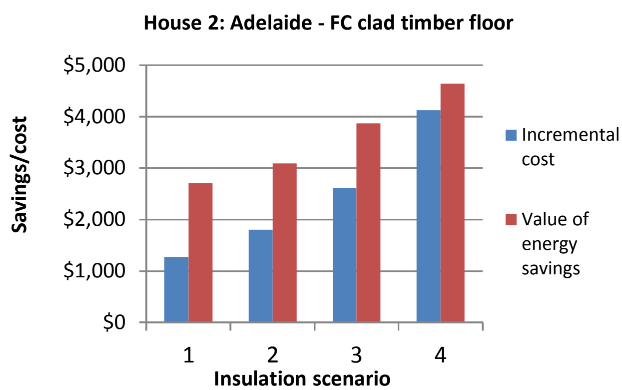


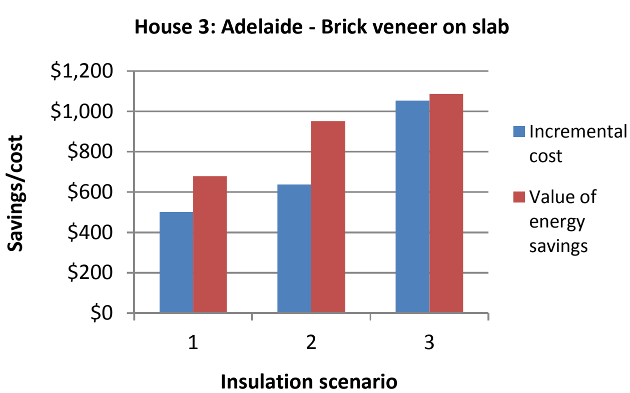

House 1: Adelaide - Brick veneer timber floor (insulated)
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$0
Savings/cost
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings

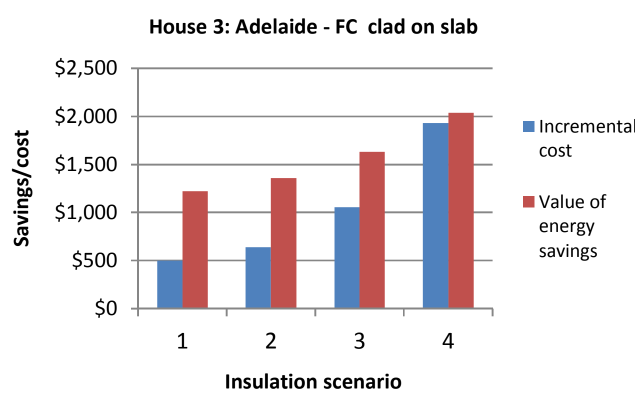

House 2: Adelaide - Brick veneer on slab
$5,000
$4,000
$3,000
$2,000
$1,000
$0
Savings/cost
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings

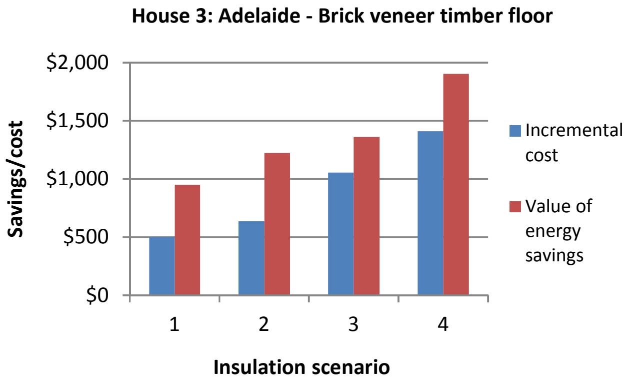

House 2: Adelaide - FC clad on slab
$5,000
$4,000
$3,000
$2,000
$1,000
$0
Savings/cost
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings

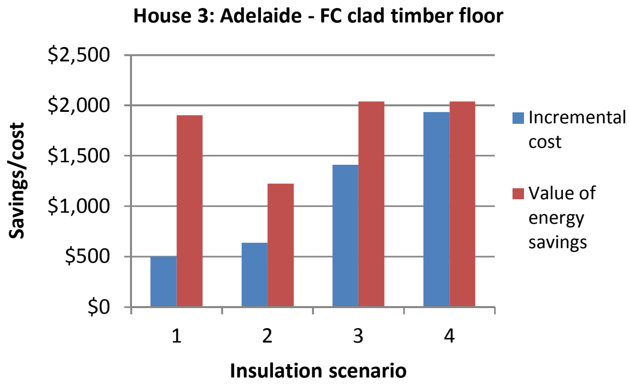

House 2: Adelaide - Brick veneer timber floor
$5,000
$4,000
$3,000
$2,000
$1,000
$0
Savings/cost
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings


House 2: Adelaide - FC clad timber floor
$5,000
$4,000
$3,000
$2,000
$1,000
$0
Savings/cost
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings


House 3: Adelaide - Brick veneer on slab
$1,200
$1,000
$800
$600
$400
$200
$0
Savings/cost
1
2
3
Insulation scenario
Incremental cost
Value of energy savings


House 3: Adelaide - FC clad on slab
$2,500
$2,000
$1,500
$1,000
$500
$0
Savings/cost
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings





The story for Adelaide is similar to that of Sydney in terms of cost-effective levels of wall and ceiling insulation generally. However, the single-storey houses (1 and 3) with timber floors are benefitting significantly from the use of R2.1 floor insulation as well.

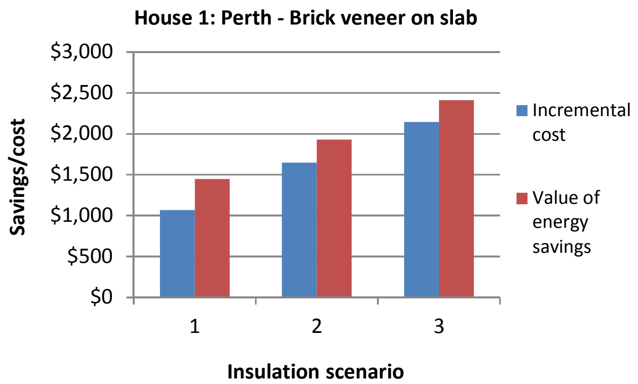
Table 4.8 **Adelaide**

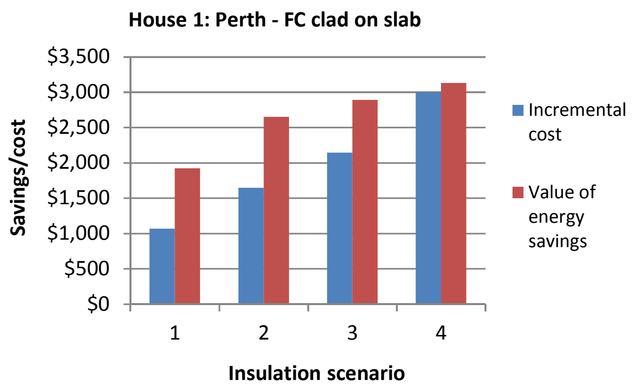
House fabric	House 1	House 2	House 3
Brick veneer on slab	Ceiling R6.0 (+2.0) Wall R2.7 (+0.7)	Ceiling R6.0 (+2.0) Wall R2.7	Ceiling R6.0 (+2.0) Wall R2.5 (+0.5)
Fibre-cement clad on slab	Ceiling R6.0 (+2.0) Wall R3.0 (+1.0)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.7)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.7)
Brick veneer timber floor	Ceiling R6.0 (+2.0) Wall R2.7 (+0.7) Floor R2.1 (+2.1)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.7)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.7) Floor R2.1 (+2.1)
Fibre-cement clad timber floor	Ceiling R6.0 (+2.0) Wall R2.7 (+0.7) Floor R2.1 (+2.1)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.7)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.7) Floor R2.1 (+2.1)

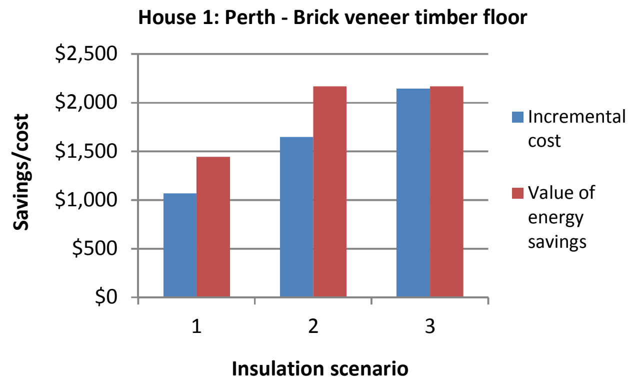
4.5 Perth

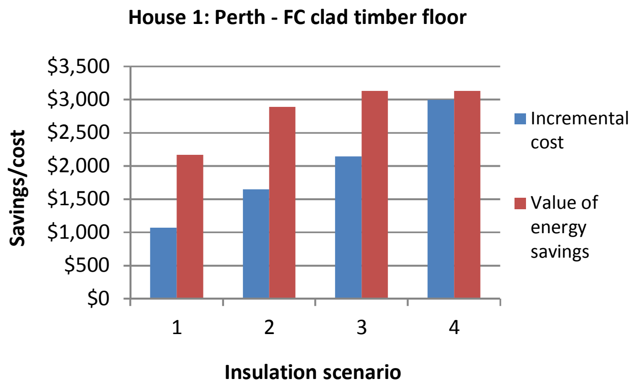
Table 4.9 **Insulation scenarios**

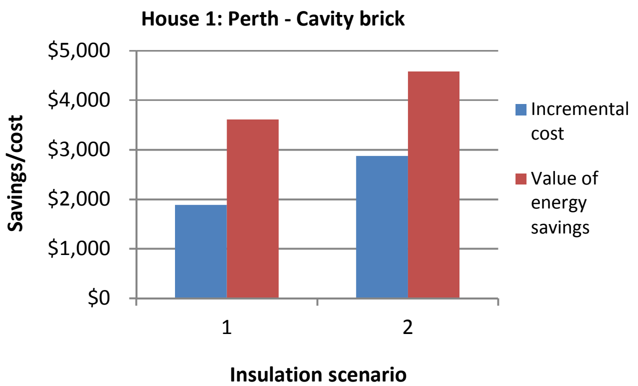
DTS insulation	Scenario 1	Scenario 2	Scenario 3
Non-cavity brick designs			
Roof – R4.0	Roof – R5.0	Roof – R6.0	Roof – R6.0
Wall – R2.0	Wall – R2.5	Wall – R2.5	Wall – R2.7
Cavity brick designs			
Roof – R4.0	Roof – R5.0	Roof – R6.0	–
Wall – R0.5	Wall – R1.5	Wall – R1.5	–

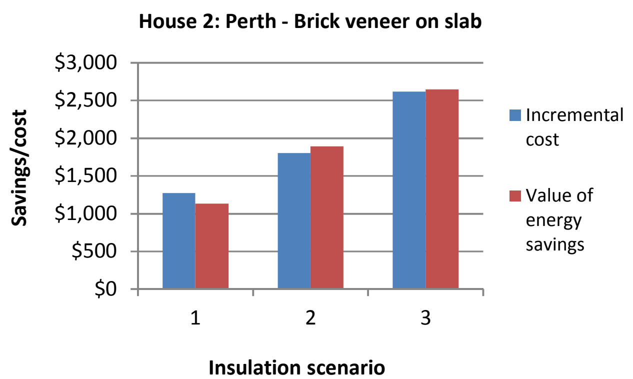

House 1: Perth - Brick veneer on slab
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
Savings/cost
1
2
3
Insulation scenario
Incremental cost
Value of energy savings

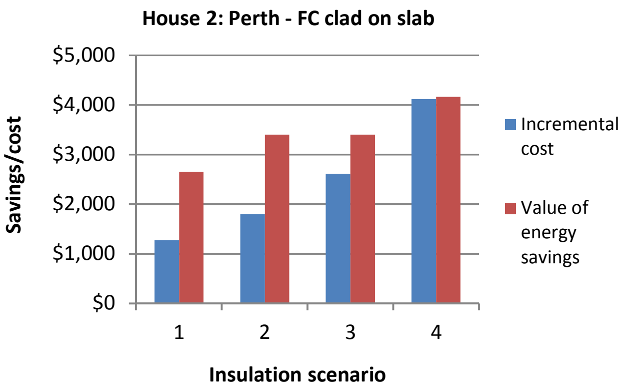

House 1: Perth - FC clad on slab
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
Savings/cost
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings

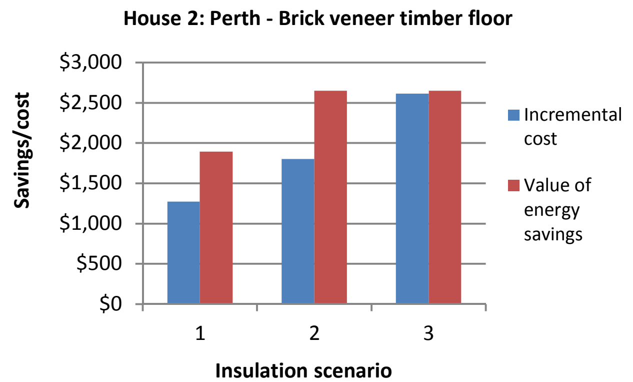

House 1: Perth - Brick veneer timber floor
$2,500
$2,000
$1,500
$1,000
$500
$0
Savings/cost
1
2
3
Insulation scenario
Incremental cost
Value of energy savings

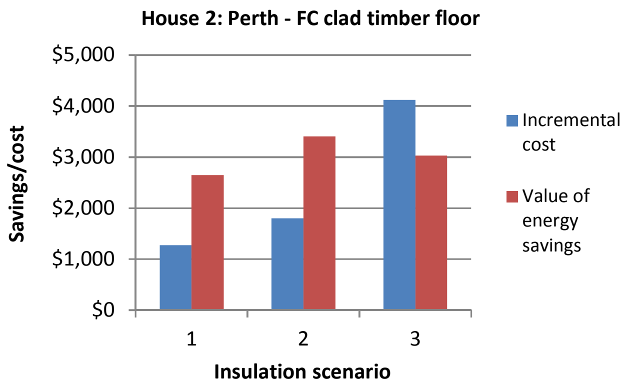

House 1: Perth - FC clad timber floor
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
Savings/cost
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings

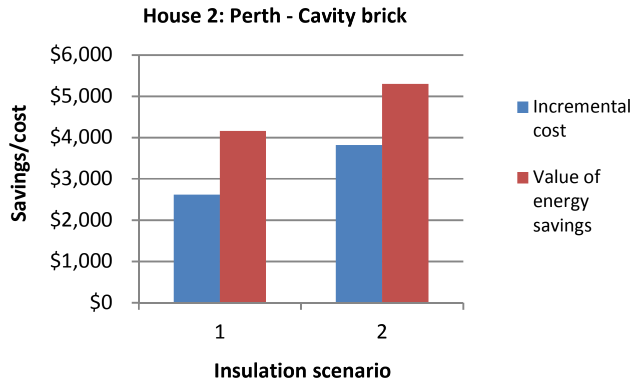

House 1: Perth - Cavity brick
$5,000
$4,000
$3,000
$2,000
$1,000
$0
Savings/cost
1
2
Insulation scenario
Incremental cost
Value of energy savings

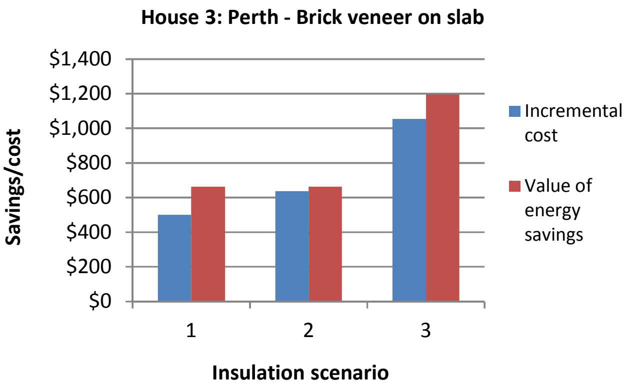

House 2: Perth - Brick veneer on slab
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
Savings/cost
1
2
3
Insulation scenario
Incremental cost
Value of energy savings

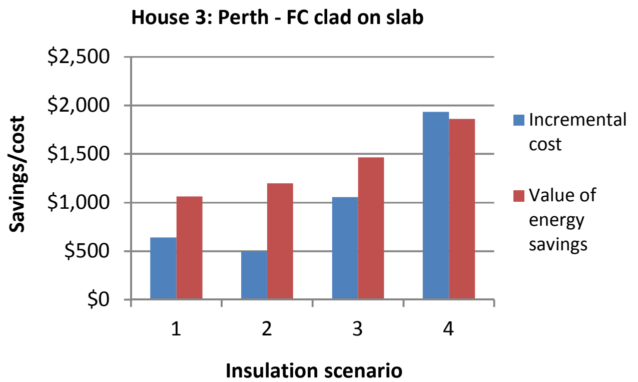

House 2: Perth - FC clad on slab
$5,000
$4,000
$3,000
$2,000
$1,000
$0
Savings/cost
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings

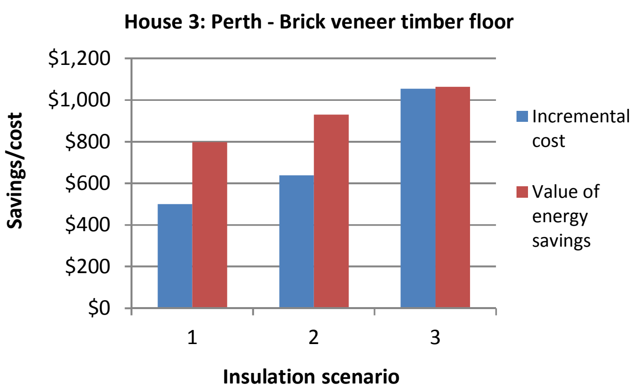

House 2: Perth - Brick veneer timber floor
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
Savings/cost
1
2
3
Insulation scenario
Incremental cost
Value of energy savings

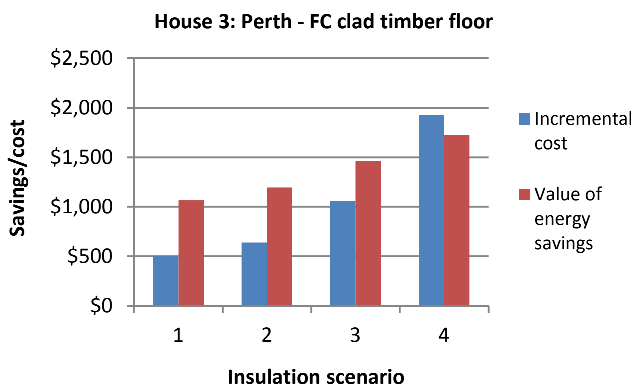

House 2: Perth - FC clad timber floor
Savings/cost
$5,000
$4,000
$3,000
$2,000
$1,000
$0
1
2
3
Insulation scenario
Incremental cost
Value of energy savings

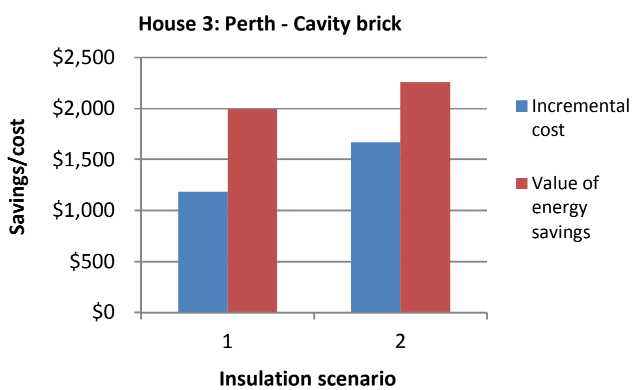

House 2: Perth - Cavity brick
Savings/cost
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$0
1
2
Insulation scenario
Incremental cost
Value of energy savings


House 3: Perth - Brick veneer on slab
Savings/cost
$1,400
$1,200
$1,000
$800
$600
$400
$200
$0
1
2
3
Insulation scenario
Incremental cost
Value of energy savings


House 3: Perth - FC clad on slab
Savings/cost
$2,500
$2,000
$1,500
$1,000
$500
$0
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings


House 3: Perth - Brick veneer timber floor
Savings/cost
$1,200
$1,000
$800
$600
$400
$200
$0
1
2
3
Insulation scenario
Incremental cost
Value of energy savings


House 3: Perth - FC clad timber floor
Savings/cost
$2,500
$2,000
$1,500
$1,000
$500
$0
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings


House 3: Perth - Cavity brick
Savings/cost
$2,500
$2,000
$1,500
$1,000
$500
$0
1
2
Insulation scenario
Incremental cost
Value of energy savings

The brick veneer on slab (House 2) is the only design where insulation levels higher than the DTS are not cost effective.

Table 4.10 **Perth**

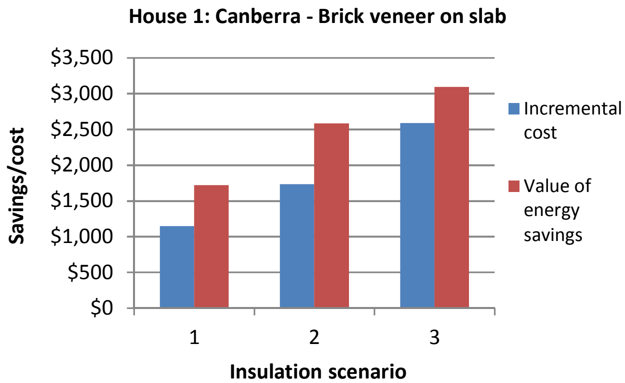
House fabric	House 1	House 2	House 3
Brick veneer on slab	Ceiling R6.0 (+2.0) Wall R2.5 (+0.5)	Ceiling R4.0 Wall R2.0	Ceiling R5.0 (+1.0) Wall R2.5 (+0.5)
Fibre-cement clad on slab	Ceiling R6.0 (+2.0) Wall R2.7(+0.2)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)
Brick veneer timber floor	Ceiling R6.0 (+2.0) Wall R2.5 (+0.5)	Ceiling R6.0 (+2.0) Wall R2.5 (+0.5)	Ceiling R6.0 (+2.0) Wall R2.5(+0.5)
Fibre-cement clad timber floor	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)	Ceiling R6.0 (+2.0) Wall R2.7(+0.2)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)
Cavity brick	Ceiling R6.0 (+2.0) Wall R1.5 (+1.0)	Ceiling R6.0 (+2.0) Wall R1.5 (+1.0)	Ceiling R6.0 (+2.0) Wall R1.5 (+1.0)

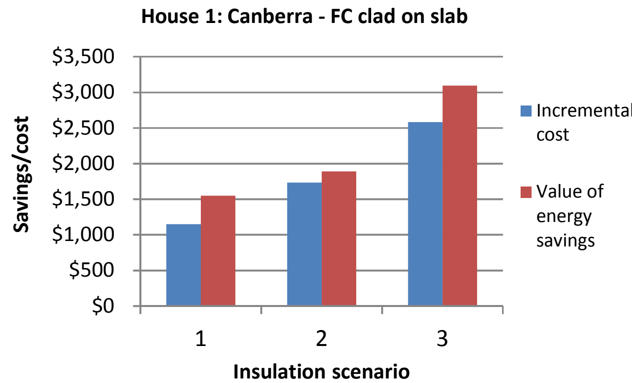
4.6 Canberra

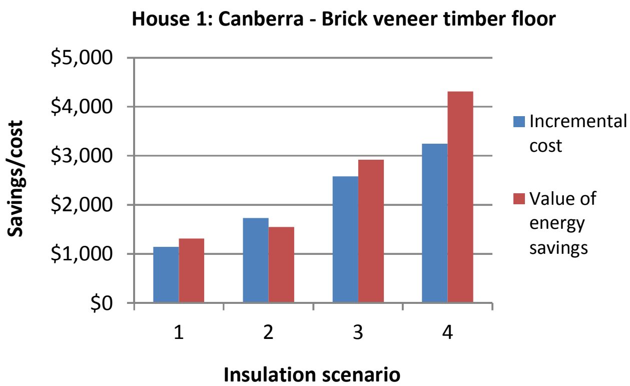
R6.0 ceiling and R3.0 wall is cost-effective for all House 1 designs, and for House 2 and 3 designs, R6.0 and R2.7 levels of insulation are cost effective. That R3.0 wall insulation is cost effective in House 1 only is probably due to House 1's lower wall to floor ratio.

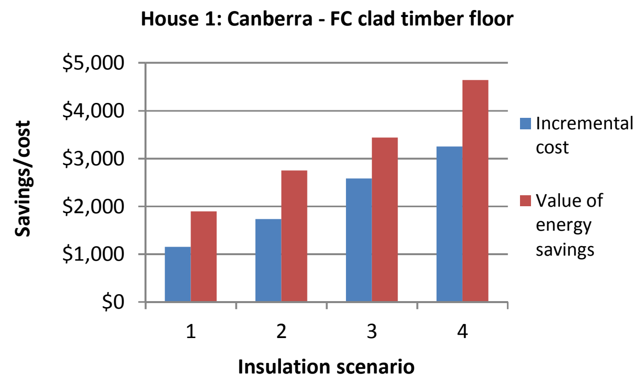
Table 4.11 **Insulation scenarios**

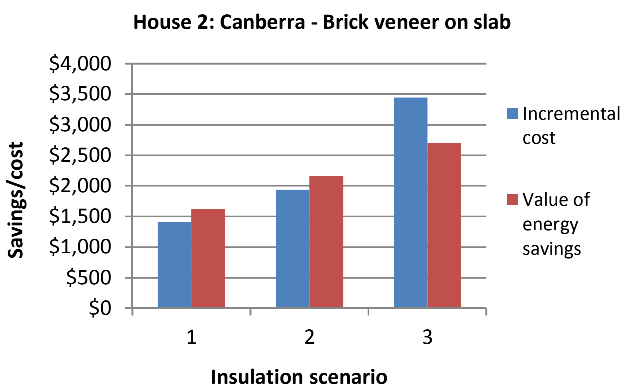
DTS insulation	Scenario 1	Scenario 2	Scenario 3	Scenario 4 (timber floors)
Roof – R4.0	Roof – R5.0	Roof – R6.0	Roof – R6.0	Roof – R6.0
Wall – R2.5	Wall – R2.7	Wall – R2.7	Wall – R3.0	Wall – R3.0
Enclosed floor – R1.5	–	–	–	Floor- R3.5

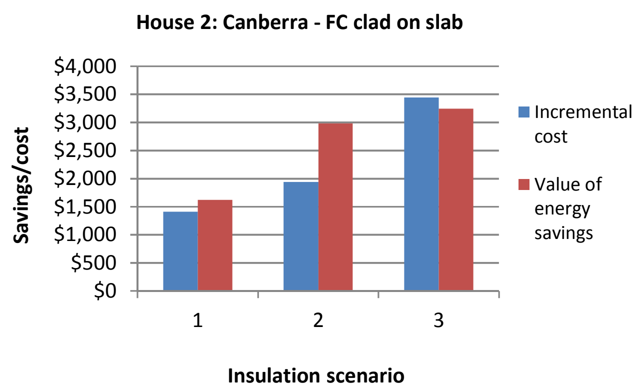

House 1: Canberra - Brick veneer on slab
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
Savings/cost
1
2
3
Insulation scenario
Incremental cost
Value of energy savings

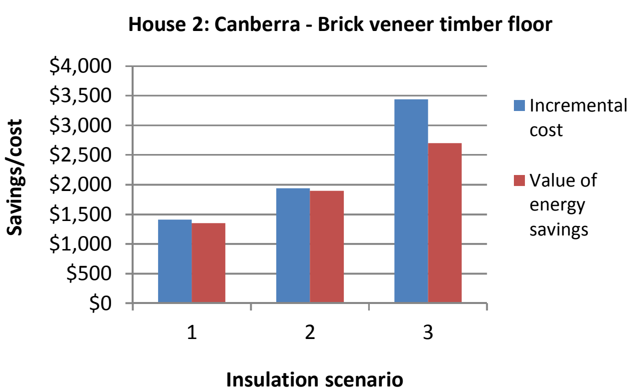

House 1: Canberra - FC clad on slab
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
Savings/cost
1
2
3
Insulation scenario
Incremental cost
Value of energy savings

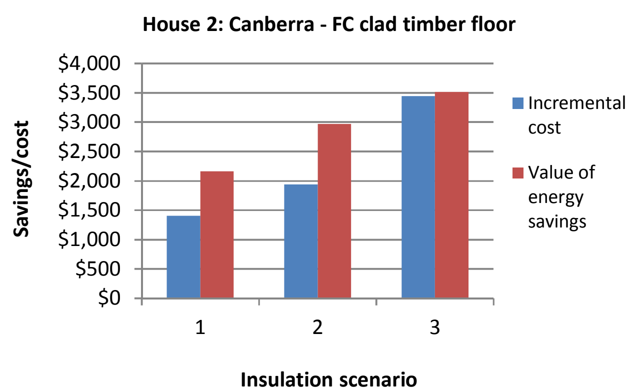

House 1: Canberra - Brick veneer timber floor
$5,000
$4,000
$3,000
$2,000
$1,000
$0
Savings/cost
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings

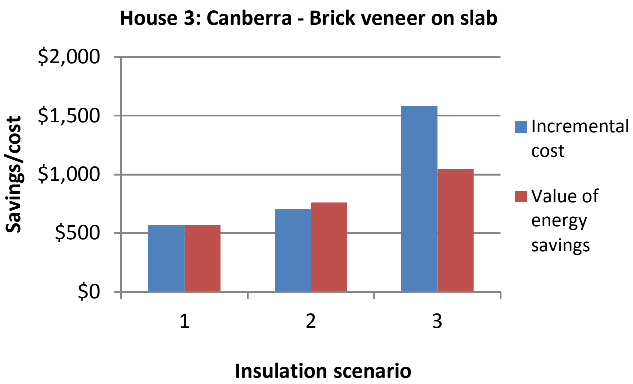

House 1: Canberra - FC clad timber floor
$5,000
$4,000
$3,000
$2,000
$1,000
$0
Savings/cost
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings

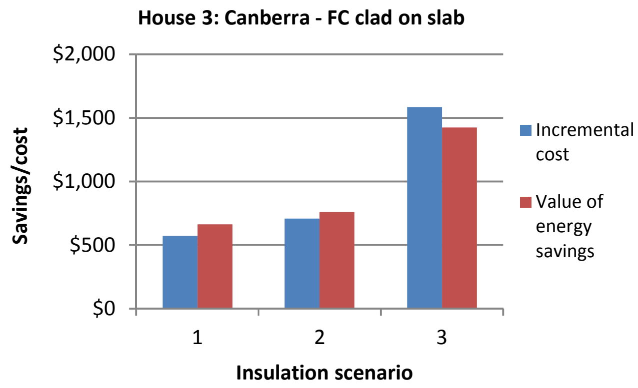

House 2: Canberra - Brick veneer on slab
$4,000
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
Savings/cost
1
2
3
Insulation scenario
Incremental cost
Value of energy savings

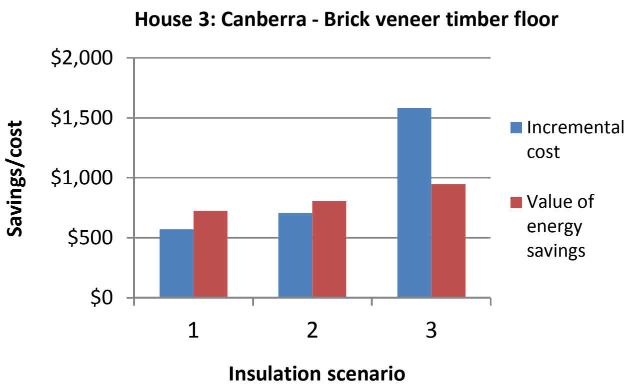

House 2: Canberra - FC clad on slab
$4,000
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
Savings/cost
1
2
3
Insulation scenario
Incremental cost
Value of energy savings

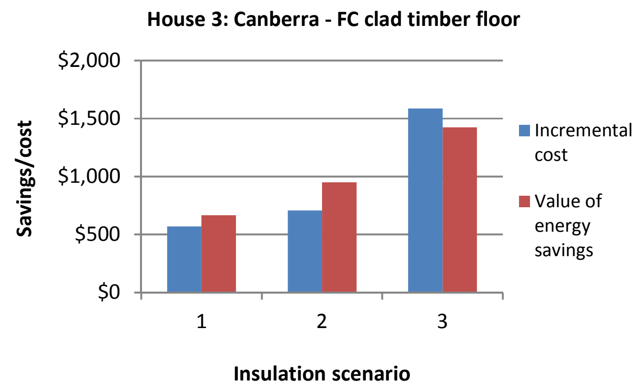

House 2: Canberra - Brick veneer timber floor
$4,000
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
Savings/cost
1
2
3
Insulation scenario
Incremental cost
Value of energy savings


House 2: Canberra - FC clad timber floor
$4,000
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
Savings/cost
1
2
3
Insulation scenario
Incremental cost
Value of energy savings









R6.0 ceiling and R3.0 wall is cost-effective for all House 1 designs, and for House 2 and 3 designs, R6.0 and R2.7 levels of insulation are cost effective.

Table 4.12 **Canberra**

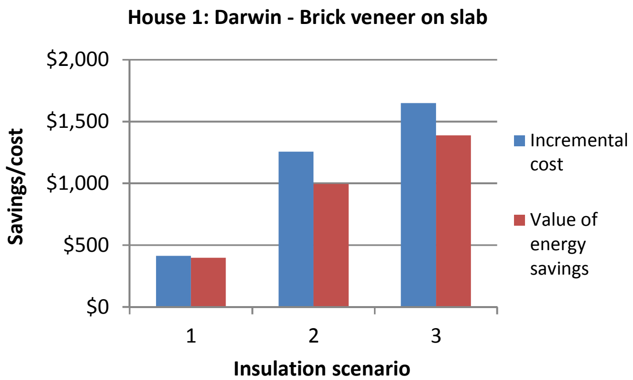
House fabric	House 1	House 2	House 3
Brick veneer on slab	Ceiling R6.0 (+2.0) Wall R3.0 (+0.5)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)
Fibre-cement clad on slab	Ceiling R6.0 (+2.0) Wall R3.0 (+0.5)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)
Brick veneer timber floor*	Ceiling R6.0 (+2.0) Wall R3.0 (+0.5)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)
Fibre-cement clad timber floor*	Ceiling R6.0 (+2.0) Wall R3.0 (+0.5)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)

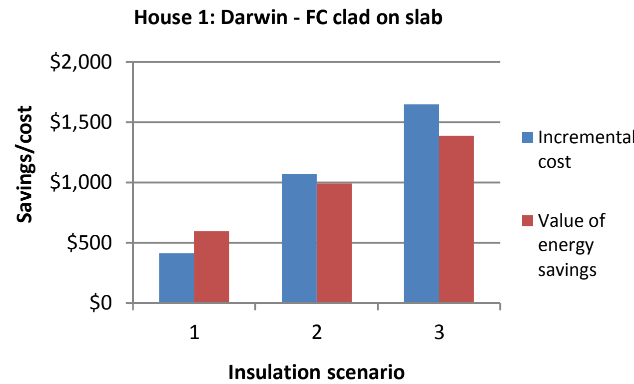
* Floor insulation (R2.1) cost-effective alternative

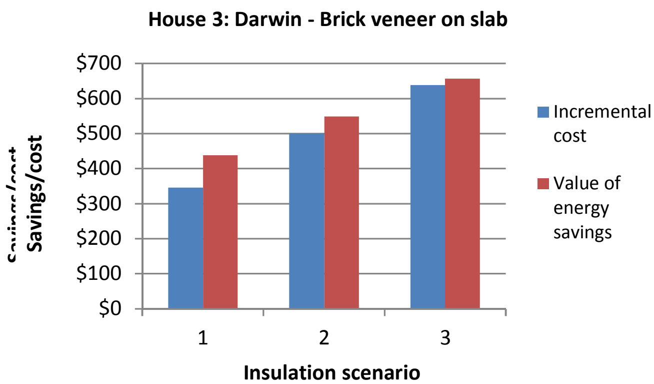
4.7 Darwin

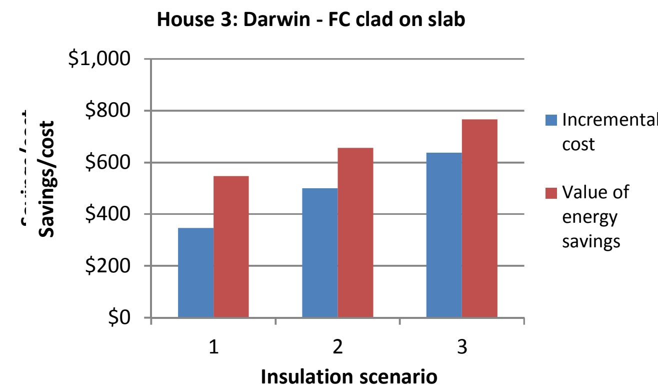
Table 4.13 **Insulation scenarios**

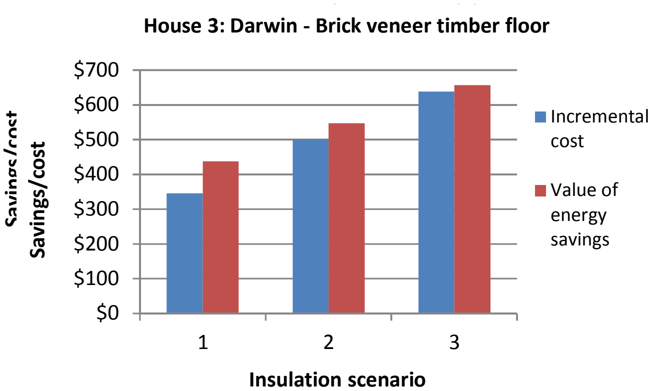
DTS insulation	Scenario 1	Scenario 2	Scenario 3
Roof – R4.0	–	Roof – R5.0	Roof – R6.0
Wall – R2.0	Wall – R2.5	Wall – R2.5	Wall – R2.5
Enclosed floor – R1.0	Enclosed floor – R1.0	Enclosed floor – R1.0	Enclosed floor – R1.0

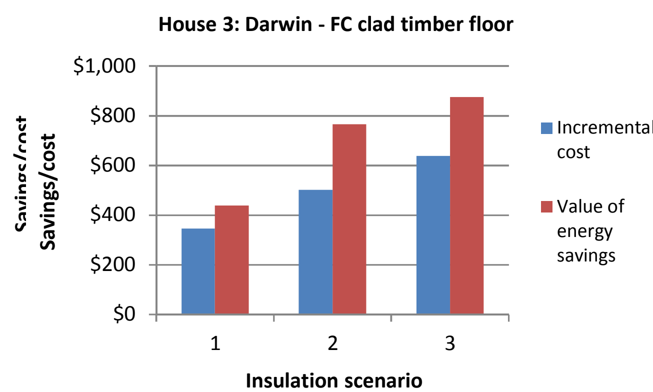

House 1: Darwin - Brick veneer on slab
$2,000
$1,500
$1,000
$500
$0
Savings/cost
1
2
3
Insulation scenario
Incremental cost
Value of energy savings

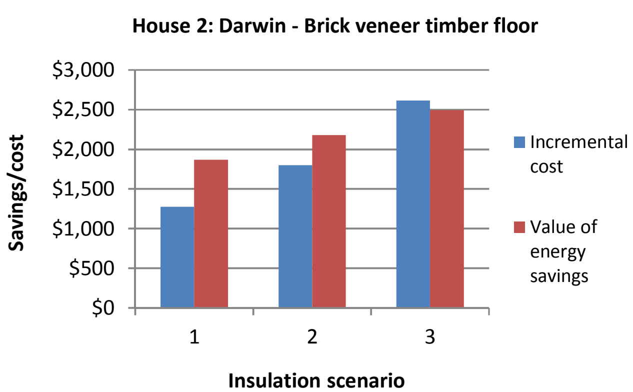

House 1: Darwin - FC clad on slab
$2,000
$1,500
$1,000
$500
$0
Savings/cost
1
2
3
Insulation scenario
Incremental cost
Value of energy savings

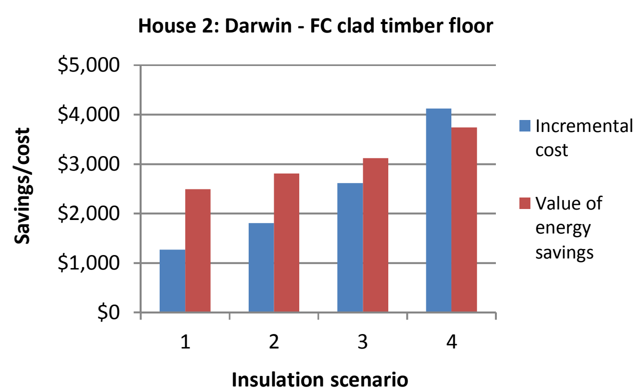

House 3: Darwin - Brick veneer on slab
$700
$600
$500
$400
$300
$200
$100
$0
Savings/cost
1
2
3
Insulation scenario
Incremental cost
Value of energy savings


House 3: Darwin - FC clad on slab
$1,000
$800
$600
$400
$200
$0
Savings/cost
1
2
3
Insulation scenario
Incremental cost
Value of energy savings


House 3: Darwin - Brick veneer timber floor
$700
$600
$500
$400
$300
$200
$100
$0
Savings/cost
1
2
3
Insulation scenario
Incremental cost
Value of energy savings


House 3: Darwin - FC clad timber floor
$1,000
$800
$600
$400
$200
$0
Savings/cost
1
2
3
Insulation scenario
Incremental cost
Value of energy savings


House 2: Darwin - Brick veneer timber floor
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
Savings/cost
1
2
3
Insulation scenario
Incremental cost
Value of energy savings


House 2: Darwin - FC clad timber floor
$5,000
$4,000
$3,000
$2,000
$1,000
$0
Savings/cost
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings

In Darwin's climate, exceeding the DTS minimum level of ceiling insulation of R4.0 is not cost effective for Houses 1 and 3; however, increasing wall insulation to R2.5 from the minimum level of R2.0 is (except for House 1 brick veneer on slab) is cost effective. Higher wall (at least an extra R0.7) and ceiling insulation (and extra R2.0) is cost effective for House 2. These results generally weaken the argument made by some that insulation in hot-humid climates is not cost effective and leads to overheating.

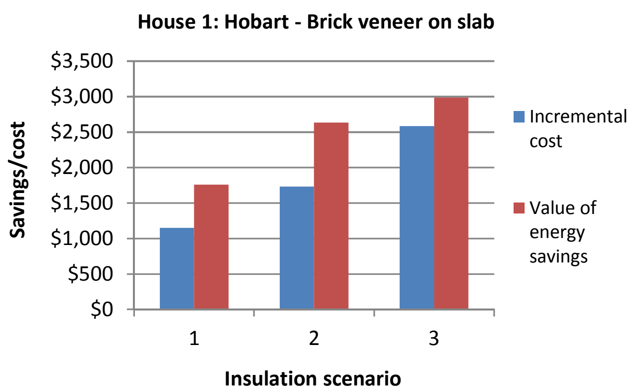
Table 4.14 **Darwin**

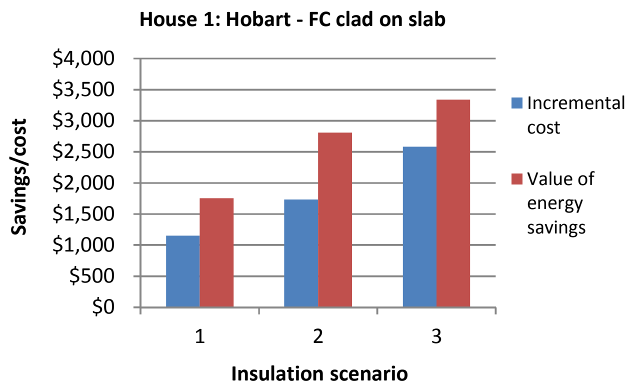
House fabric	House 1	House 2	House 3
Brick veneer on slab	Ceiling R4.0 Wall R2.0	Ceiling R6.0 (+2.0) Wall R2.5(+0.5)	Ceiling R4.0 Wall R2.5(+0.5)
Fibre-cement clad on slab	Ceiling R4.0 Wall R2.5(+0.5)	Ceiling R6.0(+2.0) Wall R2.5(+0.5)	Ceiling R6.0(+2.0) Wall R2.5(+0.5)
Brick veneer timber floor	Ceiling R4.0 Wall R2.5 (+0.5)	Ceiling R6.0 Wall R2.5 (+0.5)	Ceiling R4.0 Wall R2.5(+0.5)
Fibre-cement clad timber floor	Ceiling R4.0 Wall R2.5(+0.5)	Ceiling R6.0(+2.0) Wall R2.7 (+0.2)	Ceiling R4.0 Wall R2.5(+0.5)

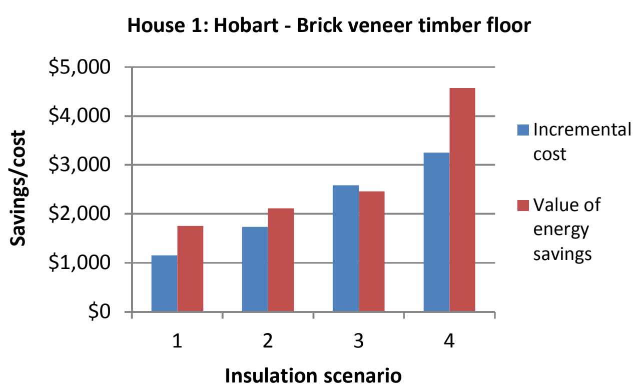
4.8 Hobart

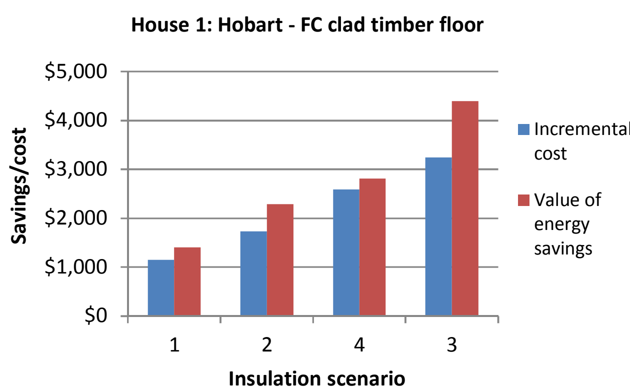
Table 4.15 **Insulation scenarios**

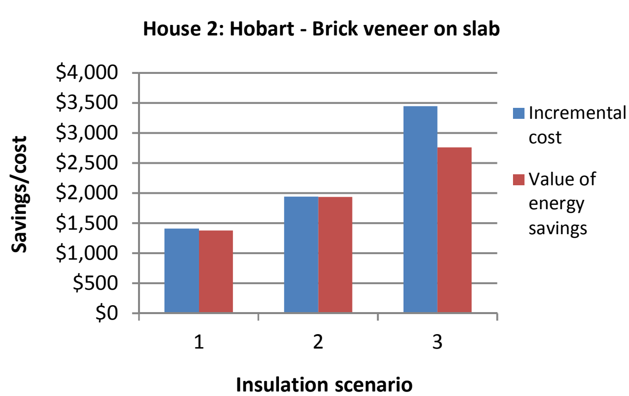
DTS insulation	Scenario 1	Scenario 2	Scenario 3	Scenario 4 (timber floor houses)
Roof – R4.0	Roof – R5.0	Roof – R6.0	Roof – R6.0	Roof – R6.0
Wall – R2.5	Wall – R2.7	Wall – R2.7	Wall – R3.0	Wall – R3.0
Enclosed floor – R1.5	–	–	–	Floor-R3.5

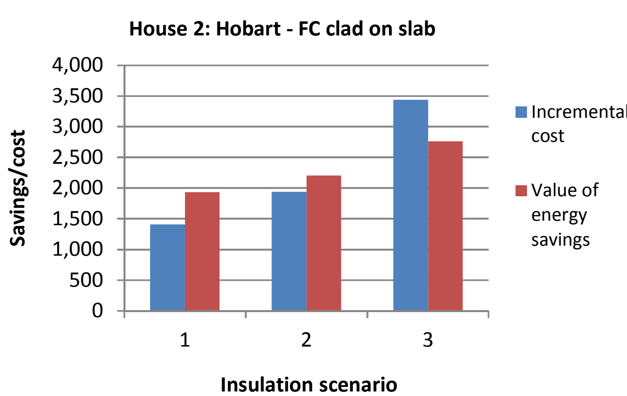


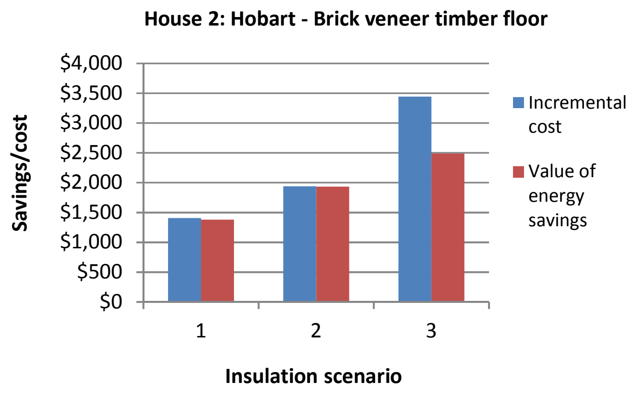


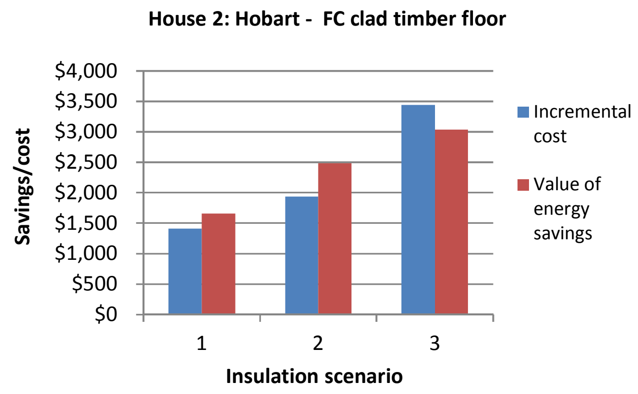


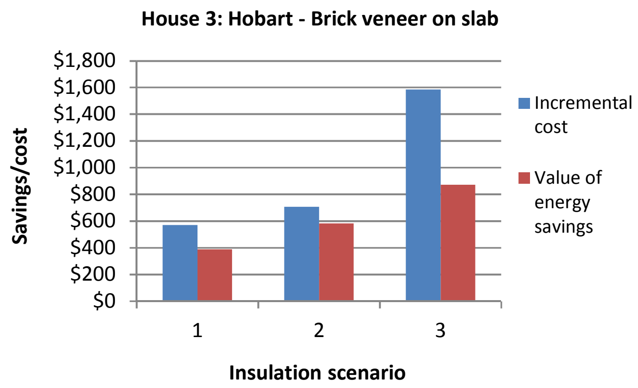


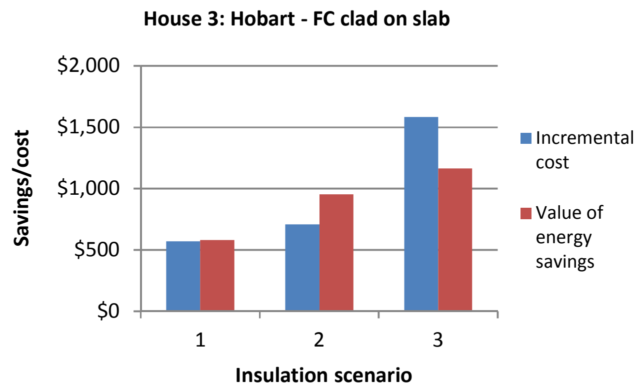


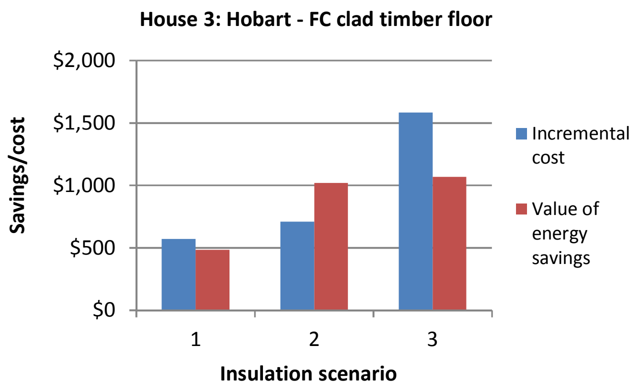


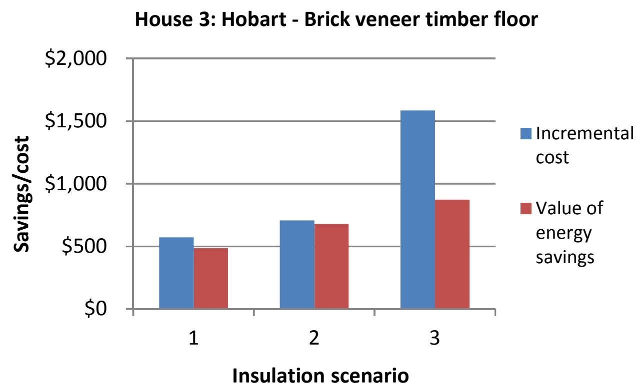












In Hobart, except for the brick veneer on slab designs of House 2 and 3, R6.0 ceiling insulation and up to R3.0 wall insulation is cost effective. Combined with R6.0 ceiling and R2.7 wall insulation, R3.5 floor insulation greatly improves the thermal performance of the House 1 timber floor designs, while remaining cost effective.

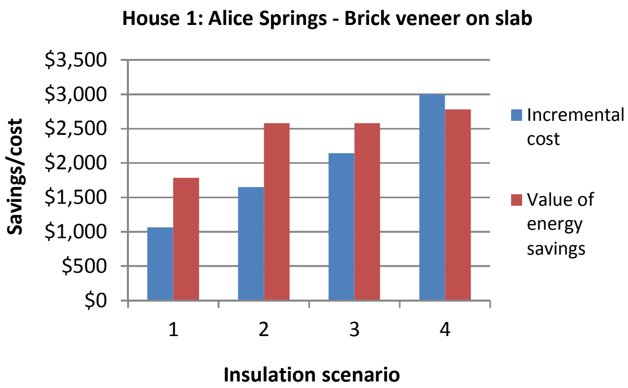
Table 4.16 **Hobart**

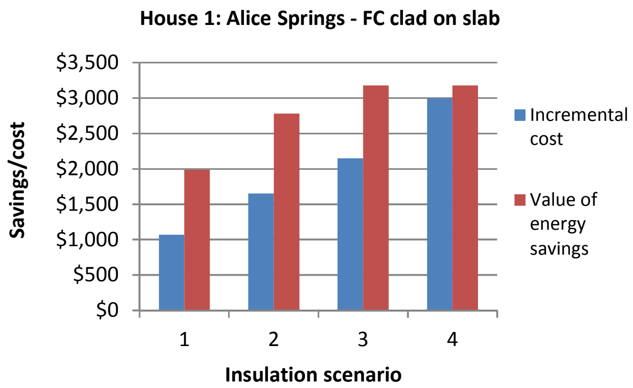
House fabric	House 1	House 2	House 3
Brick veneer on slab	Ceiling R6.0 (+2.0) Wall R3.0 (+0.5)	Ceiling R5.0 (+1.0) Wall R2.5	Ceiling R5.0 (+1.0) Wall R2.5
Fibre-cement clad on slab	Ceiling R6.0 (+2.0) Wall R3.0 (+0.5)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)	Ceiling R6.0 (+2.0) Wall R2.7(+0.2)
Brick veneer timber floor	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2) Floor R3.5 (+1.5)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)
Fibre-cement clad timber floor	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2) Floor R3.5 (+1.5)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)

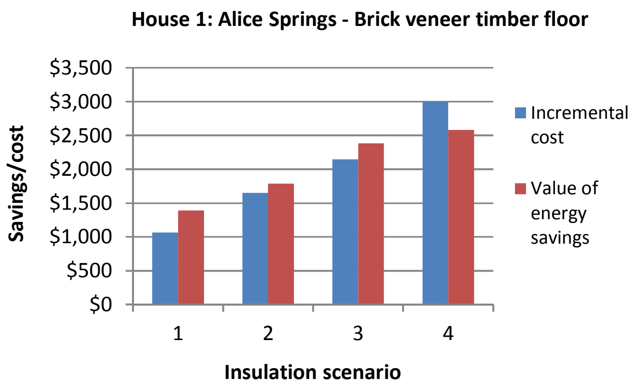
4.9 Alice Springs

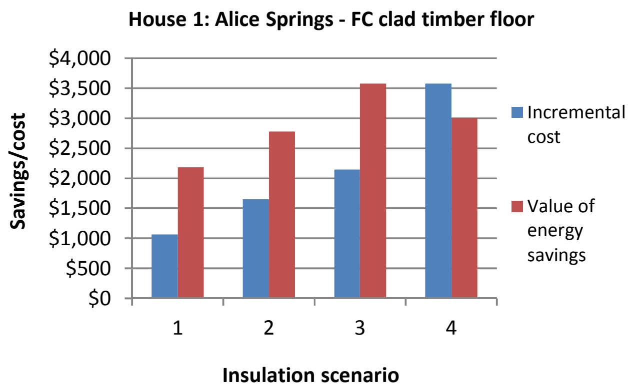
Table 4.17 **Insulation scenarios**

DTS insulation	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Roof – R4.0	Roof – R5.0	Roof – R6.0	Roof – R6.0	Roof – R6.0
Wall – R2.0	Wall – R2.5	Wall – R2.5	Wall – R2.7	Wall – R3.0

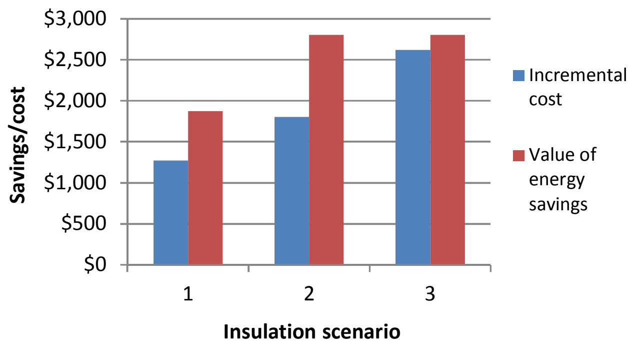




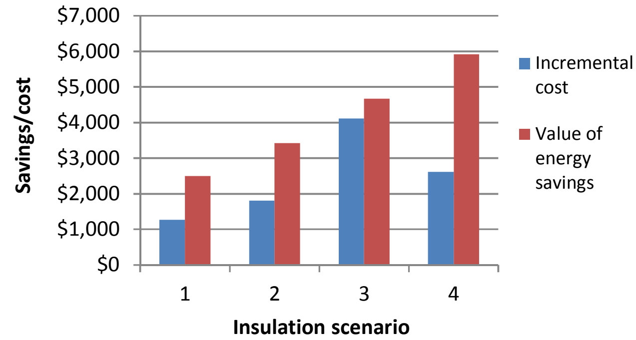




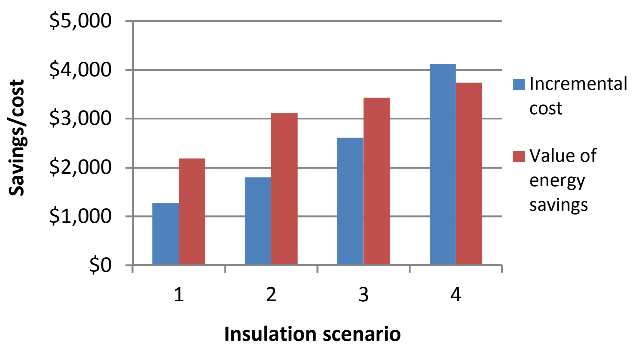
House 2: Alice Springs - Brick veneer on slab



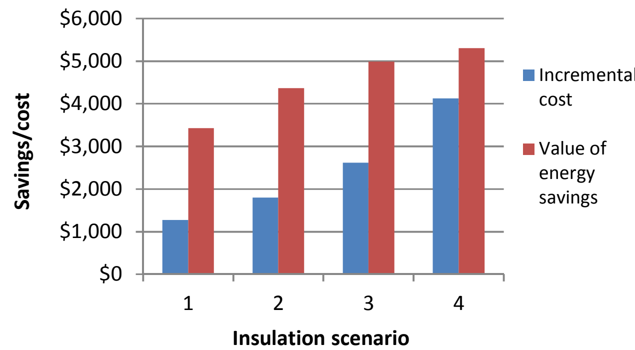
House 2: Alice Springs - FC clad on slab



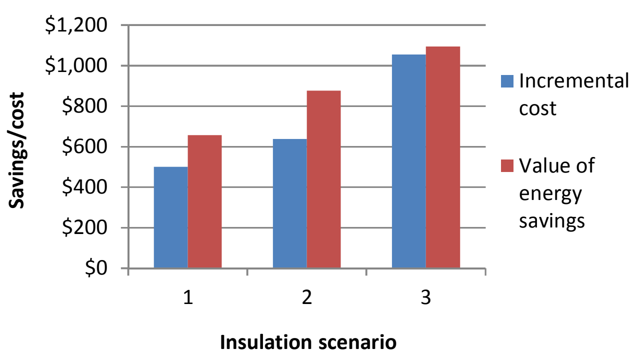
House 2: Alice Springs - Brick veneer timber floor



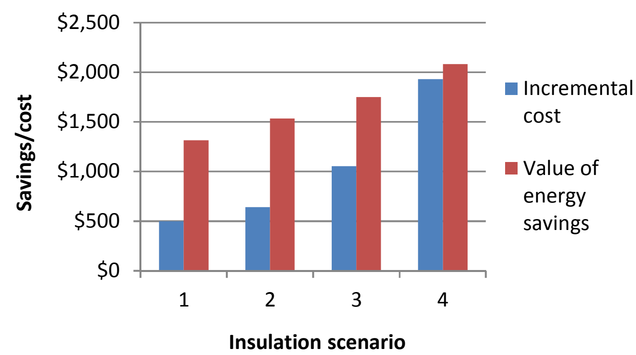
House 2: Alice Springs - FC clad timber floor



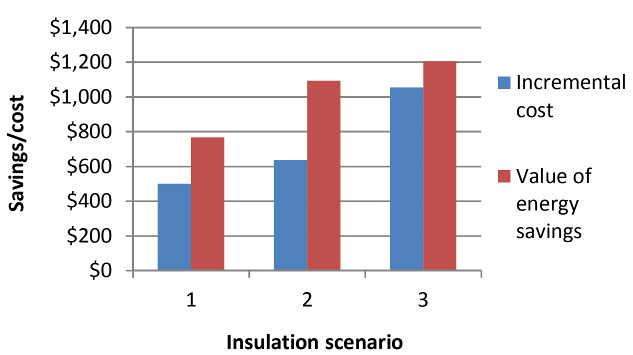
House 3: Alice Springs - Brick veneer on slab



House 3: Alice Springs - FC clad on slab



House 3: Alice Springs - Brick veneer timber floor



House 3: Alice Springs - FC clad timber floor

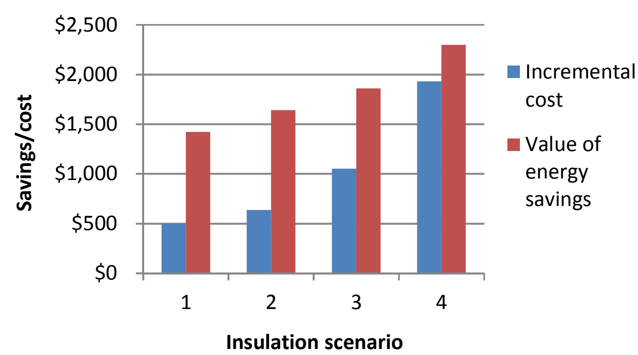


Table 4.18 shows that in all cases higher insulation levels are cost effective in Alice Springs. Generally, higher insulation levels are more cost effective in cooler climates but Alice Springs experiences both hot days, and cool to cold days and nights. For fibre-cement clad houses on timber floors R3.0 wall insulation together with R6.0 ceiling insulation is cost effective. This is even when taking into account the additional cost of deeper walls studs.

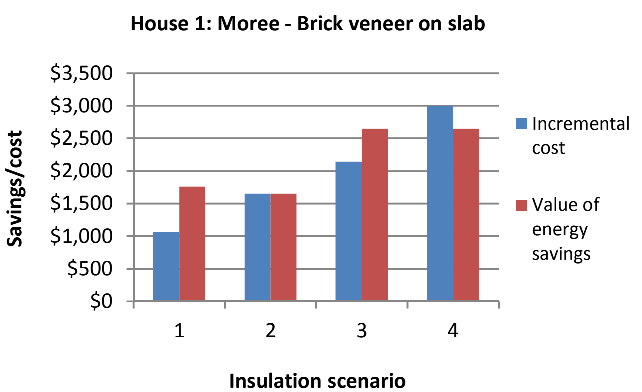
Table 4.18 **Alice Springs**

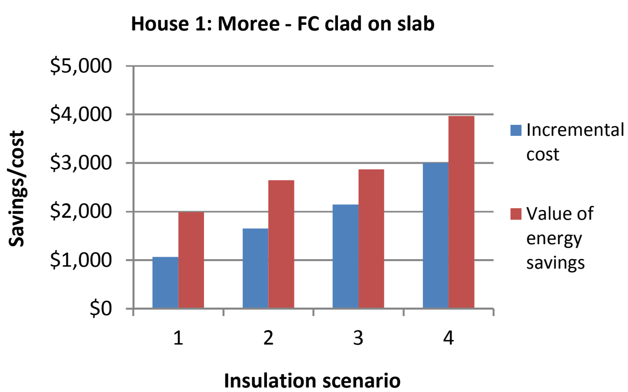
House fabric	House 1	House 2	House 3
Brick veneer on slab	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)	Ceiling R6.0 (+2.0) Wall R2.5 (+0.5)	Ceiling R6.0 (+2.0) Wall R2.5 (+0.5)
Fibre-cement clad on slab	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)
Brick veneer timber floor	Ceiling R5.0 (+1.0) Wall R2.5 (+0.5)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.2)
Fibre-cement clad timber floor	Ceiling R6.0 (+2.0) Wall R3.0 (+1.0)	Ceiling R6.0 (+2.0) Wall R3.0 (+1.0)	Ceiling R6.0 (+2.0) Wall R3.0 (+1.0)

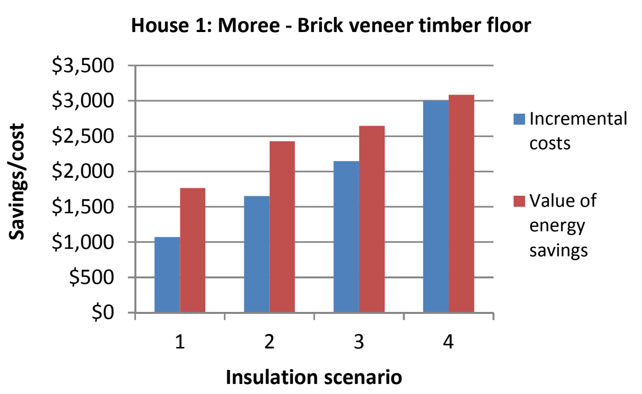
4.10 Moree

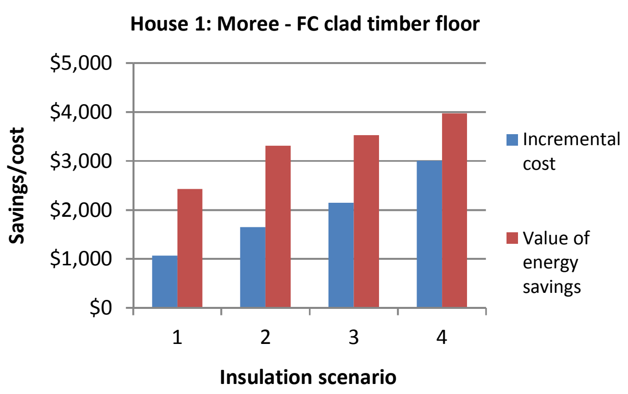
Table 4.19 **Insulation scenarios**

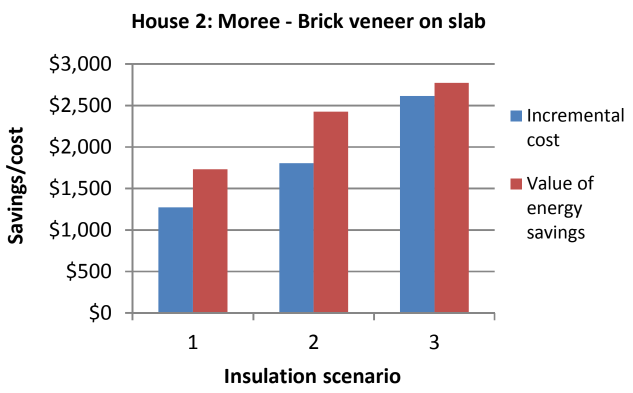
DTS insulation	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Roof – R4.0	Roof – R5.0	Roof – R6.0	Roof – R6.0	Roof – R6.0
Wall – R2.0	Wall – R2.5	Wall – R2.5	Wall – R2.7	Wall – R3.0
Enclosed floor – R1.5	–	–	–	–

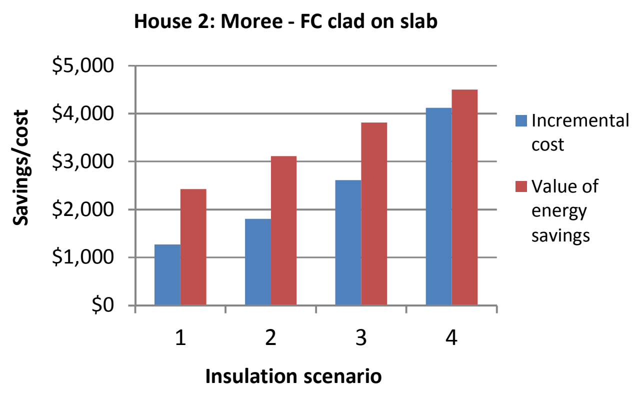


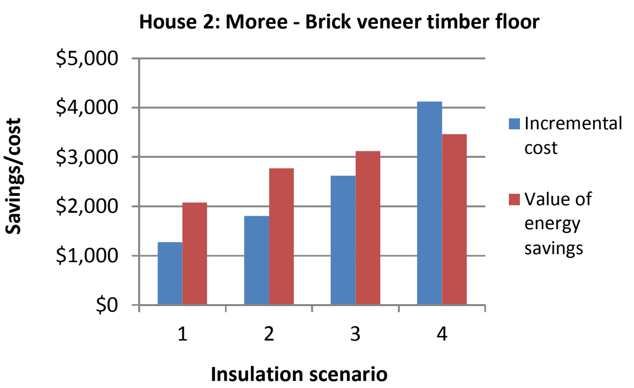


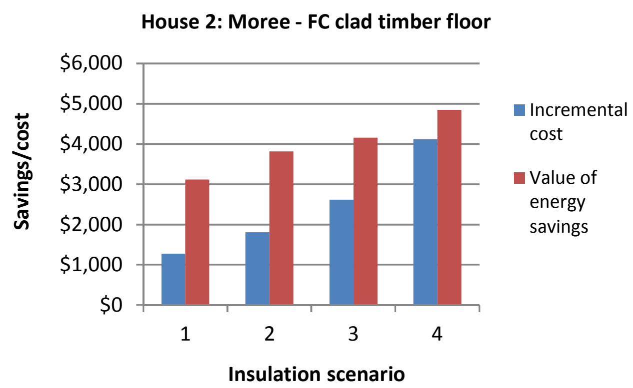


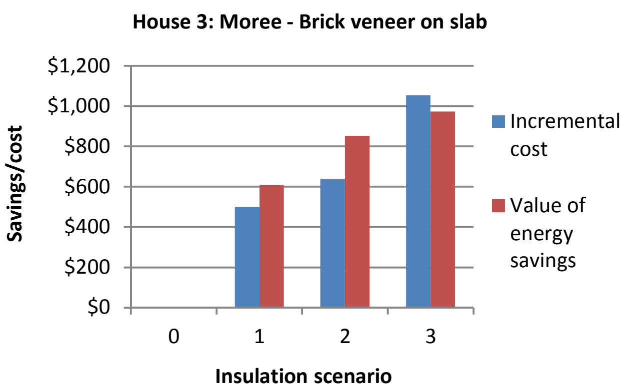


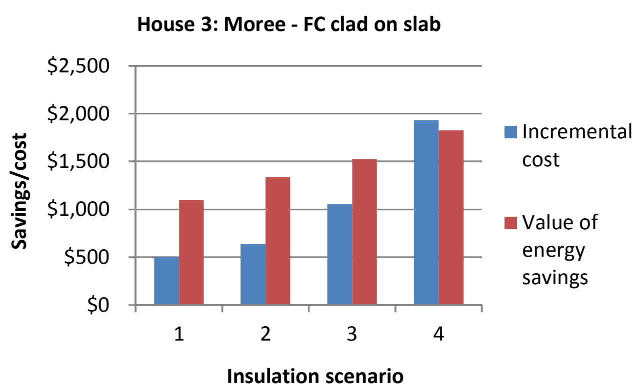

House 2: Moree - Brick veneer on slab
Savings/cost
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
1
2
3
Insulation scenario
Incremental cost
Value of energy savings

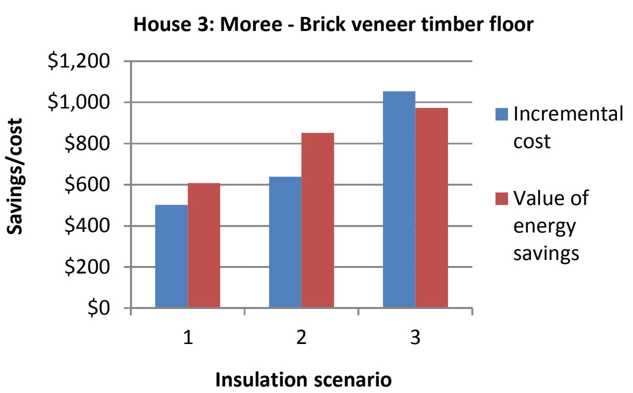

House 2: Moree - FC clad on slab
Savings/cost
$5,000
$4,000
$3,000
$2,000
$1,000
$0
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings

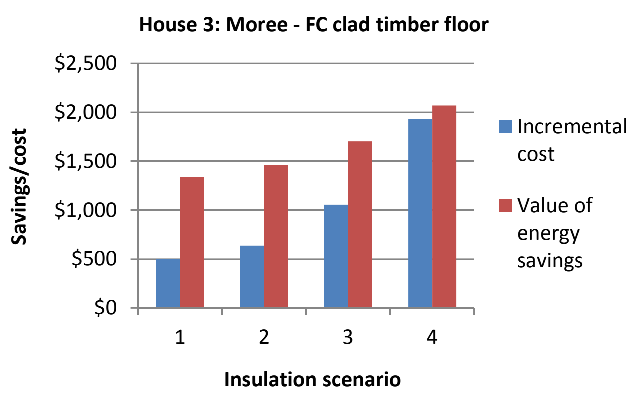

House 2: Moree - Brick veneer timber floor
Savings/cost
$5,000
$4,000
$3,000
$2,000
$1,000
$0
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings


House 2: Moree - FC clad timber floor
Savings/cost
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$0
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings


House 3: Moree - Brick veneer on slab
Savings/cost
$1,200
$1,000
$800
$600
$400
$200
$0
0
1
2
3
Insulation scenario
Incremental cost
Value of energy savings


House 3: Moree - FC clad on slab
Savings/cost
$2,500
$2,000
$1,500
$1,000
$500
$0
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings


House 3: Moree - Brick veneer timber floor
Savings/cost
$1,200
$1,000
$800
$600
$400
$200
$0
1
2
3
Insulation scenario
Incremental cost
Value of energy savings


House 3: Moree - FC clad timber floor
Savings/cost
$2,500
$2,000
$1,500
$1,000
$500
$0
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings

At 6 stars, Moree's heating load is greater than its cooling load which helps make higher insulation levels cost effective. In all cases higher insulation levels are cost effective. R6.0 ceiling insulation is cost effective in all cases, and in 2 cases R3.0 wall insulation is worthwhile economically.

Table 4.20 **Moree**

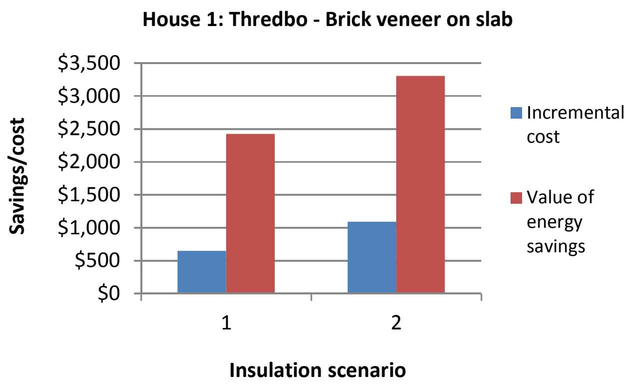
House fabric	House 1	House 2	House 3
Brick veneer on slab	Ceiling R6.0 (+2.0) Wall R2.5 (+0.5)	Ceiling R6.0 (+2.0) Wall R2.5 (+0.5)	Ceiling R6.0 (+2.0) Wall R2.5 (+0.5)
Fibre-cement clad on slab	Ceiling R6.0 (+2.0) Wall R3.0 (+1.0)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.7)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.7)
Brick veneer timber floor	Ceiling R6.0 (+2.0) Wall R2.7 (+0.7)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.7)	Ceiling R6.0 (+2.0) Wall R2.5 (+0.5)
Fibre-cement clad timber floor	Ceiling R6.0 (+2.0) Wall R2.7 (+0.7)	Ceiling R6.0 (+2.0) Wall R3.0 (+1.0)	Ceiling R6.0 (+2.0) Wall R2.7 (+0.7)

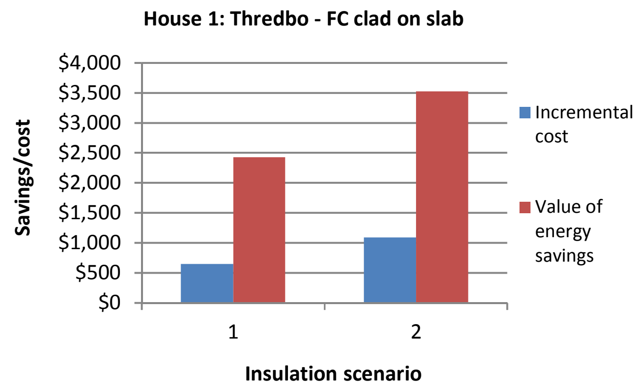
4.11 Thredbo

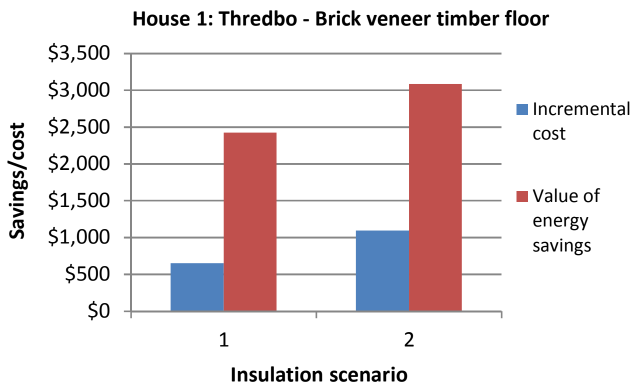
The following graphs show that all scenarios are extremely cost effective for each design of each house. At this stage only two scenarios have been modelled. Scenario 1 is with R8.0 ceiling insulation (R2.0 more than the DTS) and Scenario 2 is with R8.0 ceiling insulation and R4.0 wall insulation (R0.5 more wall insulation than DTS). More ceiling insulation could be added, although there could be issues with compression, compromising its effectiveness. Wall ceiling beyond R4.0 could also be modelled, although a stud deeper than 140 mm would be needed.

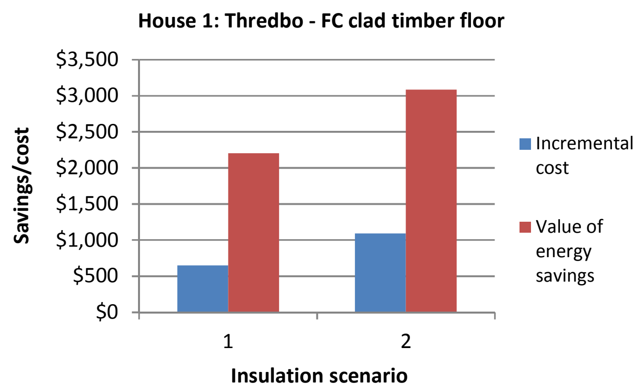
Table 4.21 **Insulation scenarios**

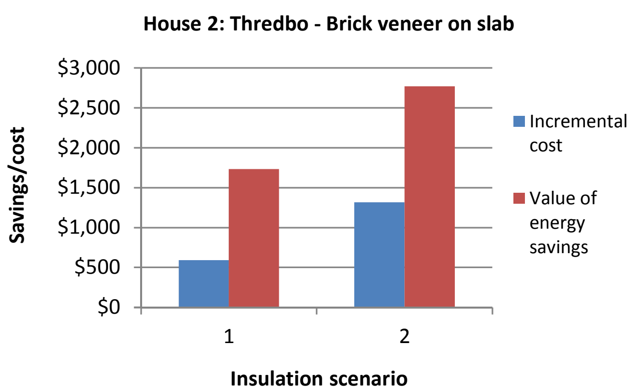
DTS insulation	Scenario 1	Scenario 2
Roof – R6.0	Roof – R8.0	Roof – R8.0
Wall – R3.5	Wall – R3.5	Wall – R4.0
Enclosed floor – R2.5	–	–

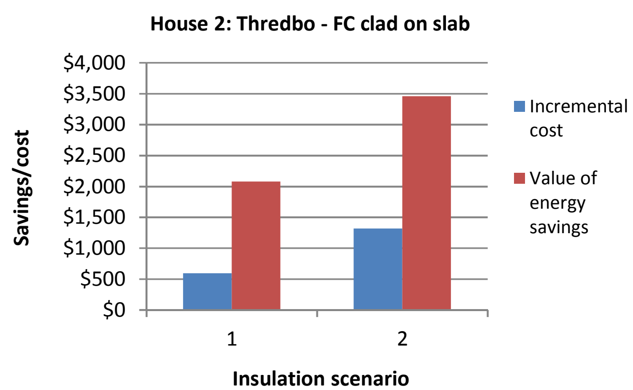

House 1: Thredbo - Brick veneer on slab
Savings/cost
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
1
2
Insulation scenario
Incremental cost
Value of energy savings

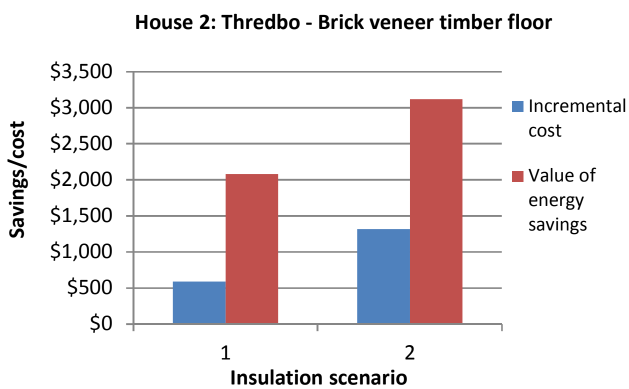

House 1: Thredbo - FC clad on slab
Savings/cost
$4,000
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
1
2
Insulation scenario
Incremental cost
Value of energy savings

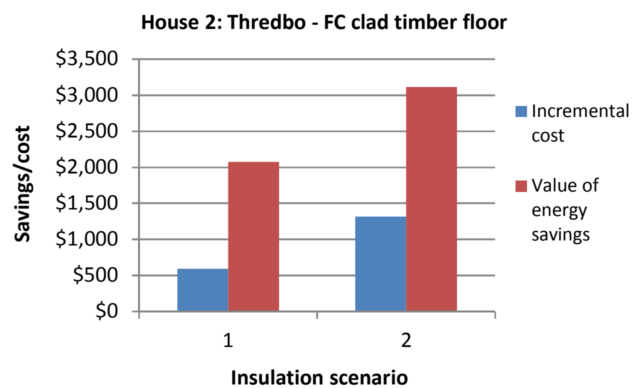

House 1: Thredbo - Brick veneer timber floor
Savings/cost
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
1
2
Insulation scenario
Incremental cost
Value of energy savings

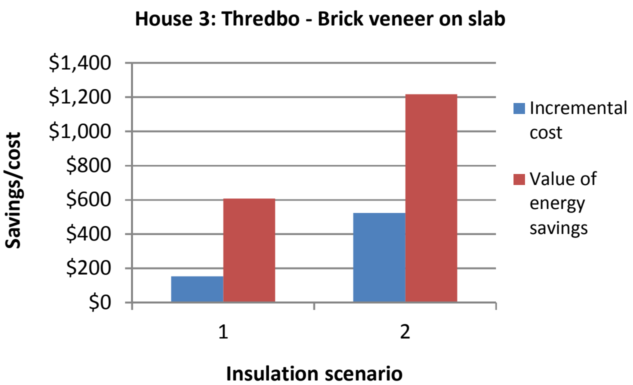

House 1: Thredbo - FC clad timber floor
Savings/cost
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
1
2
Insulation scenario
Incremental cost
Value of energy savings

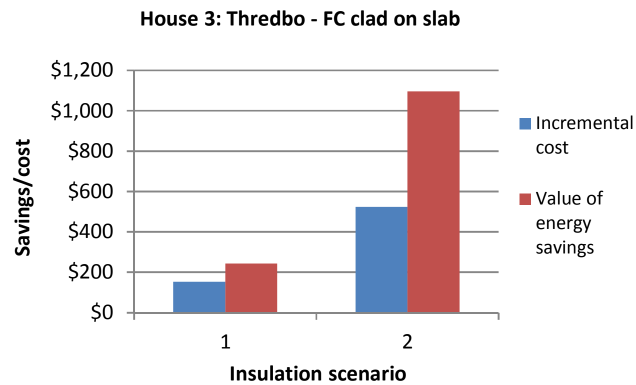

House 2: Thredbo - Brick veneer on slab
Savings/cost
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
1
2
Insulation scenario
Incremental cost
Value of energy savings

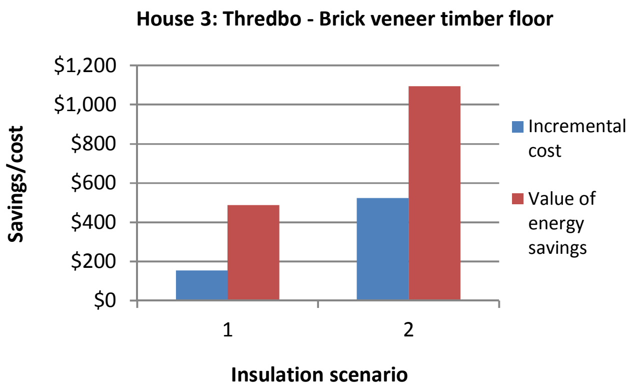

House 2: Thredbo - FC clad on slab
Savings/cost
$4,000
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
1
2
Insulation scenario
Incremental cost
Value of energy savings

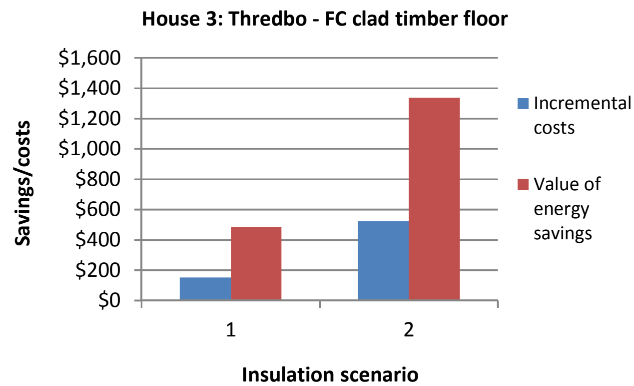

House 2: Thredbo - Brick veneer timber floor
Savings/cost
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
1
2
Insulation scenario
Incremental cost
Value of energy savings


House 2: Thredbo - FC clad timber floor
Savings/cost
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
1
2
Insulation scenario
Incremental cost
Value of energy savings





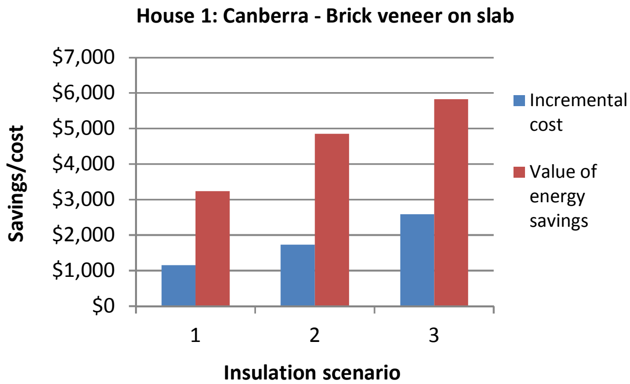


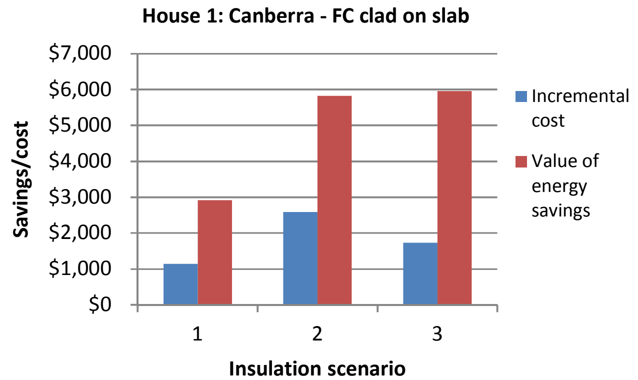


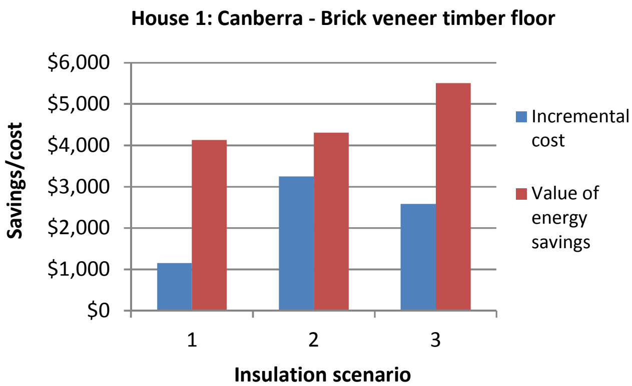
4.12 Canberra & Hobart – gas (House 1)

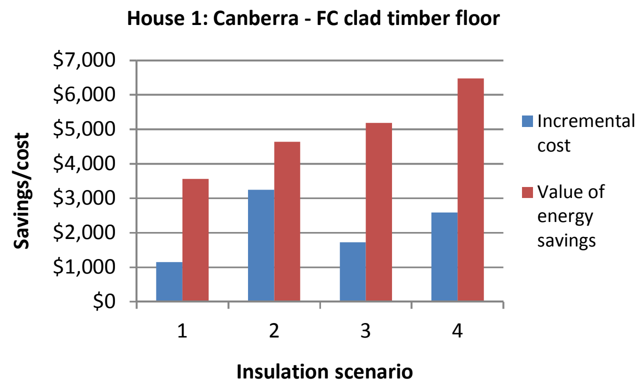
We modelled House 1 in Canberra and Hobart (climates where heating demand dominates the total space-conditioning demand) with gas heating instead of a heat pump.

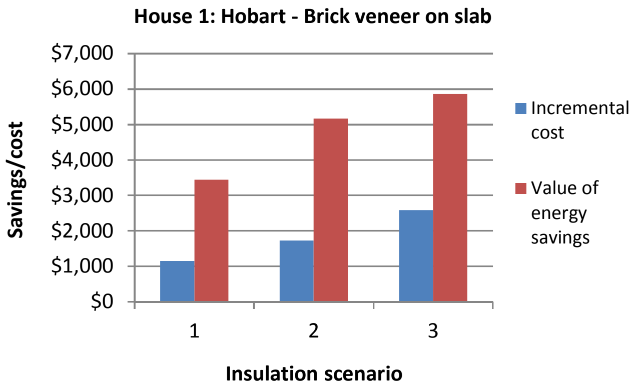
It can be seen that with gas heating the insulation scenarios are cost effective in all cases (much more so than when heating demand is met by heat pump). The primary reason for this is that the efficiency of gas heating is much lower than that of a heat pump meaning that, for a given output, the energy input is much greater for gas heating.

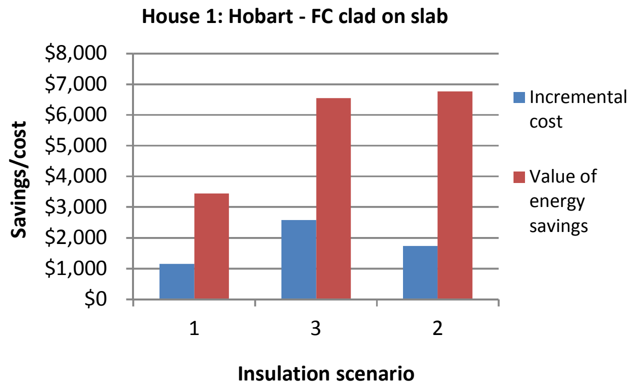

House 1: Canberra - Brick veneer on slab
Savings/cost
$7,000
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$0
1
2
3
Insulation scenario
Incremental cost
Value of energy savings

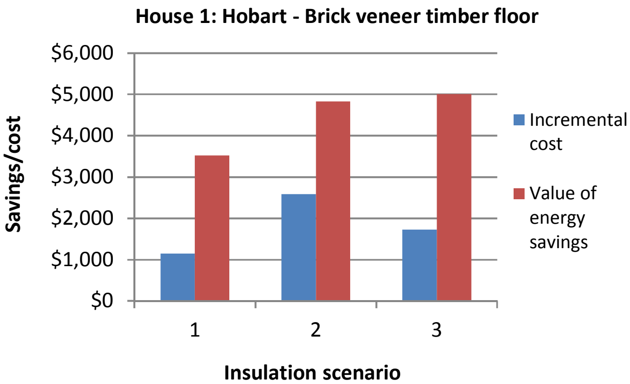

House 1: Canberra - FC clad on slab
Savings/cost
$7,000
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$0
1
2
3
Insulation scenario
Incremental cost
Value of energy savings

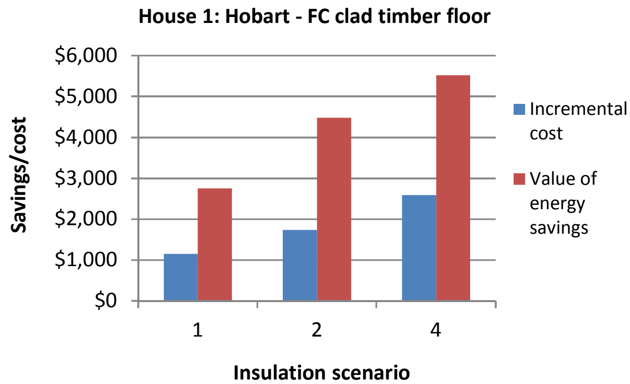

House 1: Canberra - Brick veneer timber floor
Savings/cost
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$0
1
2
3
Insulation scenario
Incremental cost
Value of energy savings


House 1: Canberra - FC clad timber floor
Savings/cost
$7,000
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$0
1
2
3
4
Insulation scenario
Incremental cost
Value of energy savings


House 1: Hobart - Brick veneer on slab
Savings/cost
$7,000
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$0
1
2
3
Insulation scenario
Incremental cost
Value of energy savings

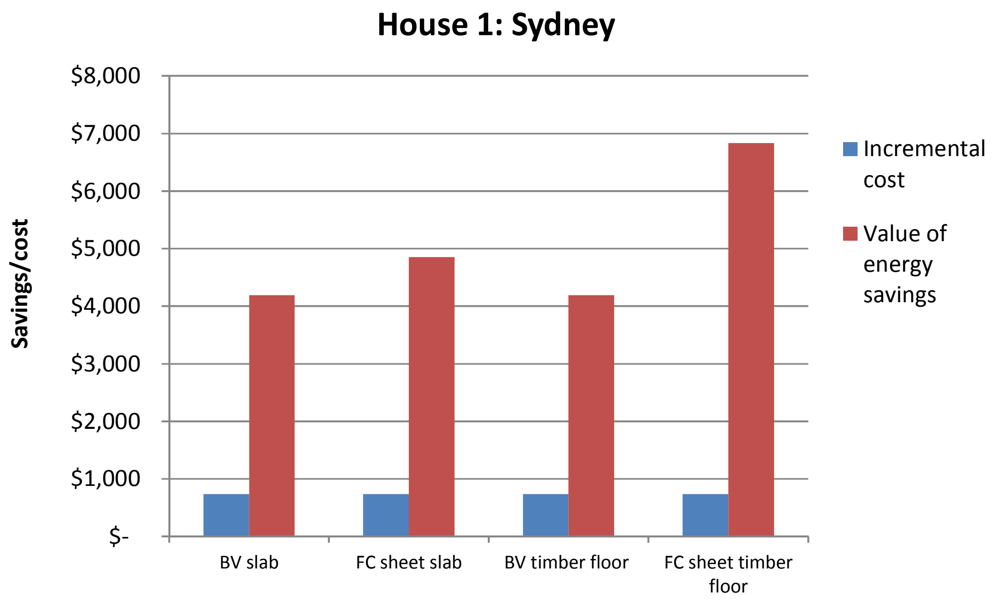

House 1: Hobart - FC clad on slab
Savings/cost
$8,000
$7,000
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$0
1
3
2
Insulation scenario
Incremental cost
Value of energy savings

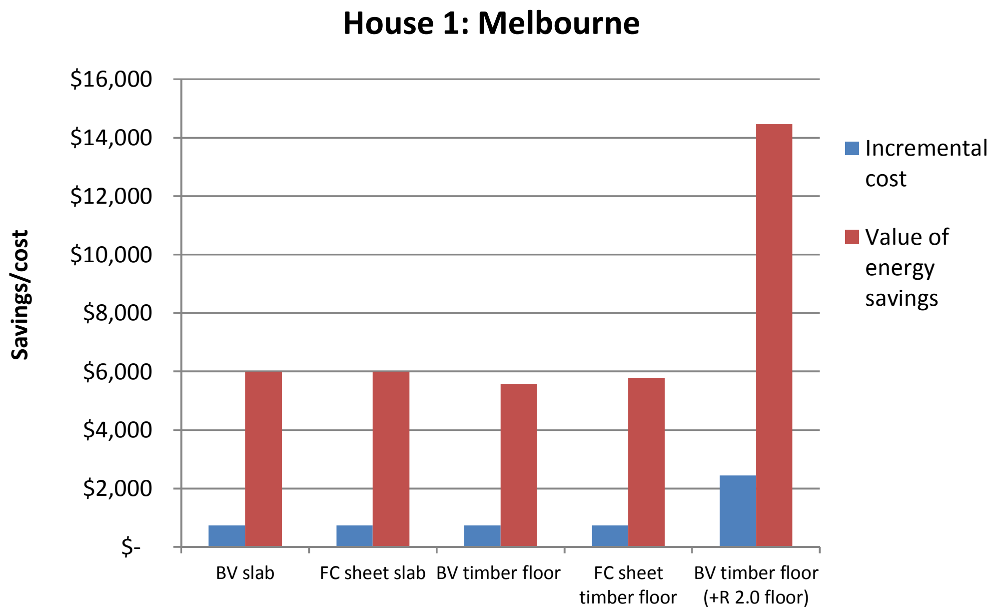

House 1: Hobart - Brick veneer timber floor
Savings/cost
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$0
1
2
3
Insulation scenario
Incremental cost
Value of energy savings

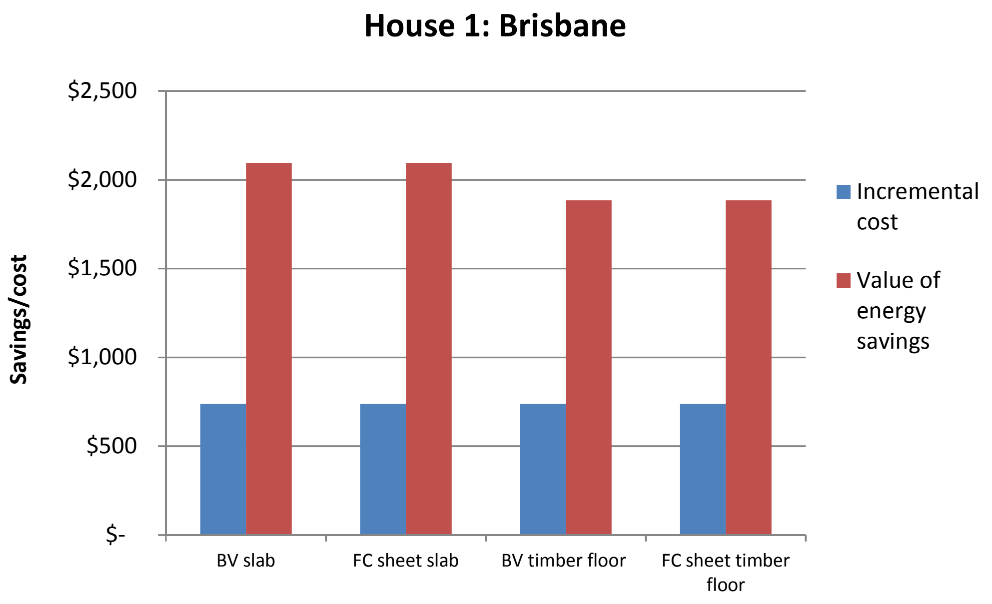

House 1: Hobart - FC clad timber floor
Savings/cost
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$0
1
2
4
Insulation scenario
Incremental cost
Value of energy savings

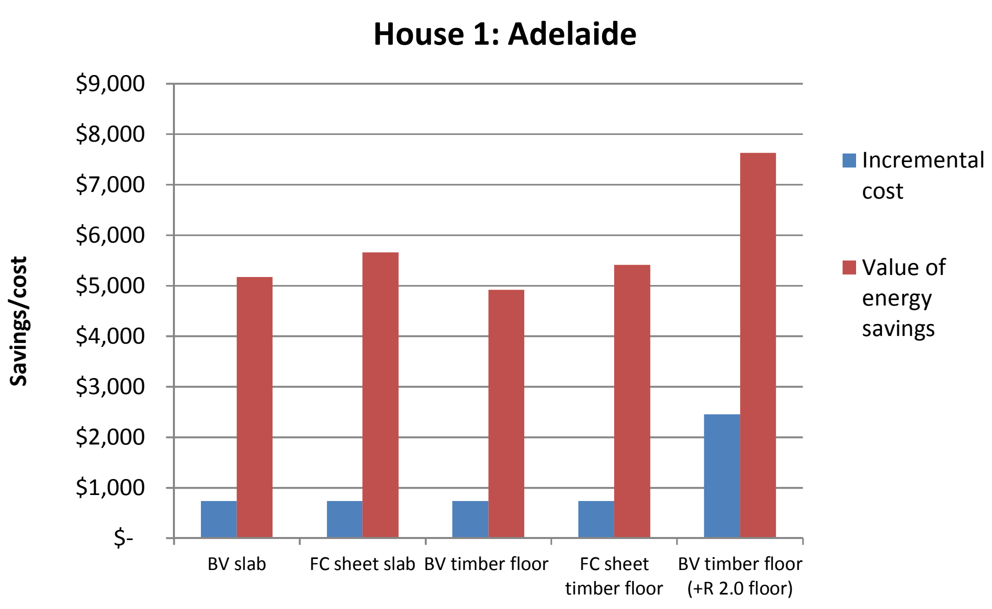
4.13 Retrofit

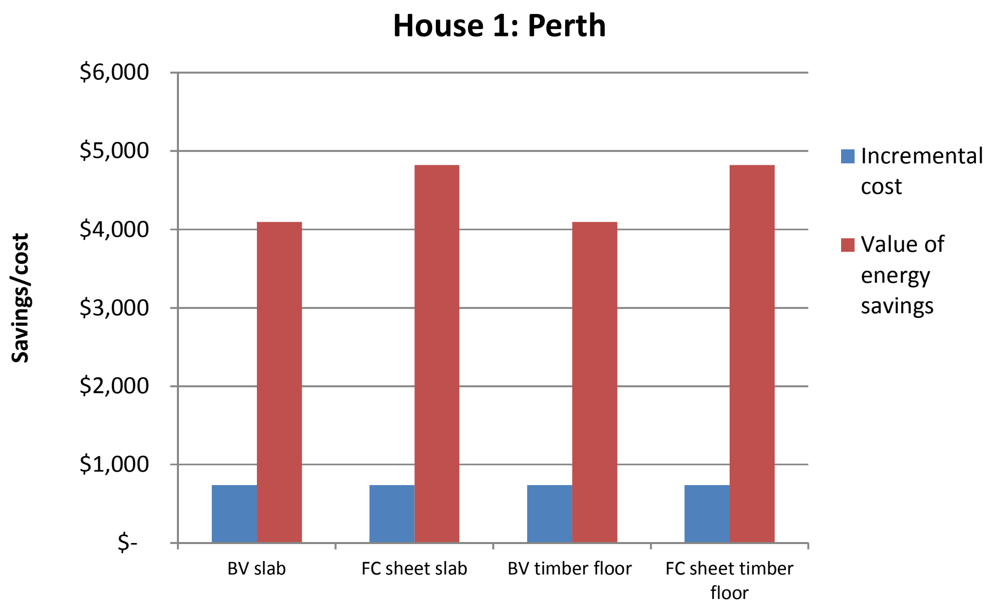
The following graphs show the costs and benefits of installing additional R2.0 ceiling insulation to existing single storey homes (House 1). It was assumed that they already had R2.0 ceiling insulation but no wall and floor insulation. It can be seen that retrofitting additional insulation to houses with relatively low levels of insulation is extremely cost effective. This is particularly the case in the cooler climates where the cost of the additional insulation is completely overwhelmed by the savings it provides over a 30-year period.

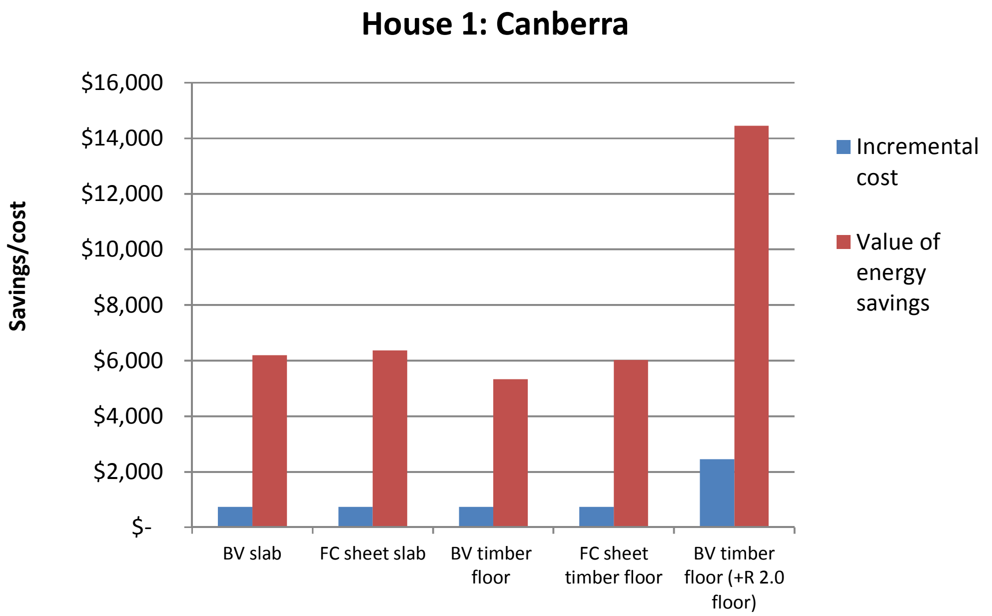


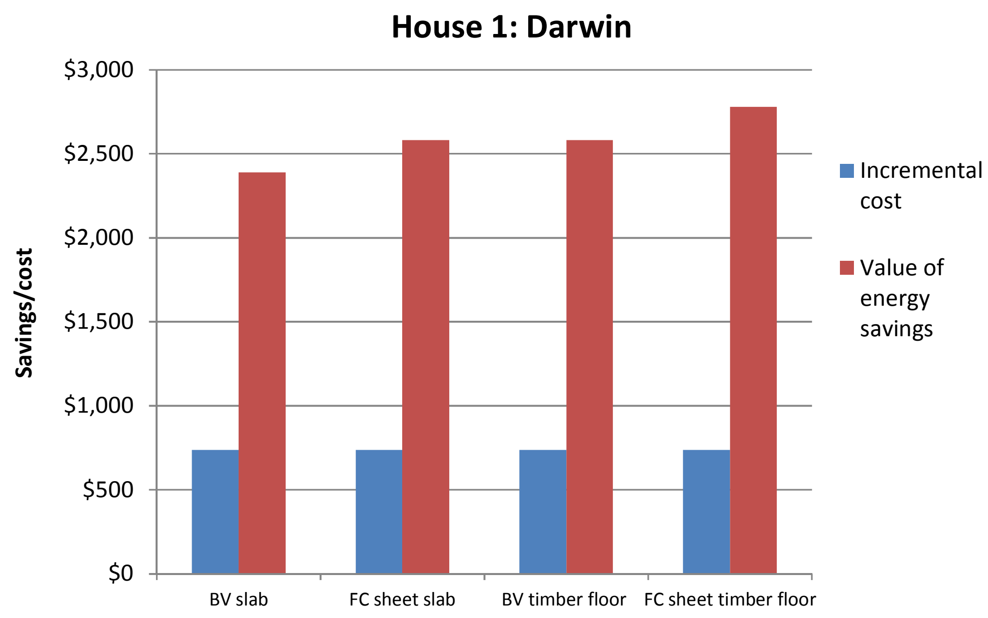


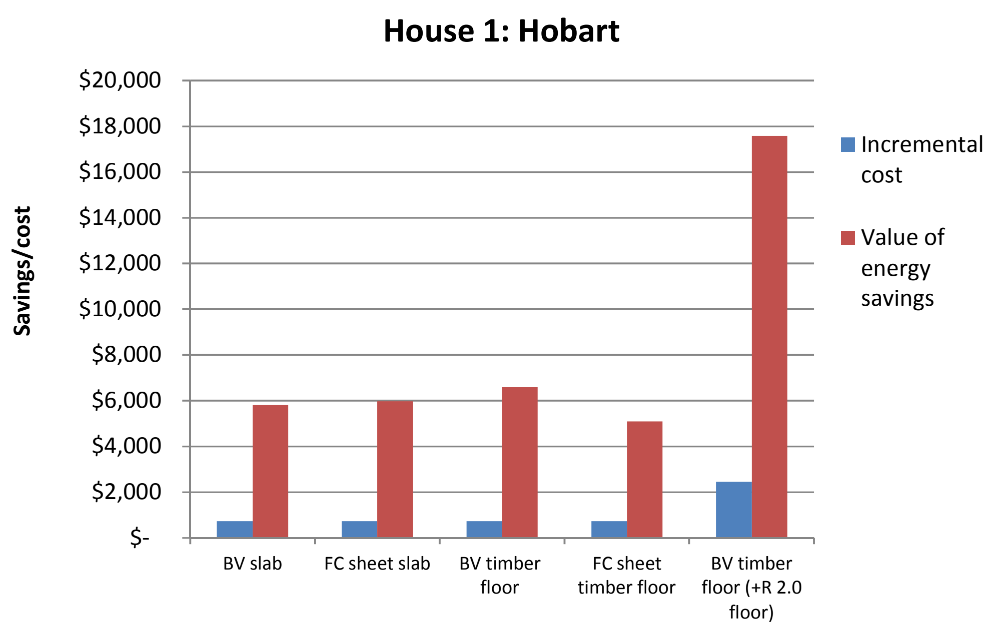

House 1: Brisbane
Savings/cost
$2,500
$2,000
$1,500
$1,000
$500
$-
BV slab
FC sheet slab
BV timber floor
FC sheet timber floor
Incremental cost
Value of energy savings

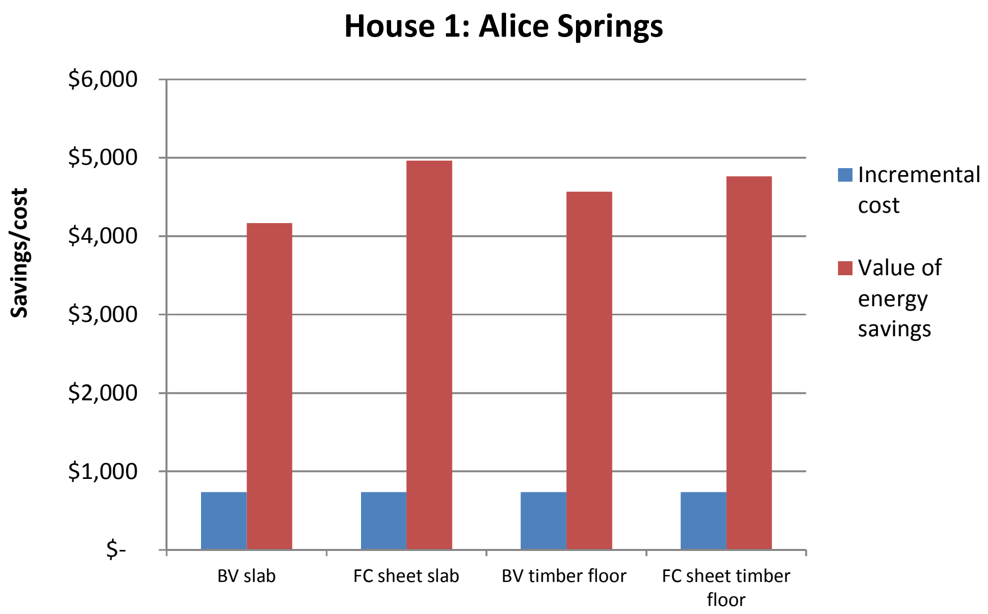

House 1: Adelaide
Savings/cost
$9,000
$8,000
$7,000
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$-
BV slab
FC sheet slab
BV timber floor
FC sheet timber floor
BV timber floor (+R 2.0 floor)
Incremental cost
Value of energy savings

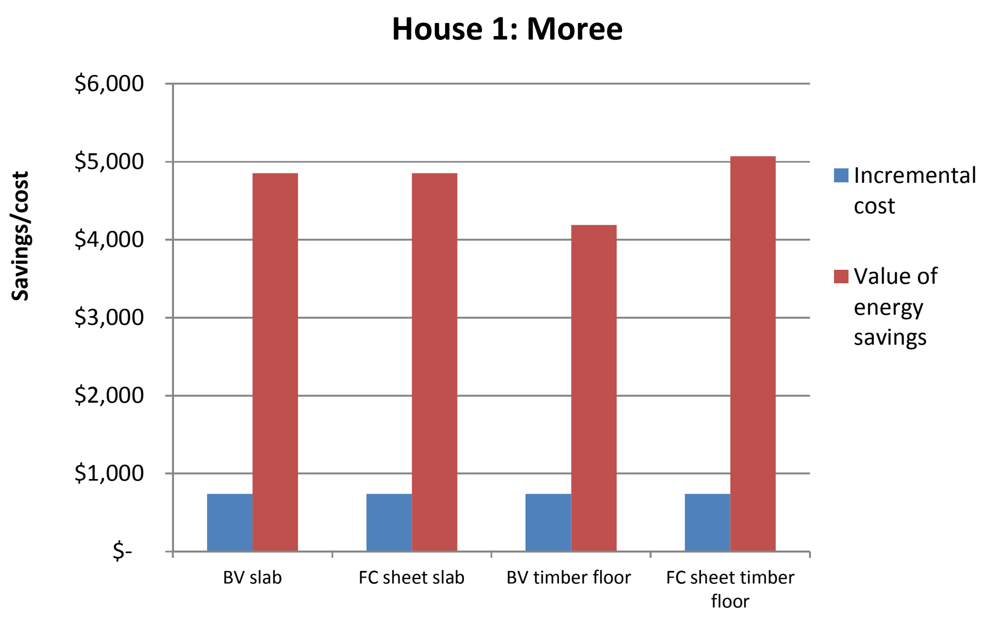

House 1: Perth
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$-
Savings/cost
BV slab
FC sheet slab
BV timber floor
FC sheet timber floor
Incremental cost
Value of energy savings

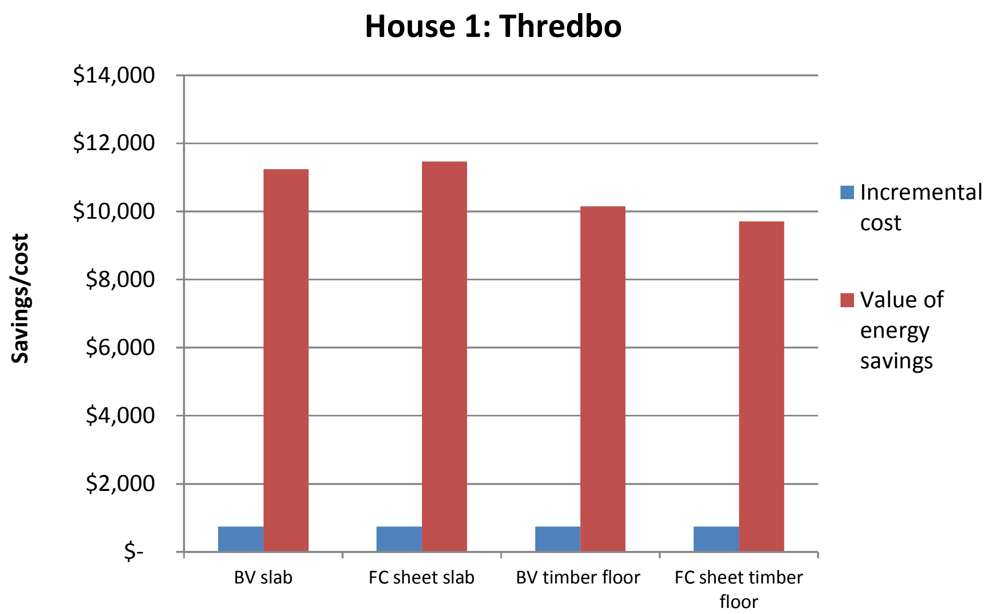

House 1: Canberra
$16,000
$14,000
$12,000
$10,000
$8,000
$6,000
$4,000
$2,000
$-
Savings/cost
BV slab
FC sheet slab
BV timber floor
FC sheet timber floor
BV timber floor (+R 2.0 floor)
Incremental cost
Value of energy savings


House 1: Darwin
Savings/cost
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
BV slab
FC sheet slab
BV timber floor
FC sheet timber floor
Incremental cost
Value of energy savings


House 1: Hobart
Savings/cost
$20,000
$18,000
$16,000
$14,000
$12,000
$10,000
$8,000
$6,000
$4,000
$2,000
$-
BV slab
FC sheet slab
BV timber floor
FC sheet timber floor
BV timber floor (+R 2.0 floor)
Incremental cost
Value of energy savings


House 1: Alice Springs
Savings/cost
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$-
BV slab
FC sheet slab
BV timber floor
FC sheet timber floor
Incremental cost
Value of energy savings


House 1: Moree
Savings/cost
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$-
BV slab
FC sheet slab
BV timber floor
FC sheet timber floor
Incremental cost
Value of energy savings


House 1: Thredbo
Savings/cost
$14,000
$12,000
$10,000
$8,000
$6,000
$4,000
$2,000
$-
BV slab
FC sheet slab
BV timber floor
FC sheet timber floor
Incremental cost
Value of energy savings

5. Results – New Zealand

The following graphs show the results for New Zealand. Only House 1 was modelled.

It can be seen from the graphs below that higher insulation levels are cost effective in Auckland, Wellington and Christchurch for all construction types. The high level of cost effectiveness is in part due to the relatively low minimum levels of insulation required for climate zones, which are cool/cold to mild.

As previously mentioned, the analysis was limited to the three cities only, in climate zones where there is likely to be significant variation in heating demand. Modelling across a range of climates in each climate zone is likely to yield a variation in the cost effectiveness of a given insulation scenario.

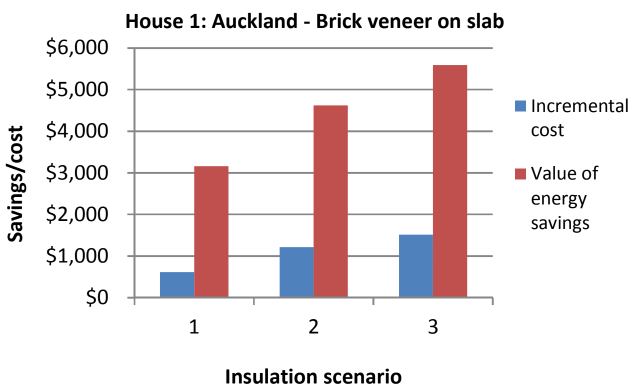
Table 5.1 **Insulation scenarios (Auckland and Wellington)**

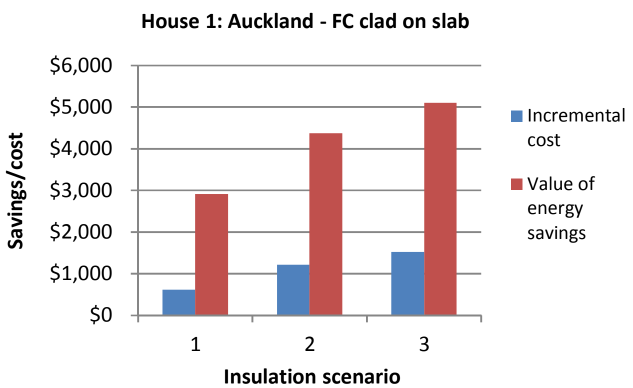
DTS insulation levels	Scenario 1	Scenario 2	Scenario 3
Roof – R3.2.0	Roof – R4.1	Roof – R5.2	Roof – R6.3
Wall – R2.6	Wall – R3.2	Wall – R3.2	Wall – R3.2

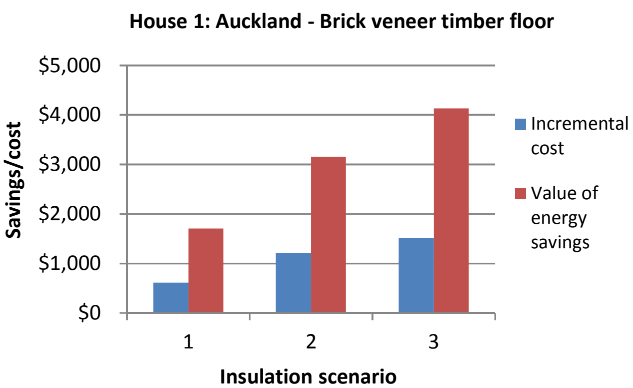
Table 5.2 **Insulation scenarios (Christchurch)**

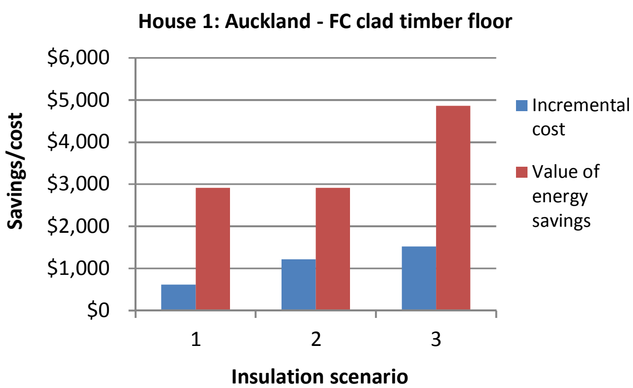
DTS insulation levels	Scenario 1	Scenario 2
Roof – R3.8	Roof – R5.2	Roof – R6.3
Wall – R2.8	Wall – R3.2	Wall – R3.2

5.1 Auckland

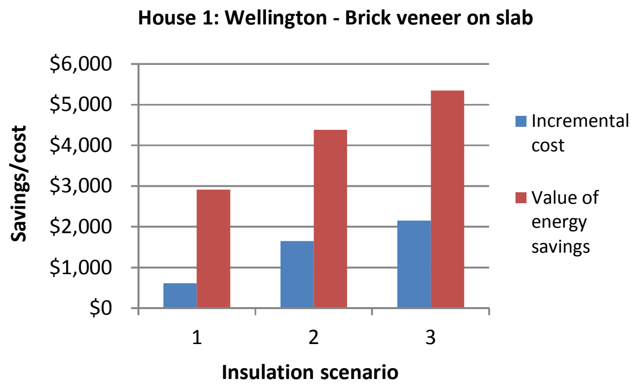


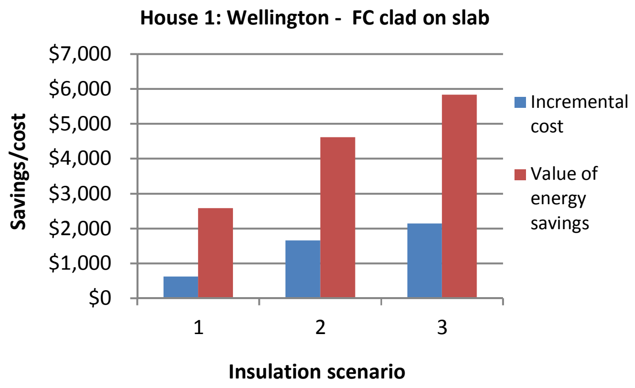


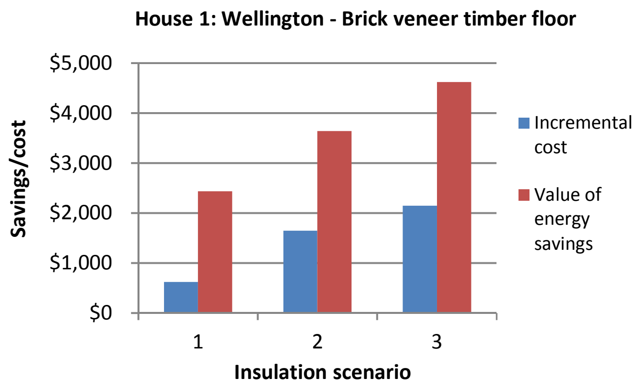


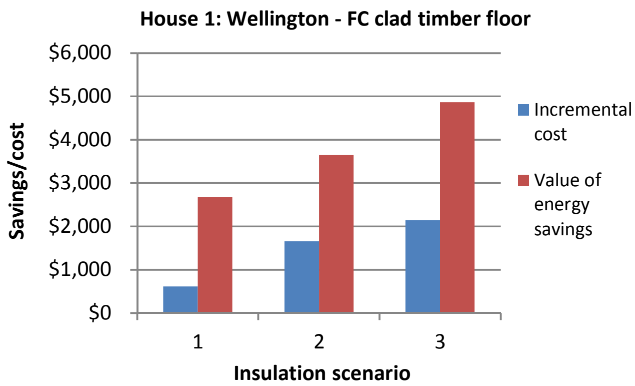


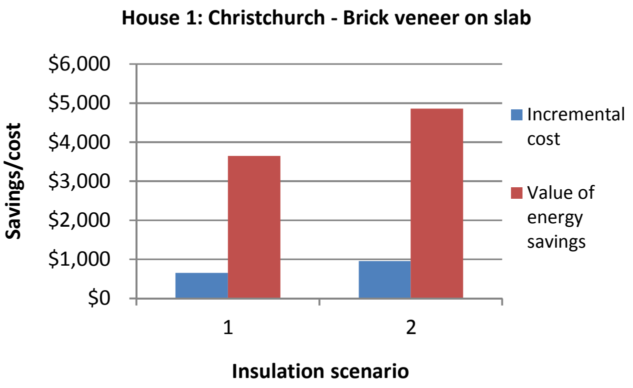
5.2 Wellington

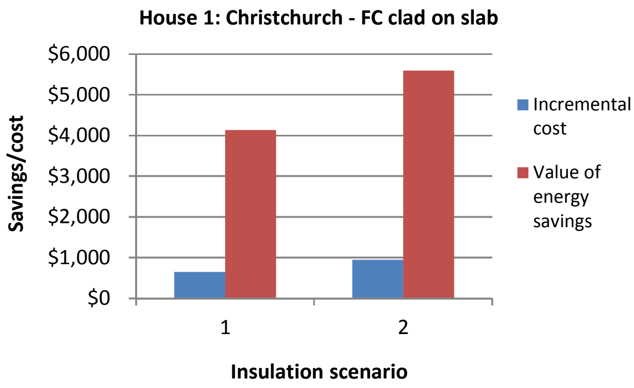


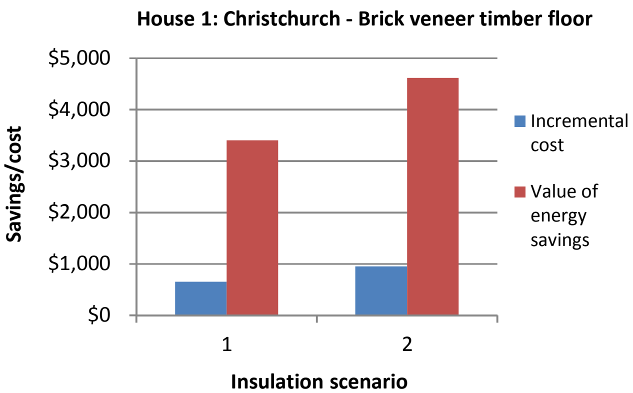


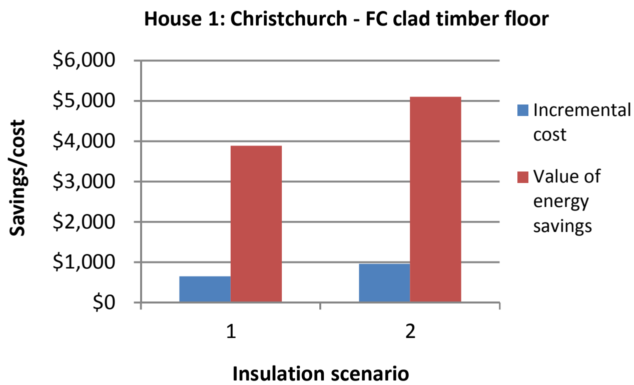








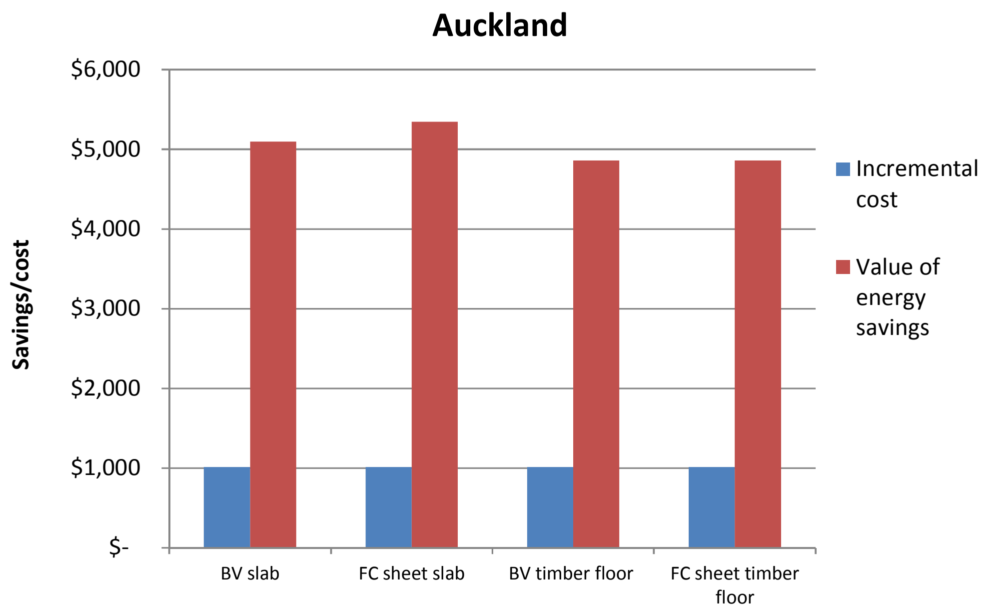


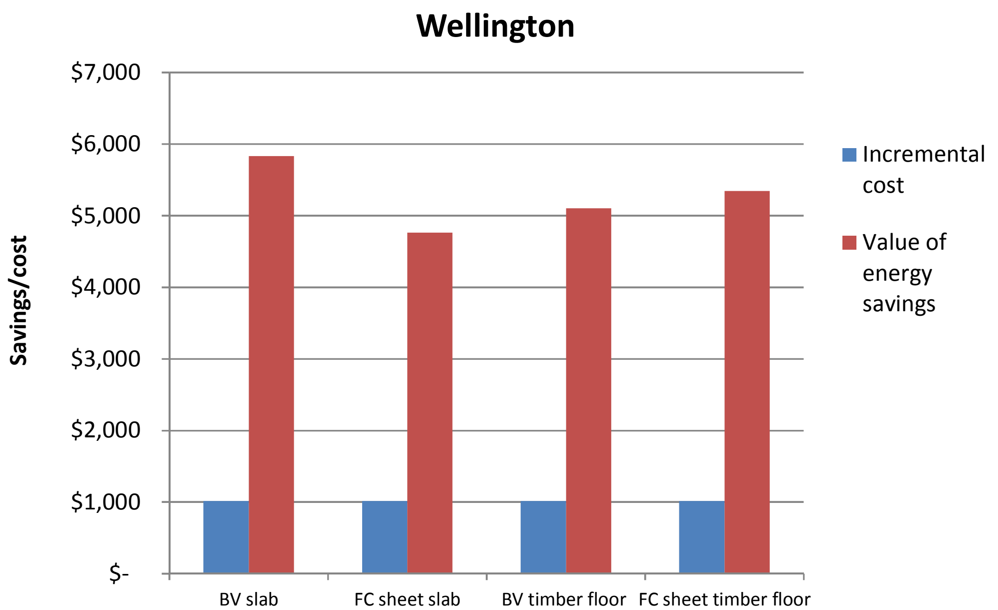


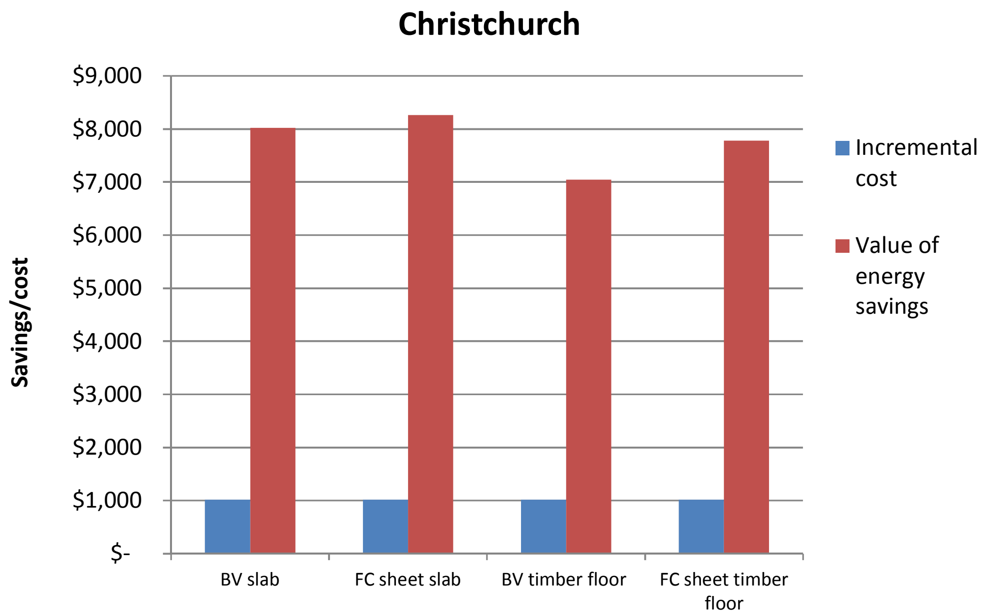
5.3 Christchurch

5.4 Retrofit

The following graphs show clearly that it is cost-effective to retrofit ceiling insulation (R2.0) to existing homes in each of the New Zealand cities modelled.


Auckland
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$-
Savings/cost
BV slab
FC sheet slab
BV timber floor
FC sheet timber floor
Incremental cost
Value of energy savings


Wellington
$7,000
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$-
Savings/cost
BV slab
FC sheet slab
BV timber floor
FC sheet timber floor
Incremental cost
Value of energy savings


Christchurch
Savings/cost
$9,000
$8,000
$7,000
$6,000
$5,000
$4,000
$3,000
$2,000
$1,000
$-
BV slab
FC sheet slab
BV timber floor
FC sheet timber floor
Incremental cost
Value of energy savings

6. Conclusions

Overall, this study has found that in almost all the Australian climate zones examined, insulation levels higher than the minimum required for residential buildings are cost effective over a 30-year period. There are some variations in the degree of cost-effective savings by climate zone and by building type. However, generally ceiling insulation of R6.0 and wall insulation of between R2.5 and R2.7 is cost effective. That represents on average around a 50% increase in the R-value of ceilings and up to a 35% increase in the R-value of walls. In some climate zones where there is a significant heating load, the installation of additional floor insulation (to R3.5 in total) proves to be very cost effective when combined with increases in wall and ceiling insulation.

Retrofitting insulation to existing homes is very cost effective. It was assumed that additional R2.0 ceiling insulation was added to dwellings which already had R2.0 ceiling insulation (taking total ceiling insulation to R4.0) but no floor or wall insulation. (This is typical of many homes built to prior to the introduction of energy efficiency regulations). The simple payback for the additional insulation is less than 8 years in almost every case. Given that almost 30% of the existing Australian housing stock is either uninsulated or under-insulated there is obviously enormous potential to save a lot of energy very cost effectively.

In New Zealand, higher insulation levels are even more cost effective than they are in Australia. In Auckland, Wellington and Christchurch installing roof insulation up to R6.3 and wall insulation up to R3.2 in new dwellings is worthwhile economically. Retrofitting insulation to existing homes is also very cost effective. As for Australia, it was assumed that an additional R2.0 ceiling insulation was added to dwellings which already had R2.0 ceiling insulation. Simple payback for retrofitting ceiling insulation is less than 8 years for the three NZ climate zones.

7. References

ABS (Australian Bureau of Statistics) 2011, *Environmental issues: energy use and conservation*, Report No. 4602.0.55.001, March 2011.

New Zealand Department of Building and Housing 2015, *Your guide to smarter insulation,* http://www.building.govt.nz/UserFiles/File/Publications/Building/consumer/your-guide-to-smarter-insulation.pdf.

BRANZ 2005, New Zealand 2005 house condition survey, Study Report No. 142 (2005) http://www.branz.co.nz/cms_show_download.php?id=1b3afe317e851ed8de7c399dfe6c95f4d337d1df.

Stoecklein, A, Pollard, A, Camilleri, M, Tries, J and Isaacs, N 2001, *The household energy end-use project: measurement approach and sample application of the New Zealand household energy model*, presented at the CIB World Building Congress, Wellington, New Zealand, April 2001, http://www.branz.co.nz/cms_show_download.php?id=3c3780f1c49d39e17eee41ffe4e05ed8b17c5a7d.

Contact

Philip McLeod

0428 269 570

pmcleod@pittsh.com.au

transport | community | industrial & mining | carbon & energy

pitt&sherry

Brisbane
Level 2
276 Edward Street
Brisbane QLD 4000
T: (07) 3221 0080
F: (07) 3221 0083

Canberra
LGF, Ethos House
28-36 Ainslie Place
Canberra City ACT 2601
PO Box 122
Civic Square
Canberra ACT 2608
T: (02) 6295 2100

Devonport
Level 1
35 Oldaker Street
PO Box 836
Devonport TAS 7310
T: (03) 6424 1641
F: (03) 6424 9215

Hobart
199 Macquarie Street
GPO Box 94
Hobart TAS 7001
T: (03) 6210 1400
F: (03) 6223 1299

Launceston
Level 4
113 Cimitiere Street
PO Box 1409
Launceston TAS 7250
T: (03) 6323 1900
F: (03) 6334 4651

Melbourne
Level 1, HWT Tower
40 City Road
Southbank VIC 3006
PO Box 259
South Melbourne VIC 3205
T: (03) 9682 5290
F: (03) 9682 5292

Sydney
Level 1
56 Clarence Street
Sydney NSW 2000
T: (02) 8216 4700
F: (02) 8216 4747

E: info@pittsh.com.au
W: www.pittsh.com.au

incorporated as
Pitt & Sherry (Operations) Pty Ltd
ABN 67 140 184 309

CONSULT AUSTRALIA
Member Firm

sustainable*thinking*®