THE RIGHT INSULATION MATTERS

The Value of Insulating Existing Homes

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Executive Summary

This study is intended as an update of an earlier study prepared for the Insulation Council of Australia and New Zealand (ICANZ) by Energy Efficient Strategies P/L in 2011 – 2013 entitled:

The Value of Insulation Based Residential Energy Savings Measures In Australia

This report provides updated data sets at both household and jurisdictional level regarding:

- the potential scope for insulation-based upgrades.
- the potential costs of such upgrades; and
- the potential benefits of such upgrades (in their various forms).

The thermal insulation of ceilings, walls and in some cases, floors has long been recognised as some of the most significant and cost-effective means for improving the thermal performance of residential buildings. Such insulation has been demonstrated to:

- Improve thermal comfort for the occupants
- Reduce space conditioning energy consumption
- Reduce heating and cooling fuel costs to householders
- Reduce greenhouse gas emissions associated with space conditioning
- Mitigate against the impact of peak loads on power supply networks

ABS data analysed in this study indicates that there still persists in the Australian housing stock a significant number of dwellings with uninsulated or under insulated ceilings, walls and floors. This suggests a significant market failure of householders and governments to capitalise on the positive financial, environmental and health benefits associated with these insulation based retrofit options.

This study examines the opportunities, costs and benefits of the retrofitting/upgrading of insulation in Class 1 type dwelling (detached and semi-detached dwellings) as follows:

1. Retrofit of ceiling insulation to previously uninsulated ceilings
2. Retrofit of top up ceiling insulation to less than optimally insulated ceilings
3. Retrofit of wall insulation to previously uninsulated external walls
4. Retrofit of floor insulation to previously un-insulated suspended timber floors

Modelling is conducted across each of the eight jurisdictions in Australia using a range of 15 representative Australian climates zones designed to represent each of the 8 National Construction Code (NCC) climate zones as well as each of the 3 Greenhouse and Energy minimum Standards (GEMS) climate categories. The various climate categories are found in differing proportions in each of Australia's state and territory jurisdictions[1]

[1] This approach is in line with the methodology used in the analysis undertaken for the development of the energy performance standards in NCC 2022

A separate summary page of results for each of the 4 insulating activities is provided in the four following pages of this executive summary. For each activity, results are presented as follows (in order)

- National potential, including
  - Scope for upgrade*
  - Star rating improvement (average of all jurisdictions)
  - Annual Energy savings**
  - Upgrade Costs**
  - Annual cost savings**
  - Annual Greenhouse gas savings**
- Cost Effectiveness (at state/territory/climate level)

* Both the number of dwellings that would be cost effective to upgrade as well as the total number of dwellings without the particular form of insulation are reported
** The National figures reported represent the potential savings/costs if all dwellings that are cost effective to upgrade (assuming 3% discount rate and factoring in a price on carbon) were to be upgraded.

Cost effectiveness in this executive summary is assessed at a discount rate of 3% and with an assumed price on carbon equivalent to that applied by the Australian Building Codes Board for their National Construction Code update for 2022 (averaging approximately $95 over the life of the insulation improvement measure). Cost effectiveness has also been assessed at a 7% discount rate in the main body of this report, however it should be noted that for long term investments in climate change mitigation such as insulation retrofit, a discount rate of 3% or less is usually considered the most appropriate level[2].

In the following summary tables of cost effectiveness, those cases where the measure was found to be cost effective are highlighted in green. Light green indicates cost effectiveness at 3% discount rate and dark green indicates cost effectiveness at both 3% and 7% discount rates.

Apart from the modelled benefit of insulation-based energy savings measures in terms noted above there are a number of other co-benefits likely to arise from such measures but not quantified in this study, these include:

- Environmental benefits
- Improved health outcomes for householders
- Improved property values
- Employment – Green Jobs
- Improved productivity
- Reduced air pollution
- Energy security
- Poverty alleviation

Improved health outcomes are of particular importance. There is a significant body of evidence on the adverse health impacts of houses with poor thermal performance. Excess seasonal mortality is prevalent in climates with very cold winters and/or very hot summers, as are respiratory and circulatory disorders. The very young and the elderly are particularly

[2] See - The Garnaut Climate Change Review (Garnaut 2008) where it is argued that discount rates of between 1.35 per cent and 2.65 per cent are appropriate for long term investments in climate change mitigation

at risk. Improving thermal performance is associated with improved health outcomes and reduced seasonal mortality. Considerable international research has also shown multiple spin-off benefits to the health and wellbeing and productivity for people living in thermally comfortable housing, which directly reduced the demand on burdened health systems.

Also, in the coming age of residential energy efficiency disclosure, where, based on study evidence a relationship is expected to form between energy efficiency rating and house price, each energy rating star improvement realised through insulation measures is expected to add to the sale price of that property (estimated in the ACT to be in the order of $11,000 per star rating increase (DEWHA 2008))

More detailed results including disaggregation's by state/territory, climate zone and by fuel type can be found in:

- Scope for upgrade – see Section 3
- Ceiling Insulation – see Section 5
- Top up ceiling insulation – see Section 6
- Wall Insulation – see Section 7
- Floor insulation – see Section 8

Ceiling Insulation – Summary of Results

National Cost-Effective Potential* (for state level results see main report)

Scope for upgrades (Households)	**1.2 M cost effective** Out of a total of 1.2 M
Av. NatHERS Star Rating Increase	**2.1 Stars**
Annual Energy Savings	**16.6 PJ**
Upgrade Cost	**$ 4825 M** ($ 4,021 per H hold)
Annual Cost Savings	**$ 986 M / year** ($ 846 per H hold/year)
Annual Greenhouse Gas Savings	**0.52 Mt** (0.45 t per H hold)

* Cost effectiveness is gauged at a 3% discount rate with a price on carbon

Cost Effectiveness: Benefit/Cost (With Carbon Price) 3% discount rate

Climate (GEMS)	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	6.3	8.5	3.8	10.2	7.2	3.7	N/A	6.2
Average	5.7	13.4	5.2	12.2	9.0	N/A	2.5	N/A
Hot	2.9	N/A	2.5	3.8	3.4	N/A	5.3	N/A
State Average	5.4	8.6	2.8	11.7	7.9	3.7	5.2	6.2

* Cells highlighted in dark green also have a positive B/C ratio at a 7% discount rate

Ceiling Insulation Findings Summary

The insulation of ceilings not previously insulated is one of the most cost-effective measures available to property owners and governments. It is cost effective across all jurisdictions and across all climate zones within each jurisdiction.

Ceiling Top-up Insulation– Summary of Results

National Cost-Effective Potential* (for state level results see main report)

Scope for upgrades (Households)	**2.1 M cost effective** **Out of a total of 2.4 M**
Av. NatHERS Star Rating Increase	**0.5 Stars**
Annual Energy Savings	**9.4 PJ**
Upgrade Cost	**$ 6358 M** **($ 3,028 per H hold)**
Annual Cost Savings	**$ 476 M / year** **($ 226 per H hold/year)**
Annual Greenhouse Gas Savings	**0.29 Mt** **(0.14 t per H hold)**

*** Cost effectiveness is gauged at a 3% discount rate with a price on carbon**

Cost Effectiveness: Benefit/Cost (With Carbon Price) 3% discount rate

Climate (GEMS)	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	1.7	2.6	1.1	3.0	1.9	1.0	N/A	1.7
Average	1.1	2.8	1.0	2.4	1.7	N/A	0.4	N/A
Hot	0.7	N/A	0.7	1.0	0.8	N/A	1.3	N/A
State Average	1.2	2.6	0.7	2.4	1.6	1.0	1.3	1.7

*** Cells highlighted in dark green also have a positive B/C ratio at a 7% discount rate**

Top-up Ceiling Insulation Findings Summary

With 2.4 million houses in Australia expected to have less than optimal ceiling insulation installed this improvement measure presents a significant opportunity for homeowners and governments alike. At a 3% discount rate with a price on carbon, the insulation measure is on average cost effective in all jurisdictions except Queensland (although cost effective in the less significant average and cold climate zones of Queensland).

Wall Insulation– Summary of Results

National Cost-Effective Potential* (for state level results see main report)

Scope for upgrades (Households)	**1.9 M cost effective** Out of a total of 5.6 M
Av. NatHERS Star Rating Increase	**0.7 Stars**
Annual Energy Savings	**16.8 PJ**
Upgrade Cost	**$ 11,917 M** ($ 6,272 per H hold)
Annual Cost Savings	**$ 742 M / year** ($ 391 per H hold/year)
Annual Greenhouse Gas Savings	**0.55 Mt** (0.29 t per H hold)

*** Cost effectiveness is gauged at a 3% discount rate with a price on carbon**

Cost Effectiveness: Benefit/Cost (With Carbon Price) 3% discount rate

Climate (GEMS)	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	1.2	1.8	0.8	1.7	1.0	1.2	N/A	1.3
Average	0.6	1.5	0.5	0.9	0.6	N/A	0.2	N/A
Hot	0.4	N/A	0.3	0.3	0.3	N/A	0.6	N/A
State Average	0.7	1.8	0.3	1.0	0.6	1.2	0.6	1.3

* Cells highlighted in light green would also have a positive B/C ratio in circumstances where a 15% saving on installation cost might be achieved (a 15% reduction in costs is a possible saving due to expected economies of scale stemming from the scaling up of what at present is somewhat of a boutique industry to a widespread program of wall insulation retrofit – see Section 4 of the main report for further details).

Wall Insulation Findings Summary

In terms of the potential for insulation upgrade, wall insulation retrofit represents the greatest opportunity in Australia with an estimated 5.6 million homes without wall insulation. At a 3% discount rate and a price on carbon this insulation measure is on average cost effective in Victoria, South Australia, Tasmania and the ACT and also cost effective in the colder regions of NSW and WA.

Floor Insulation– Summary of Results

National Cost-Effective Potential* (for state level results see main report)

Scope for upgrades (Households)	**0.7 M cost effective** Out of a total of 2.3 M
Av. NatHERS Star Rating Increase	**0.3 Stars**
Annual Energy Savings	**4.7 PJ**
Upgrade Cost	**$ 3086 M** ($ 4,409 per H hold)
Annual Cost Savings	**$ 198 M / year** ($ 271 per H hold/year)
Annual Greenhouse Gas Savings	**0.16 Mt** (0.21 t per H hold)

*** Cost effectiveness is gauged at a 3% discount rate with a price on carbon**

Cost Effectiveness: Benefit/Cost (With Carbon Price) 3% discount rate

Climate (GEMS)	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	0.9	1.8	0.7	2.0	1.0	1.1	N/A	1.1
Average	0.2	0.9	0.2	0.5	0.2	N/A	0.0	N/A
Hot	-0.1	N/A	0.0	-0.1	0.0	N/A	0.3	N/A
State Average	0.3	1.8	0.0	0.7	0.3	1.1	0.3	1.1

*** Cells highlighted in dark green also have a positive B/C ratio at a 7% discount rate**

Floor Insulation Findings Summary

This insulation measure is best suited to the cold climate zones in each state and territory. At a 3% discount rate and including a price on carbon, the insulation measure is on average cost effective in Victoria, Tasmania and the ACT. The measure is also cost effective in the cold climate zones of SA and WA.

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Abbreviations and Definitions

AC	Air conditioner
AS	Australian Standard
CEC	Comparative Energy Consumption (energy on an energy label)
COP	Coefficient of Performance (operating)(AC efficiency measure for heating)
E3	Equipment Energy Efficiency Committee (Australia and NZ)
EER	Energy Efficiency Ratio (operating)(AC efficiency measure for cooling)
EES	Energy Efficient Strategies Pty Ltd
GEMS	Greenhouse and Energy Minimum Standards Act (Federal)
GHG	Greenhouse gases
IWG	Interagency Working Group (US Government)
kWh	Kilowatt hour (unit of energy)
MEPS	Minimum Energy Performance Standards
MJ	Megajoule (unit of energy)
NCC	National Construction Code (of Australia)
PAEC	Projected Annual Energy Consumption – see also CEC
SRI	Star Rating Index (decimal star rating)
W	Watt (unit of power)

1 Project Overview

1.1 Background

This study is intended as an update of an earlier study prepared for ICANZ by Energy Efficient Strategies P/L in 2011 – 2013 entitled:

The Value of Insulation Based Residential Energy Savings Measures In Australia

This study provides updated data sets at both household and jurisdictional level.

Unlike the earlier study, this study does not include notional scenarios of a retrofit program that could be implemented over the coming years (i.e. it does not prescribe a specific retrofit policy). Instead, the study simply focuses on:

- the potential scope for insulation-based upgrades
- the potential costs of such upgrades and
- the potential benefits of such upgrades (in their various forms)

The thermal insulation of ceilings walls and in some cases, floors has long been recognised as some of the most significant and cost-effective means for improving the thermal performance of residential buildings. Such insulation has been demonstrated to:

- Improve thermal comfort for the occupants
- Reduce space conditioning energy consumption
- Reduce heating and cooling fuel costs to householders
- Reduce greenhouse gas emissions associated with space conditioning
- Mitigate against the impact of peak loads on power supply networks
- Improve health outcomes for occupants
- Improve the value of the property

ABS data analysed in this study indicates that there persists in the Australian housing stock a significant number of dwellings with uninsulated or under insulated ceilings, walls and floors. This suggests a significant market failure of householders to capitalise on the positive financial and health benefits associated with these insulation based retrofit options.

1.2 Scope

This study examines the opportunities, costs and benefits of the retrofitting/upgrading of insulation in Class 1 type dwelling (detached and semi-detached dwellings) as follows:

1. Retrofit of ceiling insulation to previously uninsulated ceilings
2. Retrofit of top up ceiling insulation to less than optimally insulated ceilings
3. Retrofit of wall insulation to previously uninsulated external walls
4. Retrofit of floor insulation to previously un-insulated suspended timber floors

Modelling is conducted across each of the eight jurisdictions in Australia using a range of 15 representative Australian climates zones designed to represent each of the 8 NCC climate categories found in differing proportions in each of Australia's state and territory jurisdictions[3]

For energy calculations, in line with the approach taken in whole of house modelling under NatHERS, modelling was undertaken using two separate (weighted) occupancy schedules:

- Home all day schedule (60%)
- Workday Schedule (40%)

Separate runs were undertaken for a centrally conditioned case and a room only conditioned case (typically main living/kitchen area). These loads were applied to a representative stock model of heating and cooling equipment found in Australian Class 1 dwellings in order that accurate energy consumption changes by fuel type attributable to insulation upgrade activities could be determined.

Full details of the scope, method and underlying assumptions used in the modelling can be found in Appendix 1 Modelling Methods and Assumptions Details.

1.3 Acknowledgements

This study was undertaken by Energy Efficient Strategies (Victoria) with assistance from Tony Isaacs Consulting (Victoria).

The authors would like to thank.

- ICANZ members
- NatHERS

[3] This approach is in line with the methodology used in the analysis undertaken for the development of the energy performance standards in NCC 2022

2 Overview of Modelling Methodology

2.1 Overview

Modelling for this project consisted of 9 main components as follows:

1. Housing Stock Model
2. Representative dwelling type development
3. Thermal performance modelling (NatHERS simulation)
4. Heating and cooling equipment modelling
5. Fuel cost savings modelling
6. Greenhouse gas abatement modelling
7. Improvement cost estimates
8. Overall economic analysis
9. Cost modelling

Each of these components is summarised in the following sub-sections (Sections 2.2 to 2.9 inclusive). This is followed by a final subsection (2.10) that deals with the issue of rebound effect and how it is accounted for in this study.

2.2 Housing Stock Model

For this study, the scope of housing types examined was limited to the following:

- Class 1a (i) - detached houses.
- Class 1a (ii) - attached dwellings (including “town houses”, “terrace houses” and “villas”)

Class 2 dwellings (flats) were excluded – most ceilings in these dwellings are bounded above by another occupancy and as such there is no value in applying ceiling insulation or top up ceiling insulation. Similarly, the majority of floors in these dwellings are bounded below by another occupancy and as such there is no value in applying floor insulation. Wall insulation is a possibility, however typically a significant number of a class 2 dwellings boundary walls are bounded by another occupancy and the few walls which are external to the building typically have a high proportion of glazing.

The stock modelling for this project started with a representative stock of class 1 dwellings in Australia by jurisdiction. These dwellings were intended to represent the building stock built prior to the introduction of performance standards for residential dwellings in Australia (see Section 11.1.2).

The stock of dwellings was then divided into four cohorts representing housing potentially suitable for one of the four insulation upgrade options examined in this study, namely:

1. Retrofit of ceiling insulation to previously uninsulated ceilings
2. Retrofit of top up ceiling insulation to less than optimally insulated ceilings
3. Retrofit of wall insulation to previously uninsulated external walls
4. Retrofit of floor insulation to previously un-insulated suspended timber floors

The numbers of dwellings suitable for such upgrades was determined via reference to various survey data sources including the ABS. Details and results from this analysis can be found in Section 3 of this report.

2.3 Representative dwelling type development

To be able to model the thermal performance of the stock of housing (before and after improvements) in a thermal performance modelling tool, it is necessary to select some sample dwelling types to represent that stock.

Three main dwelling types were selected to represent class 1 dwellings:

- Single storey detached dwelling with a pitched roof
- Two storey detached dwelling with a pitched roof
- Semi-detached dwelling

These three base dwelling types were selected and then configured to represent an average pre-regulation house by Tony Isaacs Consulting. Plans of the sample house types used are shown in Appendix 2 Sample House Types.

Each of the three sample dwellings was modelled across 5 construction formats that represent the most common formats found in Australia (noting that the various typologies present in differing proportions according to the jurisdiction in which they are present). The types are:

- Suspended timber floor with lightweight wall construction (fibro, weatherboard) – code = **LT**
- Suspended timber floor with brick veneer wall construction code = **BT**
- Suspended timber floor with heavyweight wall construction (double brick, stone etc) code = **HT**
- Concrete slab on ground floor with brick veneer wall construction, code = **BC**
- Concrete slab on ground floor with heavyweight wall construction (double brick, stone etc) code = **HC**

Whilst a potential 6th type (lightweight construction on a concrete floor) is becoming more popular in recent years, pre regulation there were very few dwellings of this format built. For the purposes of this study the very small number of lightweight constructions on a concrete floor were aggregated with brick veneer construction on a concrete floor which has similar thermal performance characteristics in any case.

The assumed propensities of each of the dwelling variants noted above are detailed in Section 11.1.2.

2.4 Thermal performance modelling

Using the latest benchmark NatHERS thermal performance modelling tools (AccuRATE) each of the representative dwelling types was modelled to determine their thermal performance (heating and cooling loads). For each of the sites examined for potential insulation upgrade (ceiling, ceiling top up, wall and floor) modelling was conducted for 2 cases:

- A “before insulation upgrade” case

- A "after insulation upgrade case"

The difference between these two cases representing the potential savings in both heating loads and in cooling loads that could be achieved as a result of the upgrade.

Each jurisdiction was divided in to three different climate zones that represented the following region types as defined in the GEMS determination for air-conditioners (GEMS 2019 – See also Figure 1 below):

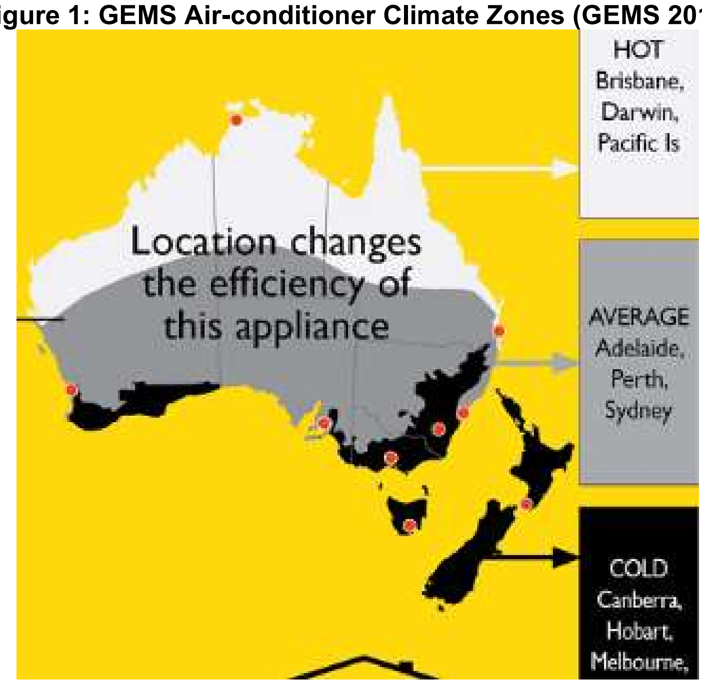
- Cold (generally equivalent to NCC climates zones 6 to 8 inclusive)
- Average (generally equivalent to NCC climates zones 4 and 5)
- Hot (generally equivalent to NCC climates zones 1 to 3 inclusive)

These divisions are important for two reasons:

1. Insulation tends to provide greater cost effectiveness in the more extreme climates found in Australia i.e. GEMs Hot[4] and particularly GEMS Cold climates with reduced cost effectiveness in the GEMS average climate. Modelling was undertaken in each of these three climate types in each jurisdiction (as applicable) because in some cases a particular form of insulation retrofit may be cost effective in only selected climate types in that jurisdiction.
2. The performance of heat pump heating and cooling equipment types (now the most common form of both heating and cooling in Australia) depends to some degree on the climate zone in which they are situated. In particular, heating performance tends to be poorer in colder climates compared to the average and hotter climate zones.

Separate thermal performance modelling runs were undertaken for houses with central heating/cooling systems installed as well as for dwellings with only room heating/cooling systems installed. These various run types were later matched to the range of heater and cooler types modelled in this study - see Section 2.5

Figure 1: GEMS Air-conditioner Climate Zones (GEMS 2019)



[4] Not including floor insulation which does not generally perform well in hotter climates

2.5 Heating and Cooling Equipment Modelling

In order that actual savings in fuel usage can be estimated it is necessary to construct a stock model of both the heating and cooling equipment that services the dwellings to which insulation upgrades are proposed to be undertaken. Both the propensity and the performance (efficiency and likely losses) of the installed heaters and coolers is required to be determined in order that the savings in heating and cooling loads attributable to the insulation activity (as determined via the thermal modelling) can be converted into estimated savings in fuel usage (electricity, natural gas, LPG and firewood)

All of the main heating and cooling types were modelled for this study including:

Heating
- Mains Gas non-ducted
- LPG Gas non-ducted
- Mains Gas ducted
- Resistive Electric slab
- Resistive Electric ducted
- Resistive Electric panel+room
- Reverse Cycle AC non-ducted
- Reverse Cycle AC ducted
- Wood Closed Combustion
- Wood Open Fires
- No Main Space Heating

Cooling
- Ducted Reverse Cycle (or cooling only) Air Conditioner
- Ducted Evaporative Cooler
- Non-ducted Reverse Cycle (or cooling only) Air Conditioner
- Nil

Full details regarding the assumed propensities and performance characteristics of the stock of heating and cooling equipment can be found in Section 11.2

2.6 Fuel cost savings modelling

Modelled space conditioning energy savings associated with each of the insulation upgrade options (see previous sections) was aggregated into each of five fuel types at state level as follows:
- Electricity – continuous load (“day rate” tariff)
- Electricity – controlled load (“off-peak” tariff)
- Gas
- LPG
- Firewood (modelled separately for both open and closed combustion)

Unit fuel costs were then applied to each fuel type to determine estimated total fuel cost savings per household by state and territory for each of the insulation options examined in this study. Details of the unit fuel costs used in this study can be found in Section 11.3

2.7 Greenhouse gas abatement modelling

Modelled space conditioning energy savings associated with each of the insulation upgrade options (see previous sections) was aggregated into each of four fuel types at state level as follows:

- Electricity (all)
- Gas
- LPG
- Firewood (modelled separately for both open and closed combustion)

Greenhouse gas emission intensities drawn from sources such as The Australian National Greenhouse Accounts Factors 2023, were then applied to each fuel type to determine estimated total greenhouse gas savings per household by state and territory for each of the insulation options examined in this study. Details of the greenhouse gas intensity factors used in this study can be found in Section 11.4.

For this study two options were modelled in respect of the monetary value of abated carbon emissions associated with insulation upgrades:

- No value
- The social cost of carbon (SCC) – based on the values as used in NCC 2022

The SCC is an estimate of the marginal impact of an additional tonne of carbon based on the future costs associated with those emissions. For the NCC 2022 Decision RIS, carbon costs based on the United States (US) Government's Interagency Working Group (IWG) on Social Cost of Greenhouse Gases 2021, medium scenario were used. For this study the same values have been used (approximately $95 / tonne over the life of the measure) – see Section 11.5 for details. However, it should be noted that this should be considered a conservative estimate of the SCC. In September 2022, the United States (US) EPA released updated estimates of the social cost of carbon to be used when monetising the value of changes in GHG emissions. These more recent US SCC estimates are now in the order of $300 - $400 per tonne over the next 25 years (using the medium scenario i.e. equivalent to that used in NCC 2022).[5]

2.8 Improvement cost estimates

Estimates for the unit cost of insulating ceilings, walls and floors were determined by ICANZ for each jurisdiction via a survey of its key members and insulation installers. The results of that survey are shown in Section 4.

Data from the sample of representative house types used in this study relating to the area of ceilings, walls and floors was then applied to the ICANZ insulation unit rates to determine estimated costs of upgrade for each of the insulation measures examined in this study.

[5] It is also worth noting that many notable economists now estimate that the market value (or "resource cost") of carbon in Australia which is a far more conservative measure than the social cost of carbon will soon rise to a level similar to that assumed in NCC 2022. – see https://www.ey.com/en_au/sustainability/australia-s-carbon-market-is-changing-gears-are-you-ready and also Hutley 2023.

2.9 Overall economic analysis

Primarily the economic modelling consisted of a comparison of the initial cost of the energy saving measure (the investment) with the appropriately discounted expected return on that investment.

The cost of the investment (i.e. the insulation-based energy savings measure) was determined by ICANZ for each jurisdiction via reference to its key members – see Section 2.8

The expected return on the investment was based on the following factors:

- Projected monetary savings in space conditioning energy usage following the application of the insulation-based energy savings measure (i.e. based on the analysis outlined in section 2.6)
- Assumed life of the measure – assumed to be 40 years. The service life of rockwool and glass-wool is typically understood to be 50 years or more. For this study a more conservative value of 40 years was used in consideration of the possibility that some of the retrofitted dwellings may end their service life in less than 50 years
- Applied Discount rate: The discount rate is the key factor applied in a net present value (NPV) calculation in order that the NPV of future fuel cost savings can be compared with the initial cost of the energy saving measure. For this study two different levels of discount rate were examined:
    - 7% representing the level commonly mandated by governments when assessing the viability of a proposed market intervention
    - 3% representing what is considered a reasonable and more realistic return on a long-term investment, particularly considering that the returns in this case (reductions in energy bills) are tax free.

  It should be noted that in the study The Garnaut Climate Change Review (Garnaut 2008) it is argued that discount rates of between 1.35 per cent and 2.65 per cent are appropriate for long term investments in climate change mitigation.

2.10 Rebound Effect

This study also considered those factors that are likely to constrain the economic and greenhouse abatement benefits arising from the particular insulation option (e.g. Rebound effects). The “rebound effect” or “comfort creep” is the perceived tendency of householder to increase their minimum comfort requirements following the application of building shell improvement measures. Such improvements in comfort requirements could take the form of changed thermostat settings and or an increase in actual conditioned floor area.

In this study the predicted benefits in terms of greenhouse gas emission savings were discounted to 75% of the modelled value in consideration of the rebound effect. This is based on analysis undertaken in the study The Value of Insulation Based Residential Energy Savings Measures in Australia (EES 2013).

In terms of the predicted financial benefits that would accrue to the householder, no discount for rebound was applied because for the householder, rebound or “comfort creep” (if it occurs) is discretionary behaviour. If it occurs, then it indicates that the householder is valuing improvements taken in comfort above the potential financial savings that could be realised if their comfort requirements were left unchanged following the application of the improvement measure.

3 Insulation Stock Profile and Opportunities

3.1 Basis of Estimates

Estimates for ceiling, wall and floor insulation rates were based on estimates published in ABS4602.

Between 1994 and 2014 the Australian Bureau of statistics published a series of seven surveys relating to “environmental issues” (ABS 4602), including selected survey data relating to various aspects concerning the insulation of dwellings including ceiling insulation.

The surveys were all taken in the month of March, except for the 1994 survey that was taken in June. The years of publication were:

a. 1994
b. 1999
c. 2002
d. 2005
e. 2008
f. 2011
g. 2014

The survey questions related to the stock of Australian housing and covered such fundamental questions as:

a. whether or not the dwelling was insulated
b. if insulated, in what locations the insulation was installed
c. the type of insulation installed
d. reasons why insulation had been installed
e. reasons why insulation had not been installed
f. related data such as the dwelling structure (separate house, flat/unit/apartment, other)

Note: Not all the above questions were asked in each of the seven survey years.

These surveys consisted of between 10,000 and 20,000 responses from a weighted representative sample of households from across Australia.

The collected survey data is based on self-reporting by homeowners and therefore some inaccuracy in reporting is to be expected. Nevertheless, the data sets from the various years exhibit a relatively high level of year-to-year consistency.

Dwellings with insulation reported

A key data set collected in the ABS surveys related to the proportion of dwellings that had some form of insulated fitted – see Table 1. As can be seen in this table a significant percentage of respondents (typically 15-20%) noted that they did not know if their dwelling was insulated or not. In these circumstances it has been assumed for the purposes of this study that the rate of insulation amongst the respondents that “don’t know” is the same as those that do know (see Table 2). This is considered to make for a conservative estimate of the potential for insulation retrofit. It is postulated that those that “don’t know” probably have a lower insulation rate than those that do know but this cannot be confirmed.

Table 1: Proportion of Dwellings With Insulation – Various Years (ABS 4602)

Year	Status	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1994	With insulation	44.5%	69.5%	28.5%	72.2%	52.0%	62.7%	43.9%	79.5%	52.1%
	Without Insulation	39.4%	17.0%	53.6%	15.7%	36.7%	28.8%	28.4%	9.7%	33.1%
	Don't know	16.1%	13.5%	17.9%	12.0%	11.3%	8.5%	27.6%	10.8%	14.7%
1999	With insulation	47.6%	71.3%	33.0%	70.8%	57.3%	64.1%	44.8%	75.8%	52.1%
	Without Insulation	31.6%	12.4%	48.6%	12.5%	29.0%	22.3%	31.6%	9.4%	33.1%
	Don't know	20.9%	16.3%	18.4%	16.7%	13.7%	13.6%	23.6%	14.8%	14.7%
2002	With insulation	50.5%	72.1%	36.2%	75.7%	64.5%	68.2%	42.2%	80.4%	57.5%
	Without Insulation	28.0%	12.1%	44.8%	12.8%	22.9%	21.2%	27.4%	7.9%	25.0%
	Don't know	21.5%	15.8%	18.9%	11.5%	12.6%	10.6%	30.3%	11.7%	17.5%
2005	With insulation	54.4%	72.3%	43.2%	78.2%	65.6%	74.6%	49.2%	78.5%	60.5%
	Without Insulation	24.8%	9.2%	35.5%	8.7%	20.4%	12.2%	16.5%	3.6%	20.6%
	Don't know	20.7%	18.5%	21.3%	13.1%	14.0%	13.2%	34.4%	17.9%	18.9%
2008	With insulation	53.4%	73.8%	46.9%	76.6%	69.4%	74.6%	48.4%	77.3%	61.5%
	Without Insulation	25.7%	8.5%	30.0%	8.6%	16.2%	10.9%	21.2%	4.6%	19.2%
	Don't know	21.0%	17.7%	23.1%	14.7%	14.3%	14.5%	30.4%	18.1%	19.3%
2011	With insulation	63.4%	76.5%	61.7%	78.0%	73.7%	78.9%	43.8%	80.5%	69.0%
	Without Insulation	18.2%	7.8%	20.3%	8.1%	12.8%	10.1%	24.2%	4.3%	14.3%
	Don't know	18.4%	15.6%	18.0%	13.9%	13.5%	11.0%	32.0%	15.1%	16.7%
2014	With insulation	62.5%	74.9%	59.9%	77.6%	75.0%	79.4%	50.1%	80.6%	68.1%
	Without Insulation	17.8%	7.2%	21.1%	6.1%	10.9%	8.8%	17.3%	5.4%	13.8%
	Don't know	19.7%	18.1%	18.6%	15.9%	14.0%	11.2%	31.8%	13.0%	18.0%

Table 2: Proportion of Dwellings with Insulation – excludes unknown (ABS 4602)

Year	Status	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1994	With insulation	53.0%	80.3%	34.7%	82.1%	58.6%	68.5%	60.7%	89.1%	61.1%
	Without Insulation	47.0%	19.7%	65.3%	17.9%	41.4%	31.5%	39.3%	10.9%	38.9%
1999	With insulation	60.1%	85.2%	40.4%	85.0%	66.4%	74.2%	58.6%	89.0%	52.1%
	Without Insulation	39.9%	14.8%	59.6%	15.0%	33.6%	25.8%	41.4%	11.0%	33.1%
2002	With insulation	64.4%	85.6%	44.7%	85.5%	73.8%	76.3%	60.6%	91.1%	69.7%
	Without Insulation	35.6%	14.4%	55.3%	14.5%	26.2%	23.7%	39.4%	8.9%	30.3%
2005	With insulation	68.7%	88.7%	54.9%	90.0%	76.3%	85.9%	74.9%	95.6%	74.6%
	Without Insulation	31.3%	11.3%	45.1%	10.0%	23.7%	14.1%	25.1%	4.4%	25.4%
2008	With insulation	67.5%	89.7%	61.0%	89.9%	81.0%	87.3%	69.5%	94.4%	76.2%
	Without Insulation	32.5%	10.3%	39.0%	10.1%	19.0%	12.7%	30.5%	5.6%	23.8%
2011	With insulation	77.7%	90.7%	75.2%	90.6%	85.2%	88.7%	64.4%	94.9%	82.8%
	Without Insulation	22.3%	9.3%	24.8%	9.4%	14.8%	11.3%	35.6%	5.1%	17.2%
2014	With insulation	77.8%	91.2%	73.9%	92.7%	87.3%	90.0%	74.3%	93.7%	83.2%
	Without Insulation	22.2%	8.8%	26.1%	7.3%	12.7%	10.0%	25.7%	6.3%	16.8%

Reported locations of insulation

A second key data set recorded in the ABS survey was the location of the insulation in dwellings that nominated that they had some form of insulation. In most of the survey years the locations were divided into 4 categories as follows:

- Roof/Ceiling
- Walls
- Floor
- Other

In 2011, only roof/ceiling, walls and other were reported, no separate reporting of floor insulation was available in that year, and it is assumed that in that year "other" included both floor insulation and any other insulation location other than roof/ceiling, wall and floor.

In 2014 the ABS survey did not include a question relating to the location of the insulation. Consequently, for 2014 it has been assumed for the purposes of this study that the values reported in 2011 are also broadly applicable in 2014, noting that changes in penetration of insulation by location in houses that report having at least one form of insulation is not expected to change significantly over a period of 3 years. Potentially a significant program of retrofitting such as the Commonwealth Home Insulation program (HIP) could effect a significant change. However, the HIP program occurred prior to 2011 (2009-2010) and it only impacted ceiling insulation which as can be seen from the table below was already at almost 100% penetration in all jurisdictions in households that reported having at least one form of insulation in their dwelling. The HIP program did impact the total number of dwellings with ceiling insulation (see Section 3.2) but not the penetration of ceiling insulation for dwellings reporting at least one form of insulation in their dwelling.

Table 3: Locations of Insulation for houses reporting insulation–Various Years (ABS 4602)[1]

Year	Location	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1994	Roof/Ceiling	96.6%	98.6%	91.8%	97.3%	99.1%	96.9%	98.0%	97.0%	97.1%
	Walls	26.1%	27.5%	25.8%	24.5%	64.0%	26.5%	23.9%	31.3%	24.6%
	Floor	0.7%	0.8%	0.7%	0.3%	0.0%	1.0%	1.9%	1.3%	0.6%
	Other	0.3%	0.1%	0.4%	0.4%	0.6%	0.3%	0.0%	0.4%	0.3%
1999	Roof/Ceiling	97.4%	98.7%	93.3%	98.4%	99.3%	97.2%	98.3%	98.6%	52.1%
	Walls	24.0%	31.5%	26.1%	27.3%	7.7%	26.6%	16.1%	39.8%	33.1%
	Floor	0.0%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	14.7%
	Other	0.1%	0.0%	0.5%	0.2%	0.0%	0.1%	0.0%	0.0%	114.7%
2002	Roof/Ceiling	98.2%	98.6%	94.5%	99.3%	99.2%	97.6%	97.1%	99.0%	98.1%
	Walls	26.8%	35.0%	26.9%	35.0%	6.8%	31.2%	26.7%	40.1%	28.4%
	Floor	0.8%	0.7%	0.7%	0.3%	0.2%	1.4%	0.0%	3.0%	0.7%
	Other	0.1%	0.3%	0.0%	0.0%	0.1%	0.0%	0.0%	0.2%	0.1%
2005	Roof/Ceiling	97.1%	98.7%	94.4%	99.0%	99.7%	98.1%	98.3%	99.2%	97.8%
	Walls	32.6%	40.2%	24.9%	34.4%	9.8%	33.4%	14.7%	43.9%	31.7%
	Floor	1.1%	0.9%	0.7%	0.7%	0.4%	3.4%	0.0%	3.3%	1.0%
	Other	0.2%	0.4%	0.0%	0.0%	0.1%	0.0%	0.0%	0.5%	0.2%

Year	Location	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
2008	Roof/Ceiling	97.2%	98.7%	95.9%	99.4%	99.3%	97.8%	98.6%	97.9%	98.0%
	Walls	33.4%	38.8%	23.4%	32.4%	8.0%	32.0%	19.2%	43.7%	30.7%
	Floor	1.5%	1.3%	0.4%	0.7%[2]	0.4%[2]	4.9%	0.0%	4.3%	1.1%
	Other	0.3%	0.4%[2]	0.3%	0.0%	0.1%[2]	0.5%	0.0%[2]	0.9%	0.2%
2011	Roof/Ceiling	97.8%	97.2%	97.9%	98.7%	99.3%	97.3%	95.3%	97.3%	97.8%
	Walls	24.1%	34.4%	16.6%	33.8%	8.2%	35.8%	15.8%	46.3%	25.4%
	Floor[3]	3.1%	3.9%	1.4%	2.3%	1.1%	4.8%	4.1%	4.1%	2.9%
	Other[3]	0.3%	0.4%	0.3%	0.0%	0.1%	0.5%	0.0%	0.9%	0.2%
2014[4]	Roof/Ceiling	97.8%	97.2%	97.9%	98.7%	99.3%	97.3%	95.3%	97.3%	97.8%
	Walls	24.1%	34.4%	16.6%	33.8%	8.2%	35.8%	15.8%	46.3%	25.4%
	Floor	3.1%	3.9%	1.4%	2.3%	1.1%	4.8%	4.1%	4.1%	2.9%
	Other	0.3%	0.4%	0.3%	0.0%	0.1%	0.5%	0.0%	0.9%	0.2%

Notes:

1. Because a dwelling may have insulation in more than one of the 4 locations noted, the total % of all 4 locations in many cases exceeds 100%.
2. Data not available for these jurisdictions in 2008. 2005 data was assumed to be applicable in 2008 in these specific cases.
3. In the 2011 survey, only Roof/Ceiling, Walls and Other were reported. It is assumed that “other” in this year included floor insulation. For 2011 it was assumed that “other” (excluding floor insulation) was the same value as for 2008 and that floor insulation was the difference between the “other” value reported in 2011 and the assumed floor value.
4. No values were reported for 2014. It was assumed that the values reported in 2011 could be applied in 2014

3.2 Ceiling Insulation Retrofit

ABS 4602 identifies eleven categories of ceiling insulation as follows:

a. Batts-fibreglass/wool/poly
b. Sisalation/reflective foil
c. Loose fill - Cellulose fibre
d. Loose fill - Rock wool
e. Loose fill - Wool
f. Loose fill - Other/Unknown
g. Foam/plastic
h. Polystyrene sheets
i. Insulated cladding
j. Other
k. Unknown

Most of these insulation types are known as “bulk” (a, c, d, e, f) or “foam” (g, h, i) type insulation and depending on their thickness generally offer a relatively high level of thermal resistance. The exception is option “b”, Sisalation/reflective foil.

Sisalation is a reflective foil typically composed of polymer or kraft paper installed directly under the roofing material (dished over roofing battens, rafters or purlins). The foil itself, being aluminium, offers almost no thermal resistance, however the reflective nature of the foils surface effectively enhances the thermal resistance of the surrounding air space. Even so, the thermal resistance achieved using Sisalation is very modest (particularly in winter) compared to bulk or foam insulation. Sisalation is often installed primarily for the purpose of creating a vapour barrier between the inside and outside of a building.

The reported proportion of ceiling insulation that is of the Sisalation type is shown in Table 4

Table 4: Proportion of Ceiling Insulation that is Sisalation only – ABS 4602

Survey Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
1994*	6.6%	2.1%	19.5%	2.1%	7.4%	3.4%	38.6%	1.7%
1999	6.6%	2.1%	19.5%	2.1%	7.4%	3.4%	38.6%	1.7%
2002	7.3%	2.6%	18.4%	1.9%	6.6%	1.9%	38.3%	0.7%
2005	7.2%	2.5%	16.2%	2.0%	5.8%	2.4%	35.9%	1.0%
2008	5.4%	2.8%	12.1%	2.1%	5.5%	2.5%	22.1%	1.1%
2011	1.5%	0.8%	8.2%	0.6%	2.4%	1.0%	13.1%	0.0%
2014	2.4%	0.7%	6.7%	1.0%	4.2%	0.0%	5.2%	1.2%

* Not recorded in 1994 ABS survey, assumed to be same as 1999 percentage

For the purposes of this study, it has been assumed that retrofitting of bulk ceiling insulation to roof spaces with Sisalation would be warranted due to the relatively poor thermal performance of a ceiling/roof whose only form of insulation is Sisalation.

To calculate the estimated number of dwellings in each of the ABS survey years that would not have ceiling insulation fitted (including ceilings/roofs with only Sisalation present) the following formula was used:

$N_{WOC} = H - [(WI \times CI \times H) \times (1-S)]$

Where:

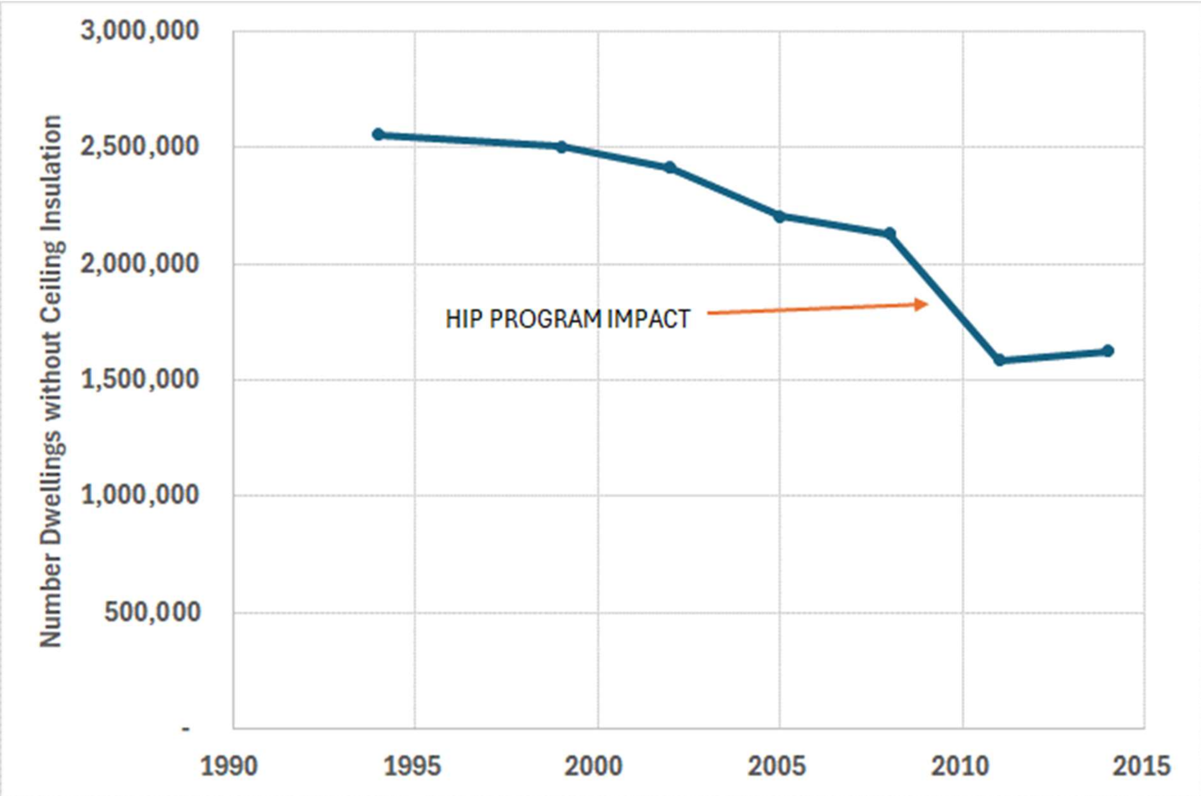
N_{WOC}	=	Estimated number of dwellings without ceiling insulation
H	=	number of class 1 dwellings in that year as reported in ABS 4602 series
WI	=	proportion of dwellings reporting some form of insulation present - ABS 4602 series (see Table 2)
CI	=	Proportion of dwellings reporting some form of insultation present that report ceiling insulation is present - ABS 4602 series (see Table 3)
S	=	proportion of ceiling insulation that is reported as Sisalation ABS 4602 (see Table 4)

Table 5: Estimated number of class 1 dwellings without ceiling insulation (000's)

Survey Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	**AUS**
1994	956.1	336.6	775.3	118.0	269.7	62.2	24.5	14.0	2,556.5
1999	907.5	286.6	840.1	104.9	266.9	54.6	27.8	14.6	2,502.9
2002	854.4	302.4	843.3	97.8	227.9	49.4	28.6	11.5	2,415.2
2005	817.3	259.1	772.1	77.9	213.1	33.5	23.5	6.6	2,203.1
2008	843.6	263.2	694.0	77.6	188.5	32.6	22.9	9.4	2,131.8
2011	561.7	245.2	489.3	70.7	148.1	29.6	30.3	8.9	1,583.9
2014	591.6	244.0	516.5	62.0	155.3	25.2	17.9	12.6	1,625.2
2025	503.2	186.4	452.6	30.2	91.4	2.0	16.6	9.0	1,291.5
Retrofit	452.9	167.8	407.4	27.2	82.3	1.8	15.0	8.1	1,162.4

In the table above (Table 5) the second last line of data is an estimate of the number of dwellings that will be without ceiling insulation in 2025 (a little over 10% of the national stock). This was estimated by applying the observed rate of decline in numbers of dwellings without ceiling insulation prior to the HIP program (approximately 30,000 houses nationally each year) to the period between 2014 (last data available from ABS) to 2025. The rate of decline in numbers of dwellings without ceiling insulation is shown graphically at the national level in Figure 2.

Figure 2: No. Class 1 Dwellings Without Ceiling Insulation by Year (ABS 4602)



Further, it has been assumed that due to access issues, only 90% of those houses without ceiling insulation in 2025 could be retrofitted with ceiling insulation The estimate of number of class 1 dwellings suitable for ceiling insulation retrofit in 2025 is shown in the last row of **Table 5**, highlighted in green.

3.3 Top-up Ceiling Insulation

As noted in section 11.1.3, it is assumed that the cohort of dwellings suitable for this energy saving measure are those dwellings constructed prior to the mid-1990s. Accordingly the number of dwellings in 1994 with ceiling insulation can be calculated as follows

N_{WC} = H x WI x CI

Where:

N_{WC} = Estimated number of dwellings with ceiling insulation
H = number of class 1 dwellings in 1994 as reported in ABS 4602 series
WI = proportion of dwellings reporting some form of insulation present - ABS 4602 series (see Table 2)
CI = Proportion of dwellings reporting some form of insulation present that report ceiling insulation is present - ABS 4602 series (see Table 3)

The calculated values are shown in the first line of Table 6
.
These values are then discounted for the following factors:

- By 31% to account for those households that are assumed to have had top up or replacement insulation undertaken since the 1994 survey (i.e. over a period of 31 years till 2025). This figure of 31% assumes a top-up rate of 1% per annum. This is considered to be conservative (high) given that the estimated retrofit rate between 1994 and 2008 (i.e. pre-HIP) was just 1.18% per annum and that figure would include retrofitting to both uninsulated and under insulated ceilings.
- By 10% to account for dwellings with inaccessible roof spaces i.e. flat roofs and cathedral ceilings.

Table 6: Estimated Number of Suitable Dwellings for Ceiling Insulation Top up in 2025 (000's)

Location	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1994 (ceiling insulated)	1,144	1,291	397	466	358	123	28	92	3,922
Less assumed retrofit[1]	355	400	123	144	111	38	9	29	1,216
Less 10% no access	79	89	27	32	25	8	2	6	271
Total	**711**	**802**	**246**	**289**	**222**	**76**	**17**	**57**	**2,436**

Note 1: Assumes a retrofit rate of 1% since 1994 until 2025.

3.4 Wall insulation

To calculate the estimated number of class 1 dwellings in each of the ABS survey years that would not have wall insulation fitted the following formula was used:

$N_{WOW} = H – [(WI \times WP \times H)]$

Where:

N_{WOW} = Estimated number of dwellings without wall insulation
H = number of class 1 dwellings in that year as reported in ABS 4602 series
WI = proportion of dwellings reporting some form of insulation present - ABS 4602 series (see Table 2)
WP = Proportion of dwellings reporting some form of insultation present that report wall insulation is present - ABS 4602 series (see Table 3)

Table 7 below shows the calculated values for the number of houses estimated to not have wall insulation by year and by jurisdiction (based on ABS 4602 data). Whilst there is an apparent slow but steady increase over time in numbers of dwellings without ceiling insulation, for the purposes of this study it has been assumed that since the last ABS 4602 survey (2014) there has been no further increase in number of houses without wall insulation[6]. Consequently, the assumed number of class 1 dwellings in 2025 without wall insulation is set at the same value as that in 2014 (see second last row of the table below).

Further, it has been assumed that due to access issues, only 90% of those houses without wall insulation in 2025 could be retrofitted with wall insulation The estimate of number of class 1 dwellings suitable for wall insulation retrofit in 2025 is shown in the last row of the table highlighted in green.

Table 7: Estimated number of class 1 dwellings without wall insulation (000's)

Survey Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1994	1,579.7	1,168.4	949.4	432.9	364.8	142.0	33.0	67.3	4,737.6
1999	1,713.5	1,185.7	1,079.3	444.6	650.2	144.5	38.9	68.2	5,324.9
2002	1,707.2	1,192.2	1,132.3	410.4	684.5	139.7	37.6	69.5	5,373.4
2005	1,664.5	1,137.0	1,178.8	424.3	696.1	134.9	39.6	63.0	5,338.1
2008	1,723.5	1,230.6	1,224.2	438.2	735.8	140.4	42.6	64.3	5,599.5
2011	1,815.8	1,348.6	1,323.4	439.7	791.7	138.1	58.4	65.0	5,980.8
2014	1,868.3	1,401.0	1,394.7	452.9	853.3	138.0	48.1	71.4	6,227.7
2025	1,868.3	1,401.0	1,394.7	452.9	853.3	138.0	48.1	71.4	6,227.7
Retrofit	1,681.5	1,260.9	1,255.2	407.6	768.0	124.2	43.3	64.3	5,604.9

3.5 Floor Insulation

To calculate the estimated number of class 1 dwellings in each of the ABS survey years that would not have floor insulation fitted the following formula was used:

N_{WOF} = {H x SF]– [(WI x FP x H)]

Where:

N_{WOF}	=	Estimated number of dwellings without floor insulation
H	=	number of class 1 dwellings in that year as reported in ABS 4602 series
SF	=	Estimated proportion of all class 1 dwellings that had suspended timber floors by year based on the study Energy Use in the Australian Residential Sector 1986-2020 (EES 2008) – see Table 8
WI	=	proportion of dwellings reporting some form of insulation present - ABS 4602 series (see Table 2)
FP	=	Proportion of dwellings reporting some form of insulation present that report floor insulation is present - ABS 4602 series (see Table 3)

[6] National Construction Code minimum standards for building fabric thermal performance should have largely eliminated cases of dwellings being built without wall insulation, although it is possible that a few newer houses could have been built without wall insulation.

Table 8: Estimated proportion of class 1 dwellings with suspended timber floors (EES 2008)

Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
1994	73%	81%	72%	76%	67%	85%	73%	69%
1999	68%	78%	65%	73%	61%	83%	68%	64%
2002	66%	74%	62%	70%	58%	82%	66%	61%
2005	63%	71%	58%	68%	54%	80%	63%	58%
2008	60%	67%	54%	65%	50%	77%	60%	55%
2011	57%	64%	49%	62%	46%	74%	56%	52%
2014	54%	60%	46%	59%	43%	71%	52%	49%

Table 9 below shows the calculated values for the number of houses estimated to not have floor insulation by year and by jurisdiction (based on ABS 4602 data). These numbers have been relatively static over the survey period declining only approximately 3% in the 20-year span of the ABS survey.

For the purposes of this study, it has been assumed that since the last ABS 4602 survey (2014) the decline in the number of houses without floor insulation will have continued to track at the same rate downwards until 2025 (see estimate for 2025 in second last row of the table). Further, it has been assumed that due to access issues, only 50% of those houses without floor insulation in 2025 could be retrofitted with floor insulation The estimate of number of class 1 dwellings suitable for floor insulation retrofit in 2025 is shown in the last row of the table highlighted in green.

Table 9: Estimated number of class 1 dwellings without floor insulation (000's)

Survey Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	**AUS**
1994	1,561.1	1,293.4	819.6	427.9	410.3	151.0	33.1	70.6	4,767
1999	1,624.7	1,350.0	862.7	439.5	437.0	154.2	35.3	75.9	4,979
2002	1,608.5	1,357.7	881.9	430.1	434.1	153.4	36.2	72.3	4,974
2005	1,611.6	1,348.9	878.3	432.3	424.1	150.1	34.7	68.2	4,948
2008	1,607.4	1,360.8	863.6	418.2	413.5	146.6	36.3	64.8	4,911
2011	1,505.2	1,287.9	835.4	399.2	407.8	145.8	43.0	66.0	4,690
2014	1,480.3	1,266.0	816.1	396.1	407.7	140.9	33.7	69.0	4,610
2025	1,435.9	1,250.9	814.2	378.6	406.3	135.3	34.0	68.1	4,523.3
Retrofit	718.0	625.5	407.1	189.3	203.2	67.7	17.0	34.1	2,261.7

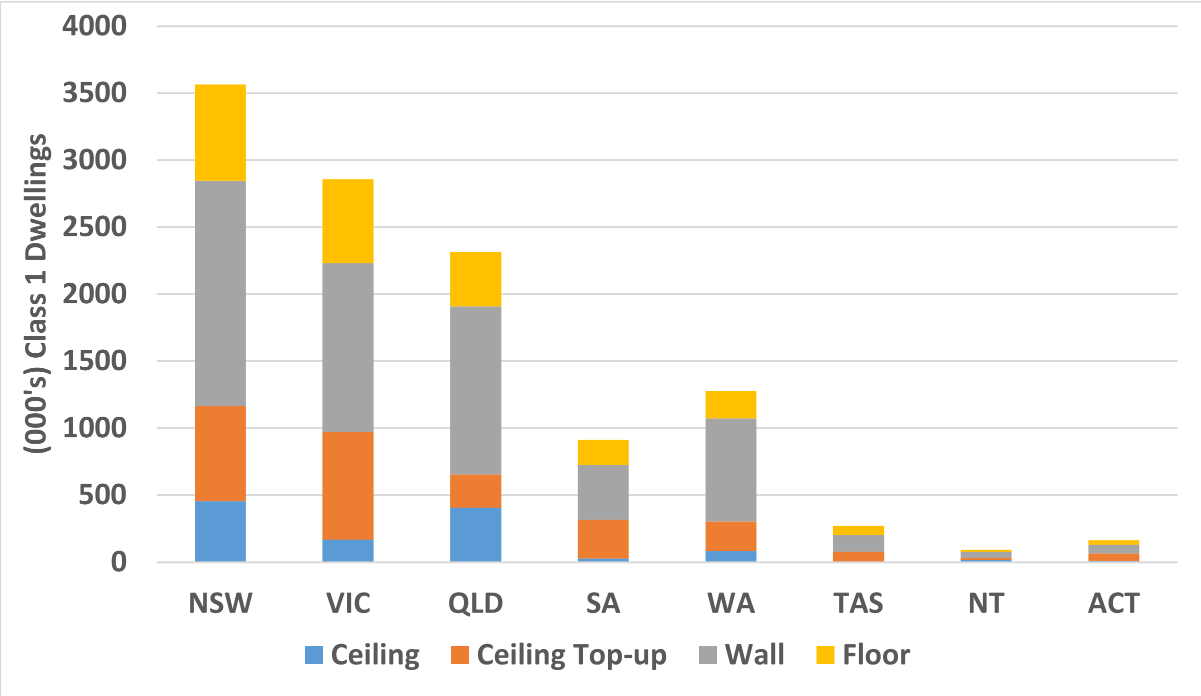
3.6 Summary of Estimated Insulation Opportunities

Based on the analysis undertaken in the preceding sub-sections of Section 3, the following Table 10 (and graphically in Figure 3) summarises the projected scope for insulation retrofit/upgrade in the Australian residential class 1 building stock in the year 2025.

Table 10: Class 1 Projected Opportunities for Class 1 Insulation Retrofit/Upgrade - 2025 (000's)

Insulation Opportunity	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Ceiling	453	168	407	27	82	2	15	8	1162
Ceiling Top-up	711	802	246	289	222	76	17	57	2436
Wall	1682	1261	1255	408	768	124	43	64	5605
Floor	718	626	407	189	203	68	17	34	2262

Figure 3: Class 1 Projected Opportunities for Insulation Retrofit/Upgrade - 2025 (000's)



4 Retrofitting Costs

The following insulation options were investigated as part of this study:

- R 4.0 To Ceiling (previously uninsulated) – GEMS Average Climate
- R 5.0 to Ceiling (previously uninsulated) – GEMS Cold and Hot Climates
- R 3.0 to Ceiling (top up over R1.0 to give R4.0 total) – GEMS Average Climate
- R 4.0 to Ceiling (top up over R1.0 to give R5.0 total) – GEMS Cold and Hot Climates
- R 2.5 Blown in silicone coated wall fill (to Brick veneer or weatherboard wall)
- R1.3 Blown in silicone coated wall fill (to Cavity brickwork – 50mm cavity)
- R 2.0 suspended timber floor insulation – GEMS Average and Hot Climates
- R 2.5 suspended timber floor insulation – GEMS Cold Climate

Estimates for the cost of the required investment in each of the energy savings measures examined in this study were determined by ICANZ for each jurisdiction via a survey of its key members and insulation installer companies. The results of that survey are shown in Table 11 . These unit prices are retail prices and include the full cost of installation.

Data was not readily available in the following cases (highlighted in blue font):

- The Northern Territory (assumed to be similar to WA)
- Top up insulation in Tasmania (assumed to be similar to Victoria)
- Wall insulation in all jurisdictions except Victoria (assumed to be similar to Victoria)

Generally, all costs are based on the installation of glasswool batt type insulation except in relation to wall insulation. In respect of wall insulation, it is assumed that blown in silicone coated glasswool or rockwool is used.

Table 11: Insulation costs (installed) per m2 of area (ICANZ 2024)

Insulation Option	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Ceiling R4.0	$20.00	$15.83	$17.50	$16.51	$14.46	$28.00	$14.46	$25.63
Ceiling R5.0	$28.46	$27.80	$28.00	$28.31	$22.76	$39.97	$22.76	$38.14
Top Up R3.0	$18.00	$13.55	$15.50	$14.98	$13.48	$26.00	$13.48	$25.00
Top Up R4.0	$20.00	$17.78	$17.50	$18.01	$16.51	$28.00	$16.51	$28.03
Wall R1.0	$43.63	$43.63	$43.63	$43.63	$43.63	$43.63	$43.63	$43.63
Wall R2.5	$51.81	$51.81	$51.81	$51.81	$51.81	$51.81	$51.81	$51.81
Floor R2.0	$31.00	$19.22	$21.40	$28.40	$29.15	$29.00	$29.15	$33.00

At present, blown-in wall insulation retrofit is somewhat of a boutique industry and as such it appears to attract a premium price. Economic analysis for this study was undertaken using the current wall insulation costs as shown in Table 11. However, consideration was given to the possibility of potential economies of scale that might be realised if a large-scale program of wall retrofit was to be instigated. In the analysis in Section 7.3 of this report, additional estimates were made of the cost effectiveness of wall insulation retrofit if a savings of 15% of the price noted in Table 11 could be realised through economies of scale.

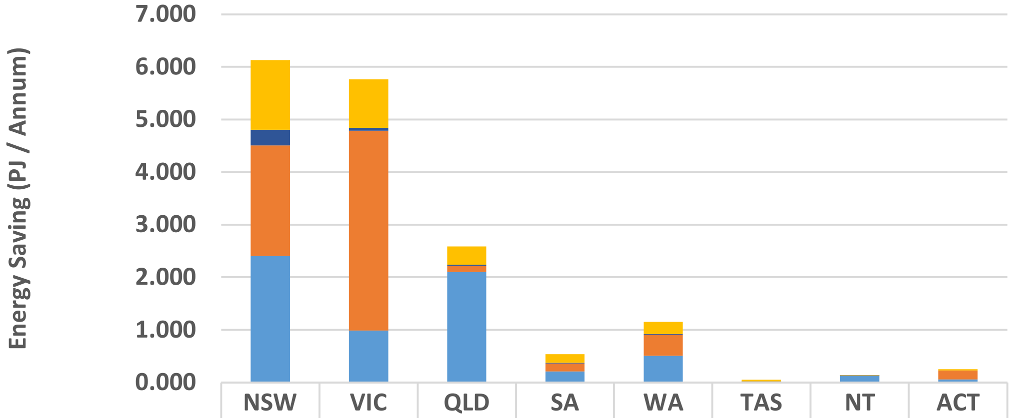
5 Modelled Benefits and Costs – Ceiling Insulation

5.1 State Level Benefits and Costs

5.1.1 Scope for energy savings

Insulating a previously uninsulated ceiling space provides scope for just over one million such upgrades across Australia (see Table 5). In terms of national energy savings, this represents a potential for saving a total of 16.6 PJ per annum, primarily in relation to electricity and natural gas (see Figure 4)

Figure 4: State level scope for energy savings - Ceiling insulation (PJ)

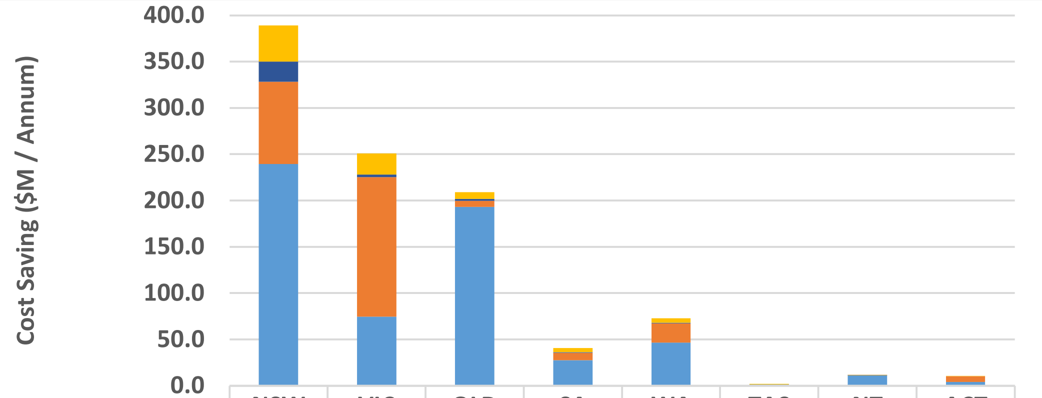


	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	6.13	5.76	2.59	0.54	1.15	0.05	0.13	0.25
Wood	1.325	0.926	0.348	0.161	0.230	0.031	0.000	0.021
LPG	0.296	0.052	0.026	0.014	0.012	0.001	0.001	0.000
Gas	2.106	3.800	0.111	0.154	0.405	0.003	0.000	0.173
Electricity	2.402	0.987	2.102	0.208	0.507	0.016	0.130	0.058

5.1.2 Scope for cost savings

In terms of national fuel cost savings, the savings in energy use represent a monetary saving nationally of approximately 1 billion dollars per annum primarily in relation to electricity and natural gas (see Figure 5).

Figure 5: State level scope for cost savings - Ceiling insulation ($M)

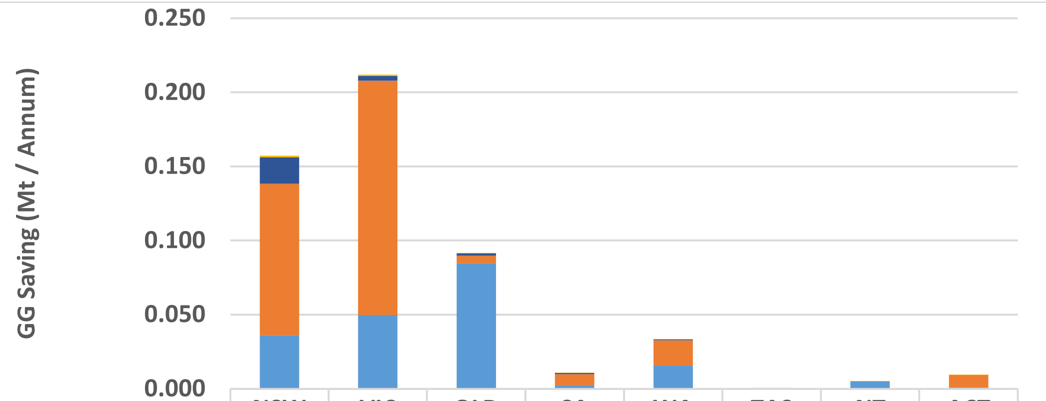


	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	388.9	250.7	209.0	40.7	72.9	2.0	11.5	10.8
Wood	39.1	22.7	7.4	4.3	5.0	0.5	0.0	0.6
LPG	21.6	2.9	1.9	1.0	0.8	0.1	0.1	0.0
Gas	88.8	150.6	6.6	7.7	20.7	0.2	0.0	6.1
Electricity	239.3	74.5	193.2	27.6	46.4	1.2	11.4	4.1

5.1.3 Scope for greenhouse gas savings

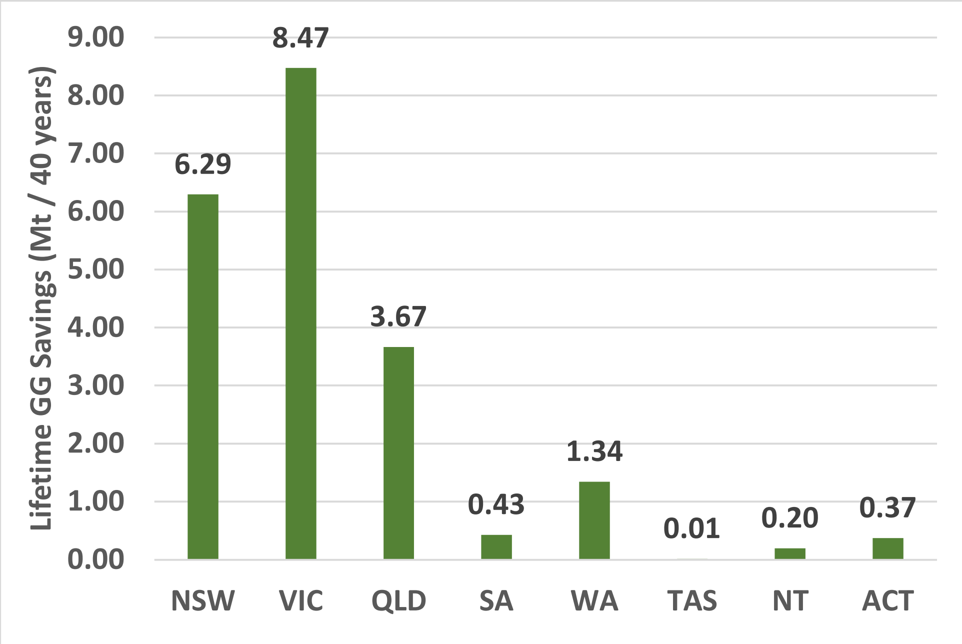
In terms of national greenhouse gas emissions savings, the savings in energy use represent a saving nationally of approximately 0.52 Mt $CO_{2\text{-}e}$ per annum primarily in relation to electricity and natural gas (see Figure 6) and lifetime savings nationally of approximately 20.8 Mt $CO_{2\text{-}e}$ (see Figure 7)

Figure 6: State level scope for annual greenhouse gas savings - Ceiling insulation (Mt CO2-e)



	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	0.157	0.212	0.092	0.011	0.034	0.0003	0.005	0.009
Wood	0.001	0.001	0.000	0.000	0.000	0.0000	0.000	0.000
LPG	0.018	0.003	0.002	0.001	0.001	0.0001	0.000	0.000
Gas	0.102	0.158	0.005	0.007	0.017	0.0001	0.000	0.008
Electricity	0.036	0.050	0.085	0.003	0.016	0.0001	0.005	0.001

Figure 7: State level scope for lifetime greenhouse gas savings - Ceiling insulation (Mt CO2-e)



5.1.4 State Level Costs

Costs to insulate all dwellings without ceiling insulation are estimated as shown in Table 12 based on the unit rates described in Section 4. These costs are split by jurisdiction and by climate zone within each jurisdiction with overall jurisdictional costs shown in the far-right hand column.

Table 12 : State Level Costs by Jurisdiction and Climate Zone – Ceiling Insulation ($M)

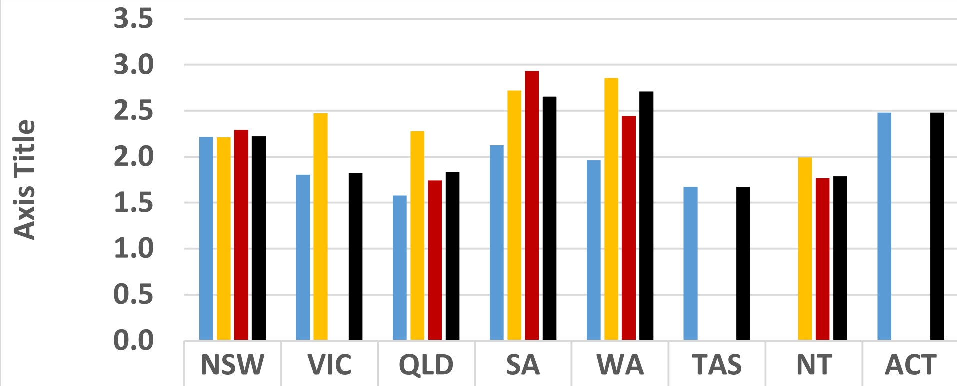
JURISDICTION	GEMS CLIMATE ZONE			OVERALL
	Cold	Average	Hot	
NSW	413	1092	255	**1760**
VIC	757	12	N/A	**769**
QLD	2	215	1651	**1868**
SA	15	68	1	**84**
WA	38	159	32	**229**
TAS	13	N/A	N/A	**13**
NT	N/A	3	52	**55**
ACT	46	N/A	N/A	**46**

5.2 Household Level Benefits and Costs

5.2.1 Improvement in NatHERS star rating

Insulating a previously uninsulated ceiling space raises the average NatHERS thermal performance rating between 1.7 to 2.7 stars, depending upon jurisdiction. The outcome also varies according to the climate zone in which the dwelling is situated – see Figure 8 (Note: zero values in this figure do not indicate zero improvement in star rating, rather, they indicate that the particular climate type is not applicable to the state or territory)

Figure 8: Household level improvement in NatHERS star rating - Ceiling insulation (Stars)

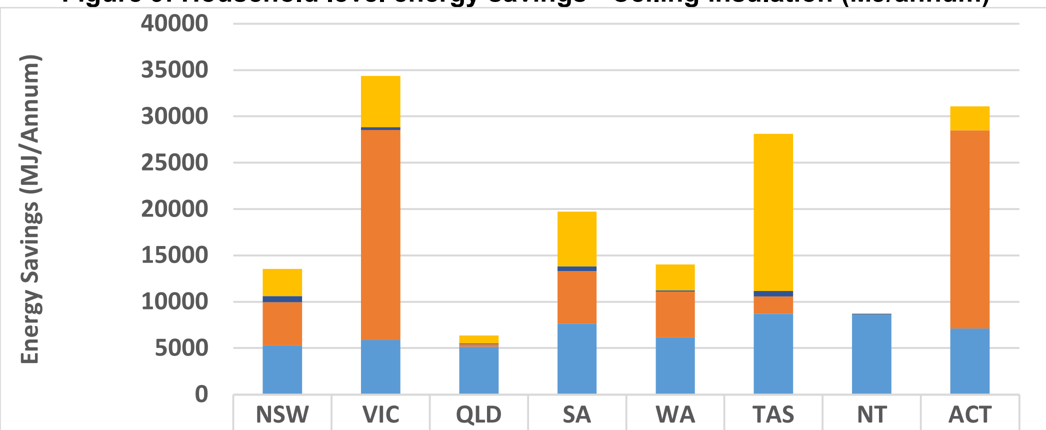


	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	2.2	1.8	1.6	2.1	2.0	1.7	0.0	2.5
Average	2.2	2.5	2.3	2.7	2.9	0.0	2.0	0.0
Hot	2.3	0.0	1.7	2.9	2.4	0.0	1.8	0.0
Overall	2.2	1.8	1.8	2.7	2.7	1.7	1.8	2.5

5.2.2 Energy savings

In terms of household energy savings, insulating a previously uninsulated ceiling space is estimated to save a state average of between 6 and 34 GJ of energy per household per annum (see Figure 9).

Figure 9: Household level energy savings - Ceiling insulation (MJ/annum)

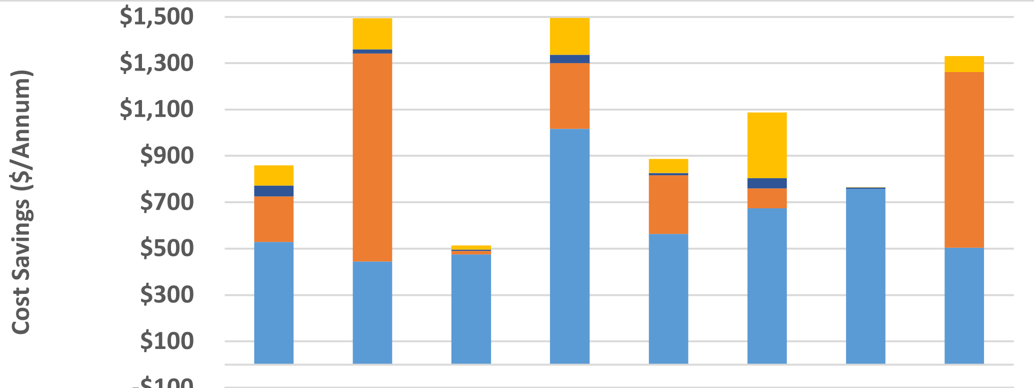


	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	13533	34356	6350	19738	14026	28129	8726	31092
Wood	2925	5516	854	5923	2800	16964	23	2592
LPG	654	311	63	510	150	596	55	0
Gas	4651	22647	272	5653	4917	1868	3	21384
Electricity	5304	5882	5160	7653	6159	8702	8645	7115

5.2.3 Cost savings

In terms of fuel cost savings, the savings in energy use represent a state average monetary saving per household of between approximately $500 and almost $1500 per household per annum (see Figure 10).

Figure 10: Household level cost savings - Ceiling insulation ($/annum)

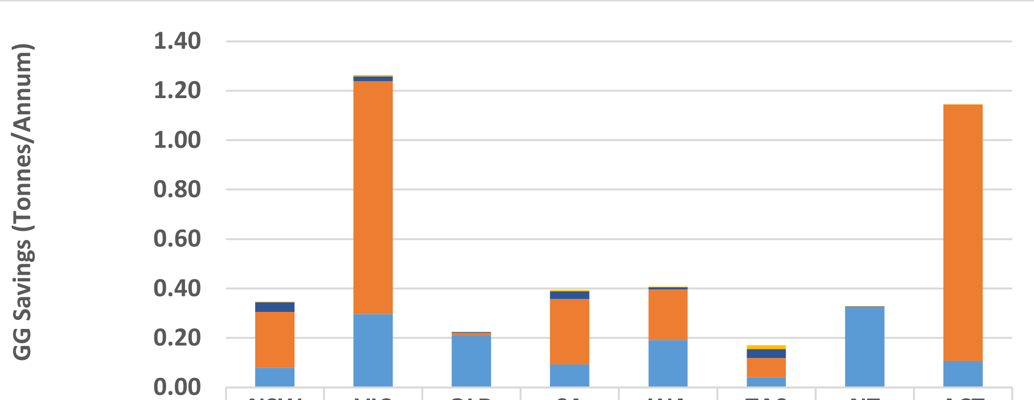


	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	$859	$1,494	$513	$1,495	$886	$1,088	$764	$1,331
Wood	$86	$135	$18	$158	$61	$283	$1	$69
LPG	$48	$17	$5	$37	$10	$45	$5	$-
Gas	$196	$898	$16	$283	$252	$87	$0	$758
Electricity	$528	$444	$474	$1,016	$564	$673	$758	$503

5.2.4 Greenhouse Gas savings

In terms of greenhouse gas emissions savings, the savings in energy use represent a state average greenhouse gas saving per household of between 0.17 and 1.26 t CO_{2-e} per annum (see Figure 11).

Figure 11: Household level greenhouse gas savings - Ceiling insulation (t CO2-e/annum)



	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	0.35	1.26	0.22	0.39	0.41	0.17	0.33	1.15
Wood	0.00	0.00	0.00	0.01	0.00	0.02	0.00	0.00
LPG	0.04	0.02	0.00	0.03	0.01	0.04	0.00	0.00
Gas	0.23	0.94	0.01	0.26	0.21	0.08	0.00	1.04
Electricity	0.08	0.30	0.21	0.09	0.19	0.04	0.32	0.11

5.2.5 Household Level Costs

Average costs to insulate per dwelling without ceiling insulation are estimated as shown in Table 13 based on the unit rates described in Section 4. These costs are split by jurisdiction and by climate zone within each jurisdiction with overall averagejurisdictional costs shown in the far-right hand column.

Table 13 : Average Costs per House by Jurisdiction and Climate Zone – Ceiling Insulation ($)

JURISDICTION	GEMS CLIMATE ZONE			OVERALL AVERAGE
	Cold	Average	Hot	
NSW	4907	3448	4907	**3887**
VIC	4642	2643	N/A	**4586**
QLD	4903	3064	4903	**4586**
SA	4864	2836	4864	**3083**
WA	3892	2473	3892	**2784**
TAS	6948	N/A	N/A	**6948**
NT	N/A	2397	3773	**3664**
ACT	5711	N/A	N/A	**5711**

5.3 Cost Effectiveness

Insulating a previously uninsulated ceiling space represents the most cost-effective insulation option examined in this study.

Cost effectiveness was gauged at both a 7% and a 3% discount rate and also with and without a price on carbon. The results of this analysis are shown below as follows:

- **Table 14** – 7% discount rate without a price on carbon: The insulation measure is cost effective in all climate zones in all jurisdictions with a B/C ratio ranging from 1.3 to 8.8 depending on jurisdiction and climate zone.
- **Table 15** – 3% discount rate without a price on carbon: The insulation measure is cost effective in all climate zones in all jurisdictions with a B/C ratio ranging from 2.0 to 13.9 depending on jurisdiction and climate zone.
- **Table 16** – 7% discount rate with a price on carbon: The insulation measure is cost effective in all climate zones in all jurisdictions with a B/C ratio ranging from 1.7 to 11.4 depending on jurisdiction and climate zone.
- **Table 17** – 3% discount rate with a price on carbon: The insulation measure is cost effective in all climate zones in all jurisdictions with a B/C ratio ranging from 2.5 to 15.8 depending on jurisdiction and climate zone.

Table 14: Cost effectiveness: w/o carbon price - Ceiling insulation (B/C – 7% Discount Rate)

Climate (GEMS)	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	3.4	4.3	2.0	5.6	3.8	2.1	N/A	3.1
Average	3.1	6.8	2.8	6.8	4.8	N/A	1.3	N/A
Hot	1.6	N/A	1.3	2.1	1.9	N/A	2.9	N/A
State Average	2.9	4.3	1.5	6.5	4.2	2.1	2.8	3.1

Table 15: Cost effectiveness: w/o carbon price - Ceiling insulation (B/C – 3% Discount Rate)

Climate (GEMS)	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	5.8	7.5	3.6	9.7	6.6	3.6	N/A	5.4
Average	5.4	11.8	4.9	11.7	8.4	N/A	2.3	N/A
Hot	2.7	N/A	2.3	3.6	3.2	N/A	5.0	N/A
State Average	5.1	7.5	2.6	11.2	7.4	3.6	4.8	5.4

Table 16: Cost effectiveness: with carbon price - Ceiling insulation (B/C – 7% Discount Rate)

Climate (GEMS)	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	3.8	5.3	2.3	6.1	4.4	2.2	N/A	3.9
Average	3.5	8.4	3.2	7.2	5.5	N/A	1.5	N/A
Hot	1.7	N/A	1.5	2.2	2.1	N/A	3.2	N/A
State Average	3.3	5.4	1.7	7.0	4.8	2.2	3.1	3.9

Table 17: Cost effectiveness: with carbon price - Ceiling insulation (B/C – 3% Discount Rate)

Climate (GEMS)	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	6.3	8.5	3.8	10.2	7.2	3.7	N/A	6.2
Average	5.7	13.4	5.2	12.2	9.0	N/A	2.5	N/A
Hot	2.9	N/A	2.5	3.8	3.4	N/A	5.3	N/A
State Average	5.4	8.6	2.8	11.7	7.9	3.7	5.2	6.2

Note: Cells above highlighted in green indicate cost effectiveness i.e. Benefit/Cost ≥ 1

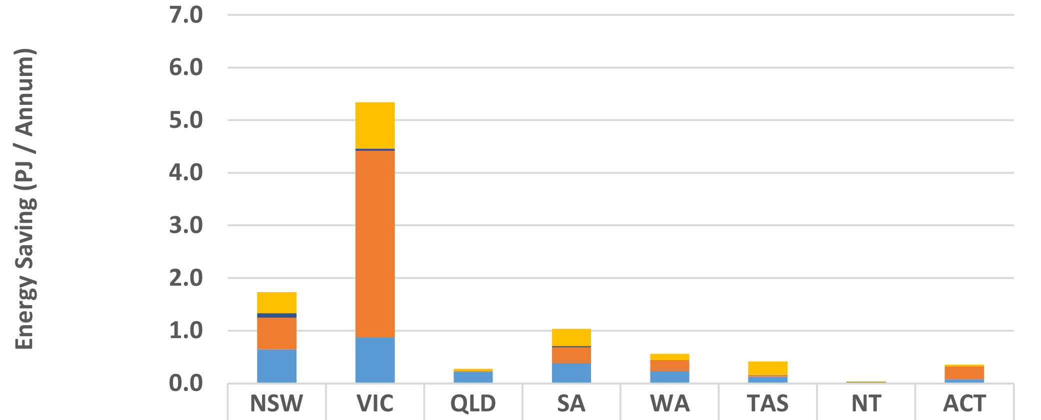
6 Modelled Benefits and Costs – Top-up Ceiling Insulation

6.1 State Level Benefits and Costs

6.1.1 Scope for energy savings

Insulating a previously insulated ceiling space with less-than-optimal insulation levels provides scope for just over 2.4 million such upgrades across Australia (see Table 6). In terms of national energy savings, this represents a potential for saving a total of 9.7 PJ per annum, primarily in relation to electricity and natural gas (see Figure 12).

Figure 12: State level scope for energy savings – Top-up ceiling insulation (PJ)

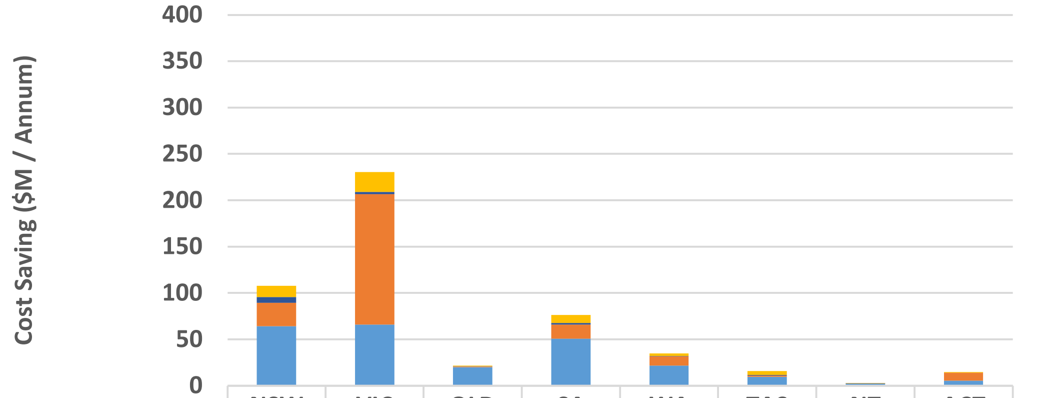


	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	1.73	5.34	0.27	1.03	0.56	0.42	0.03	0.35
Wood	0.403	0.878	0.041	0.326	0.119	0.256	0.000	0.030
LPG	0.084	0.046	0.003	0.026	0.006	0.008	0.000	0.000
Gas	0.602	3.542	0.012	0.297	0.200	0.027	0.000	0.245
Electricity	0.645	0.876	0.218	0.383	0.235	0.125	0.027	0.077

6.1.2 Scope for cost savings

In terms of national fuel cost savings, the savings in energy use represent a monetary saving nationally of approximately 0.5 billion dollars per annum primarily in relation to electricity and natural gas (see Figure 13).

Figure 13: State level scope for cost savings – Top-up Ceiling insulation ($M)

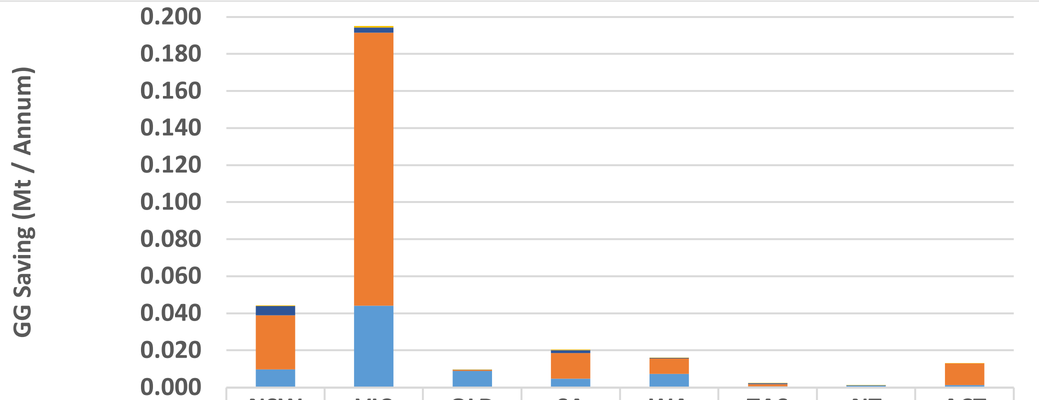


	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	107.6	230.5	21.8	76.4	34.7	15.9	2.3	14.9
Wood	11.9	21.5	0.9	8.7	2.6	4.3	0.0	0.8
LPG	6.1	2.5	0.2	1.9	0.4	0.6	0.0	0.0
Gas	25.4	140.4	0.7	14.9	10.2	1.3	0.0	8.7
Electricity	64.2	66.0	20.0	50.9	21.5	9.7	2.3	5.4

6.1.3 Scope for greenhouse gas savings

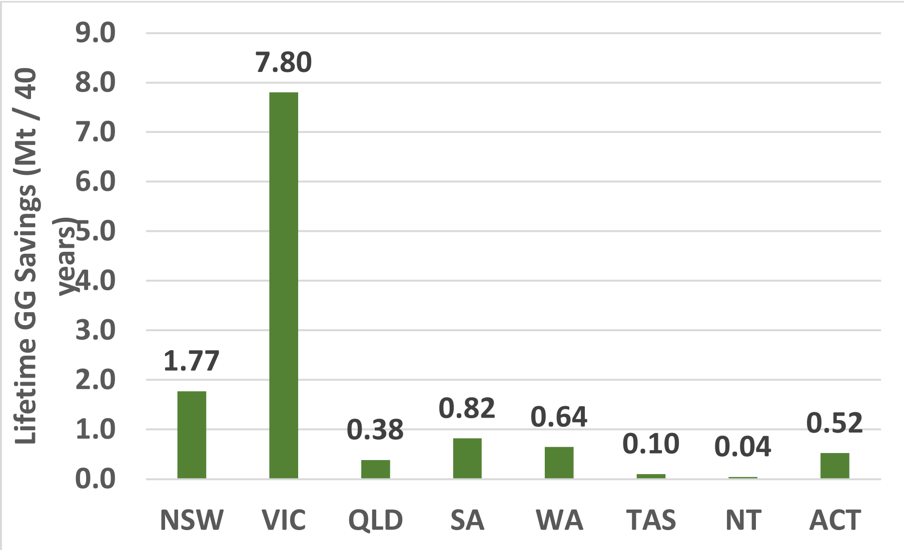
In terms of national greenhouse gas emissions savings, the savings in energy use represent a saving nationally of approximately 0.3 Mt $CO_{2\text{-}e}$ per annum primarily in relation to electricity and natural gas (see Figure 14) and lifetime savings nationally of approximately 12.1 Mt $CO_{2\text{-}e}$ (see Figure 15).

Figure 14: State level scope for annual greenhouse gas savings – Top-up Ceiling insulation (Mt CO2-e)



	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	0.044	0.195	0.010	0.020	0.016	0.002	0.001	0.013
Wood	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
LPG	0.005	0.003	0.000	0.002	0.000	0.000	0.000	0.000
Gas	0.029	0.147	0.001	0.014	0.008	0.001	0.000	0.012
Electricity	0.010	0.044	0.009	0.005	0.007	0.001	0.001	0.001

Figure 15: State level scope for lifetime greenhouse gas savings – Top-up Ceiling insulation (Mt CO2-e)



6.1.4 State Level Costs

Costs to apply top-up insulation to all dwellings without optimal levels of ceiling insulation are estimated as shown in Table 18 based on the unit rates described in Section 4. These costs are split by jurisdiction and by climate zone within each jurisdiction with overall jurisdictional costs shown in the far-right hand column.

Table 18 : State Level Costs by Jurisdiction and Climate Zone – Ceiling Top-up Insulation ($M)

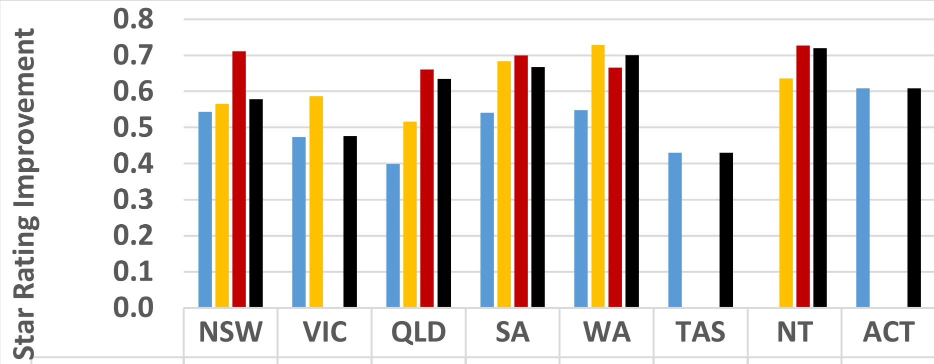
JURISDICTION	GEMS CLIMATE ZONE			OVERALL
	Cold	Average	Hot	
NSW	455	1543	282	**2280**
VIC	2314	51	N/A	**2365**
QLD	1	115	623	**739**
SA	99	653	10	**762**
WA	75	400	63	**537**
TAS	370	N/A	N/A	**370**
NT	N/A	3	43	**46**
ACT	239	N/A	N/A	**239**

6.2 Household Level Benefits and Costs

6.2.1 Improvement in NatHERS star rating

Insulating a previously, less than optimally insulated ceiling space raises the average NatHERS thermal performance rating between 0.4 to 0.7 stars depending upon jurisdiction. The outcome also varies according to the climate zone in which the dwelling is situated – see Figure 16 (Note: zero values in this figure do not indicate zero improvement in star rating, rather, they indicate that the particular climate type is not applicable to the state or territory).

Figure 16: Household level improvement in NatHERS star rating – Top-up Ceiling insulation (Stars)

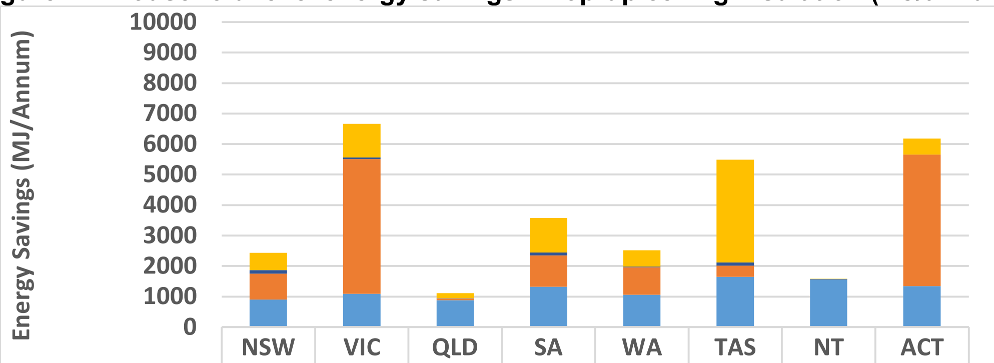


	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	0.5	0.5	0.4	0.5	0.5	0.4	0.0	0.6
Average	0.6	0.6	0.5	0.7	0.7	0.0	0.6	0.0
Hot	0.7	0.0	0.7	0.7	0.7	0.0	0.7	0.0
Overall	0.6	0.5	0.6	0.7	0.7	0.4	0.7	0.6

6.2.2 Energy savings

In terms of household energy savings, insulating a less than optimally insulated ceiling space is estimated to save a state average of between 1.1 and 6.6 GJ of energy per household per annum (see Figure 17).

Figure 17: Household level energy savings – Top-up ceiling insulation (MJ/annum)



	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	2437	6660	1114	3575	2522	5492	1574	6178
Wood	566	1095	166	1129	535	3372	4	527
LPG	118	57	12	91	27	108	10	0
Gas	846	4416	51	1029	900	362	0	4305
Electricity	908	1092	886	1326	1060	1651	1560	1346

6.2.3 *Cost savings*

In terms of fuel cost savings, the savings in energy use represent a state average monetary saving per household of between approximately $90 and $290 per household per annum (see Figure 18).

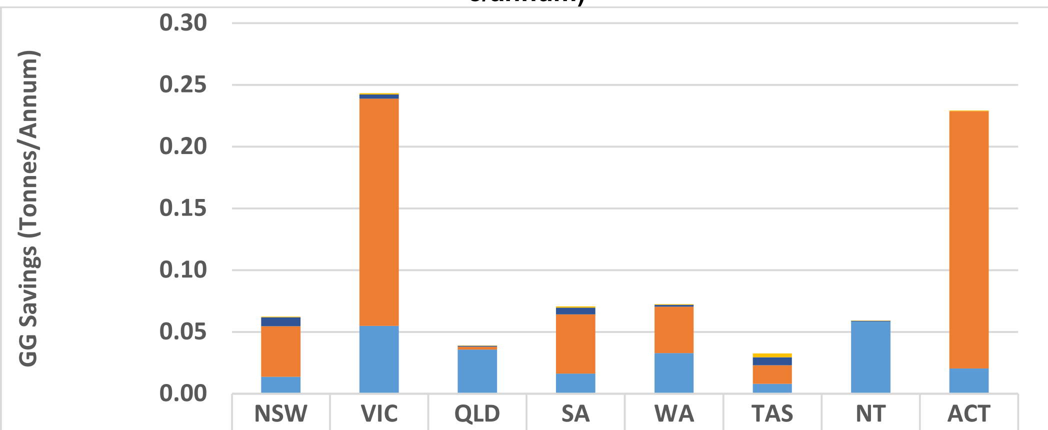
Figure 18: Household level cost savings – Top-up ceiling insulation ($/annum)

	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	$151	$287	$89	$264	$156	$209	$138	$262
Wood	$17	$27	$4	$30	$12	$56	$0	$14
LPG	$9	$3	$1	$7	$2	$8	$1	$-
Gas	$36	$175	$3	$52	$46	$17	$0	$153
Electricity	$90	$82	$81	$176	$97	$128	$137	$95

6.2.4 *Greenhouse Gas savings*

In terms of greenhouse gas emissions savings, the savings in energy use represent a state average greenhouse gas saving per household of between 0.03 and 0.24 t $CO_{2\text{-}e}$ per annum. (see Figure 19).

Figure 19: Household level greenhouse gas savings – Top-up ceiling insulation (t CO2-e/annum)



	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	0.06	0.24	0.04	0.07	0.07	0.03	0.06	0.23
Wood	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LPG	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00
Gas	0.04	0.18	0.00	0.05	0.04	0.02	0.00	0.21
Electricity	0.01	0.05	0.04	0.02	0.03	0.01	0.06	0.02

6.2.5 Household Level Costs

Average costs to top-up insulate per dwelling with sub-optimal ceiling insulation are estimated as shown in Table 19 based on the unit rates described in Section 4. These costs are split by jurisdiction and by climate zone within each jurisdiction with overall average jurisdictional costs shown in the far-right hand column.

Table 19 : Average Costs per House by Jurisdiction and Climate Zone – Top-up Ceiling Insulation ($)

JURISDICTION	GEMS CLIMATE ZONE			OVERALL AVERAGE
	Cold	Average	Hot	
NSW	3448	3103	3448	**3207**
VIC	2969	2262	N/A	**2949**
QLD	3064	2714	3064	**3004**
SA	3094	2574	3094	**2637**
WA	2823	2305	2823	**2419**
TAS	4867	N/A	N/A	**4867**
NT	N/A	2235	2737	**2697**
ACT	4197	N/A	N/A	**4197**

6.3 Cost Effectiveness

Applying top up insulation to a less than optimally insulated ceiling space represents a cost-effective insulation option in a wide range of jurisdictions and climate zones.

Cost effectiveness was gauged at both a 7% and a 3% discount rate and also with and without a price on carbon. The results of this analysis are shown below as follows:

- **Table 20**– 7% discount rate without a price on carbon: The insulation measure is on average cost effective in Victoria and South Australia. Also cost effective in the colder regions of WA.
- **Table 21–** 3% discount rate without a price on carbon: The insulation measure is on average cost effective in all jurisdictions except Queensland. Generally, the measure is not cost effective in the hot climate zones, excepting in the NT
- **Table 22**– 7% discount rate with a price on carbon: The insulation measure is on average cost effective in Victoria, South Australia, WA and ACT and the colder region of NSW.
- **Table 23**– 3% discount rate with a price on carbon: The insulation measure is on average cost effective in all jurisdictions except Queensland. Generally, the measure is not cost effective in the hot climate zones, excepting in the hot zones in the NT and SA

Table 20: Cost effectiveness: w/o carbon price - Top-up ceiling insulation (B/C – 7% Discount Rate)

Climate (GEMS)	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	0.9	1.3	0.6	1.6	1.0	0.6	N/A	0.8
Average	0.6	1.4	0.5	1.3	0.9	N/A	0.2	N/A
Hot	0.4	N/A	0.4	0.5	0.4	N/A	0.7	N/A
State Average	0.6	1.3	0.4	1.3	0.9	0.6	0.7	0.8

Table 21: Cost effectiveness: w/o carbon price - Top-up ceiling insulation (B/C – 3% Discount Rate)

Climate (GEMS)	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	1.6	2.2	1.1	2.9	1.7	1.0	N/A	1.4
Average	1.0	2.5	0.9	2.3	1.6	N/A	0.4	N/A
Hot	0.7	N/A	0.6	0.9	0.7	N/A	1.2	N/A
State Average	1.1	2.3	0.7	2.3	1.5	1.0	1.2	1.4

Table 22: Cost effectiveness: with carbon price - Top-up ceiling insulation (B/C – 7% Discount Rate)

Climate (GEMS)	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	1.0	1.6	0.7	1.8	1.1	0.6	N/A	1.0
Average	0.7	1.8	0.6	1.4	1.0	N/A	0.2	N/A
Hot	0.4	N/A	0.4	0.6	0.5	N/A	0.8	N/A
State Average	0.7	1.6	0.4	1.4	1.0	0.6	0.8	1.0

Table 23: Cost effectiveness: with carbon price - Top-up ceiling insulation (B/C – 3% Discount Rate)

Climate (GEMS)	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	1.7	2.6	1.1	3.0	1.9	1.0	N/A	1.7
Average	1.1	2.8	1.0	2.4	1.7	N/A	0.4	N/A
Hot	0.7	N/A	0.7	1.0	0.8	N/A	1.3	N/A
State Average	1.2	2.6	0.7	2.4	1.6	1.0	1.3	1.7

Note: Cells above highlighted in green indicate cost effectiveness i.e. Benefit/Cost ≥ 1

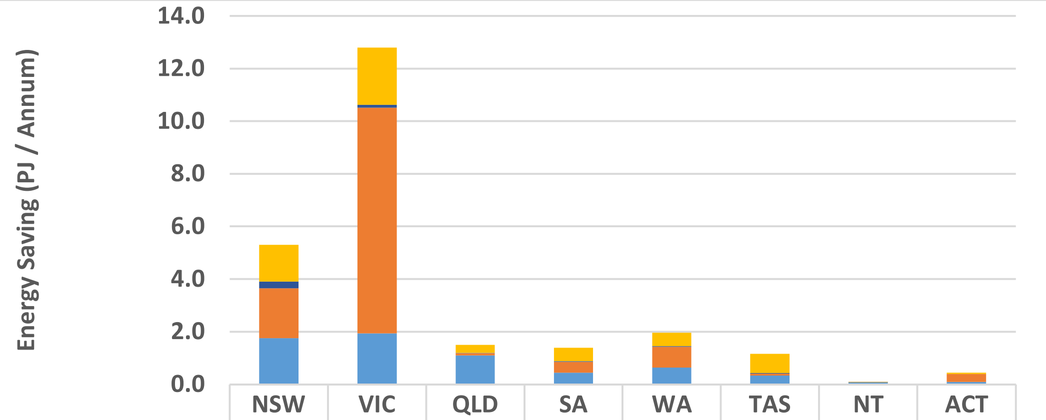
7 Modelled Benefits and Costs – Wall Insulation

7.1 State Level Benefits and Costs

7.1.1 Scope for energy savings

Insulating a previously uninsulated wall space provides scope for 5.6 million such upgrades across Australia (see Table 7). In terms of national energy savings, this represents a potential for saving a total of 24.6 PJ per annum, primarily in relation to electricity and natural gas (see Figure 20).

Figure 20: State level scope for energy savings - Wall insulation (PJ)

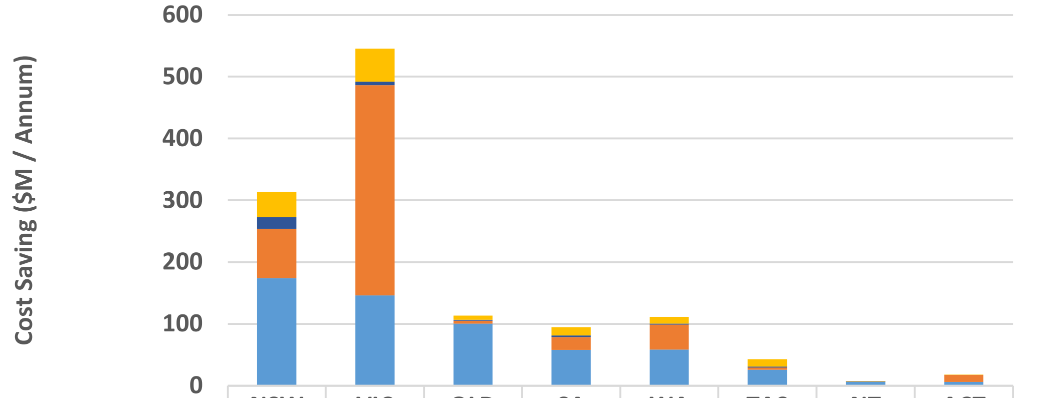


	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	5.30	12.79	1.50	1.38	1.96	1.16	0.07	0.44
Wood	1.395	2.175	0.302	0.501	0.510	0.725	0.000	0.038
LPG	0.257	0.101	0.019	0.035	0.023	0.021	0.000	0.000
Gas	1.889	8.582	0.085	0.411	0.785	0.075	0.000	0.309
Electricity	1.755	1.936	1.091	0.437	0.640	0.334	0.073	0.089

7.1.2 Scope for cost savings

In terms of national fuel cost savings, the savings in energy use represent a monetary saving nationally of approximately 1.25 billion dollars per annum primarily in relation to electricity and natural gas (see Figure 21).

Figure 21: State level scope for cost savings - Wall insulation ($M)

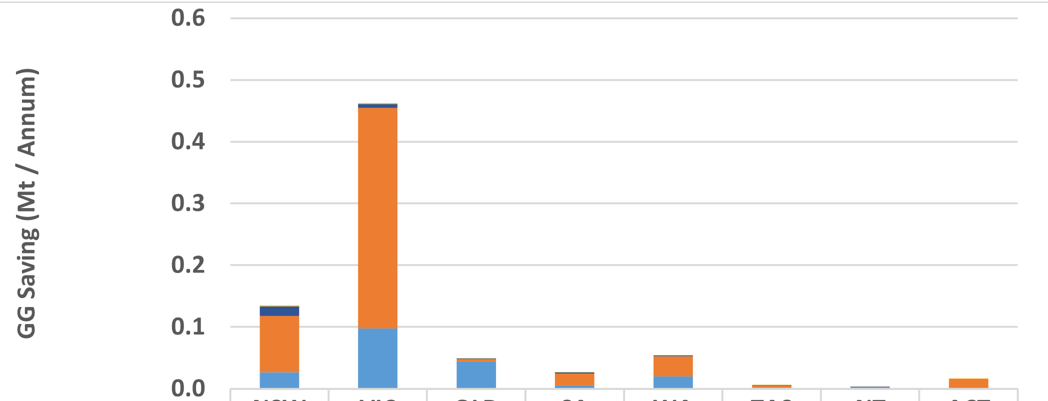


	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	313.6	544.9	113.1	94.5	111.4	43.0	6.4	18.3
Wood	41.2	53.3	6.4	13.4	11.1	12.1	0.0	1.0
LPG	18.8	5.6	1.4	2.6	1.5	1.5	0.0	0.0
Gas	79.6	340.2	5.0	20.6	40.3	3.5	0.0	10.9
Electricity	174.0	145.8	100.3	57.9	58.5	25.9	6.4	6.3

7.1.3 Scope for greenhouse gas savings

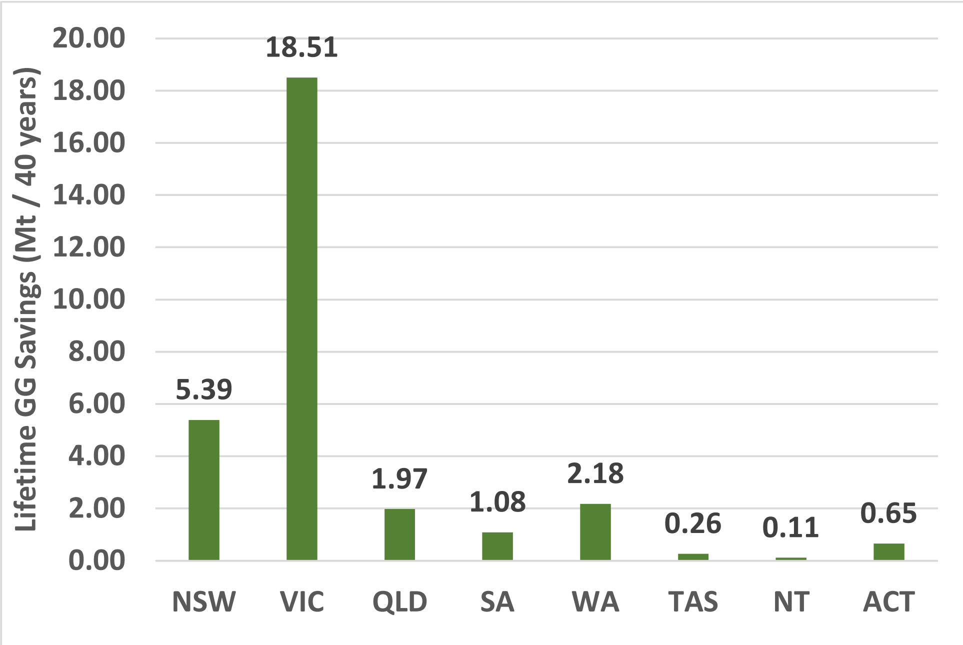
In terms of national greenhouse gas emissions savings, the savings in energy use represent a saving nationally of approximately 0.8 Mt $CO_{2\text{-}e}$ per annum primarily in relation to electricity and natural gas (see Figure 22) and lifetime savings nationally of approximately 30.2 Mt $CO_{2\text{-}e}$ (see Figure 23).

Figure 22: State level scope for annual greenhouse gas savings - Wall insulation (Mt CO2-e)



	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	0.135	0.463	0.049	0.027	0.054	0.007	0.003	0.016
Wood	0.001	0.002	0.000	0.000	0.000	0.001	0.000	0.000
LPG	0.016	0.006	0.001	0.002	0.001	0.001	0.000	0.000
Gas	0.092	0.357	0.004	0.019	0.033	0.003	0.000	0.015
Electricity	0.026	0.097	0.044	0.005	0.020	0.002	0.003	0.001

Figure 23: State level scope for lifetime greenhouse gas savings - Wall insulation (Mt CO2-e)



7.1.4 State Level Costs

Costs to insulate all dwellings without wall insulation are estimated as shown in Table 24 based on the unit rates described in Section 4. These costs are split by jurisdiction and by climate zone within each jurisdiction with overall jurisdictional costs shown in the far-right hand column.

Table 24 : State Level Costs by Jurisdiction and Climate Zone – Wall Insulation ($M)

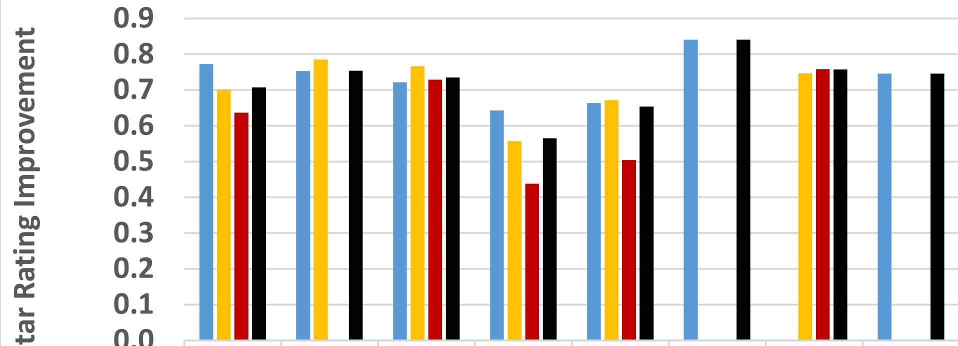
JURISDICTION	GEMS CLIMATE ZONE			OVERALL
	Cold	Average	Hot	
NSW	2030	7642	1256	**10928**
VIC	7684	221	N/A	**7906**
QLD	9	1481	7095	**8585**
SA	251	2004	26	**2281**
WA	549	3598	461	**4607**
TAS	816	N/A	N/A	**816**
NT	N/A	21	241	**262**
ACT	366	N/A	N/A	**366**

7.2 Household Level Benefits and Costs

7.2.1 Improvement in NatHERS star rating

Insulating a previously uninsulated wall space raises the average NatHERS thermal performance rating between 0.6 to 0.8 stars depending upon jurisdiction. The outcome also varies according to the climate zone in which the dwelling is situated – see Figure 24 (Note: zero values in this figure do not indicate zero improvement in star rating, rather, they indicate that the particular climate type is not applicable to the state or territory).

Figure 24: Household level improvement in NatHERS star rating - Wall insulation (Stars)

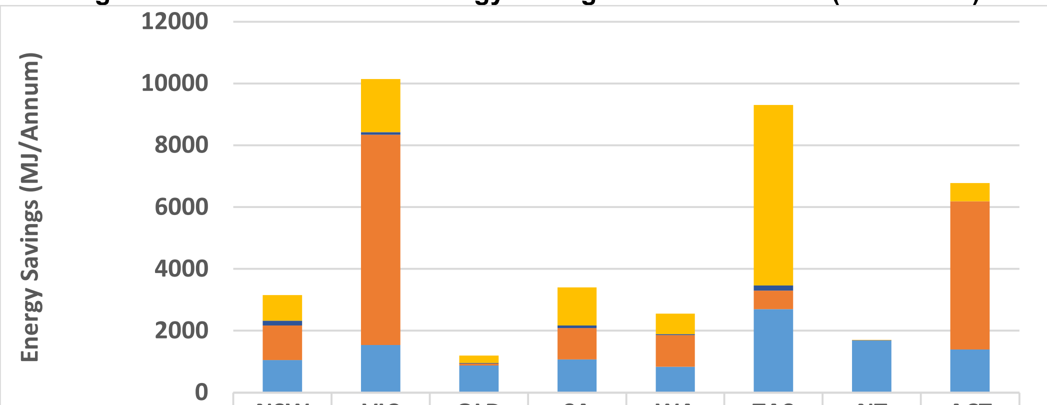


	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	0.8	0.8	0.7	0.6	0.7	0.8	0.0	0.7
Average	0.7	0.8	0.8	0.6	0.7	0.0	0.7	0.0
Hot	0.6	0.0	0.7	0.4	0.5	0.0	0.8	0.0
Overall	0.7	0.8	0.7	0.6	0.7	0.8	0.8	0.7

7.2.2 Energy savings

In terms of household energy savings, insulating a previously uninsulated Wall space is estimated to save a state average of between 1.1 and 10.1 GJ of energy per household per annum (see Figure 25).

Figure 25: Household level energy savings - Wall insulation (MJ/annum)

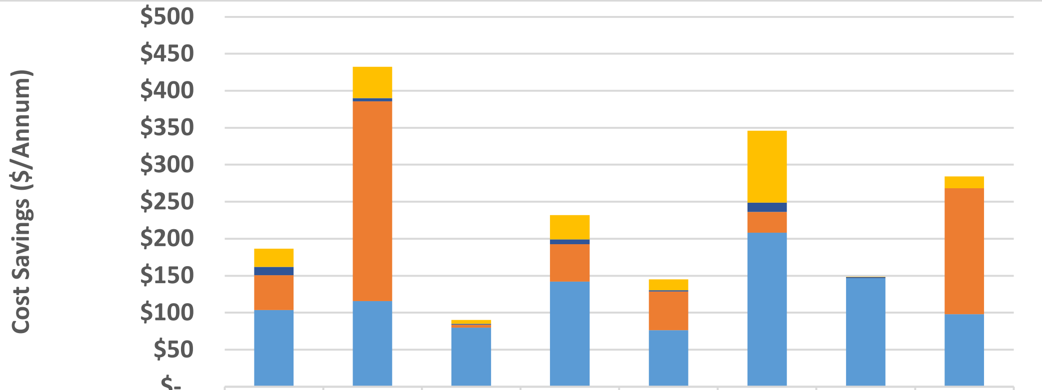


	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	3149	10147	1193	3395	2550	9301	1692	6780
Wood	830	1725	241	1228	664	5835	5	595
LPG	153	80	15	86	31	166	11	0
Gas	1123	6806	68	1009	1023	607	1	4798
Electricity	1043	1536	869	1072	833	2693	1675	1387

7.2.3 *Cost savings*

In terms of fuel cost savings, the savings in energy use represent a state average monetary saving per household of between approximately $90 and $430 per household per annum (see Figure 26).

Figure 26: Household level cost savings - Wall insulation ($/annum)

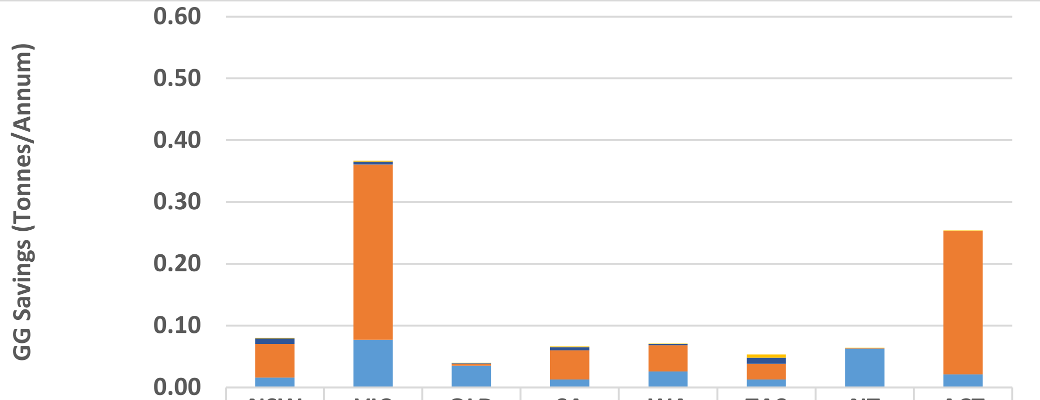


	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	$186	$432	$90	$232	$145	$346	$148	$284
Wood	$24	$42	$5	$33	$14	$97	$0	$16
LPG	$11	$4	$1	$6	$2	$12	$1	$-
Gas	$47	$270	$4	$51	$52	$28	$0	$170
Electricity	$103	$116	$80	$142	$76	$208	$147	$98

7.2.4 *Greenhouse Gas savings*

In terms of greenhouse gas emissions savings, the savings in energy use represent a state average greenhouse gas saving per household of between 0.05 and 0.37 t CO_{2-e} per annum (see Figure 27).

Figure 27: Household level greenhouse gas savings - Wall insulation (t CO2-e/annum)



	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	0.08	0.37	0.04	0.07	0.07	0.05	0.06	0.25
Wood	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
LPG	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00
Gas	0.05	0.28	0.00	0.05	0.04	0.03	0.00	0.23
Electricity	0.02	0.08	0.04	0.01	0.03	0.01	0.06	0.02

7.2.5 Household Level Costs

Average costs to insulate per dwelling without wall insulation are estimated as shown in Table 25 based on the unit rates described in Section 4. These costs are split by jurisdiction and by climate zone within each jurisdiction with overall average jurisdictional costs shown in the far-right hand column.

Table 25 : Average Costs per House by Jurisdiction and Climate Zone – Wall Insulation ($)

JURISDICTION	GEMS CLIMATE ZONE			OVERALL AVERAGE
	Cold	Average	Hot	
NSW	6499	6499	6499	**6499**
VIC	6270	6270	N/A	**6270**
QLD	6839	6839	6839	**6839**
SA	5597	5597	5597	**5597**
WA	5999	5999	5999	**5999**
TAS	6567	N/A	N/A	**6567**
NT	N/A	6045	6045	**6045**
ACT	5698	N/A	N/A	**5698**

7.3 Cost Effectiveness

Insulating a previously uninsulated wall space is a cost-effective insulation option in a wide range of jurisdictions and climate zones.

Cost effectiveness was gauged at both a 7% and a 3% discount rate and also with and without a price on carbon. In the following tables results are shown for the case relating to wall insulation at its full cost of installation (cost effective results highlighted in dark green). Those results below 1.0 that are highlighted in pale green represent cost effective cases where the cost of installation is reduced by 15% should economies of scale be realised (see Section 4).

- **Table 26**– 7% discount rate without a price on carbon: The insulation measure is on average not cost effective. If a 15% economy of scale price reduction can be achieved, then the measure would be cost effective in Victoria and the cold climate region of SA only.
- **Table 27–** 3% discount rate without a price on carbon: The insulation measure is on average cost effective in Victoria, South Australia, Tasmania and the ACT and cost effective in the colder regions of NSW. If a 15% economy of scale price reduction can be achieved, then the measure would also be cost effective in the average climate zone of SA and the cold climate zone of WA
- **Table 28**– 7% discount rate with a price on carbon: The insulation measure is on average cost effective in Victoria the colder regions only of SA. If a 15% economy of scale price reduction can be achieved, then the measure would also be cost effective in the ACT.
- **Table 29**– 3% discount rate with a price on carbon: The insulation measure is on average cost effective in Victoria, South Australia, Tasmania and the ACT and cost effective in the colder regions of NSW and WA. If a 15% economy of scale price reduction can be achieved, then the measure would also be cost effective in the average climate zone of SA.

Table 26: Cost effectiveness: w/o carbon price - Wall insulation (B/C – 7% Discount Rate)

Climate (GEMS)	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	0.6	0.9	0.4	0.9	0.5	0.7	N/A	0.7
Average	0.3	0.8	0.3	0.5	0.3	N/A	0.1	N/A
Hot	0.2	N/A	0.2	0.2	0.2	N/A	0.3	N/A
State Average	0.4	0.9	0.2	0.6	0.3	0.7	0.3	0.7

Table 27: Cost effectiveness: w/o carbon price - Wall insulation (B/C – 3% Discount Rate)

Climate (GEMS)	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	1.1	1.6	0.7	1.6	0.9	1.2	N/A	1.2
Average	0.6	1.3	0.5	0.9	0.5	N/A	0.1	N/A
Hot	0.3	N/A	0.3	0.3	0.3	N/A	0.6	N/A
State Average	0.7	1.6	0.3	1.0	0.6	1.2	0.6	1.2

Table 28: Cost effectiveness: with carbon price - Wall insulation (B/C – 7% Discount Rate)

Climate (GEMS)	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	0.7	1.1	0.5	1.0	0.6	0.7	N/A	0.8
Average	0.4	0.9	0.3	0.6	0.4	N/A	0.1	N/A
Hot	0.2	N/A	0.2	0.2	0.2	N/A	0.4	N/A
State Average	0.4	1.1	0.2	0.6	0.4	0.7	0.4	0.8

Table 29: Cost effectiveness: with carbon price - Wall insulation (B/C – 3% Discount Rate)

Climate (GEMS)	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	1.2	1.8	0.8	1.7	1.0	1.2	N/A	1.3
Average	0.6	1.5	0.5	0.9	0.6	N/A	0.2	N/A
Hot	0.4	N/A	0.3	0.3	0.3	N/A	0.6	N/A
State Average	0.7	1.8	0.3	1.0	0.6	1.2	0.6	1.3

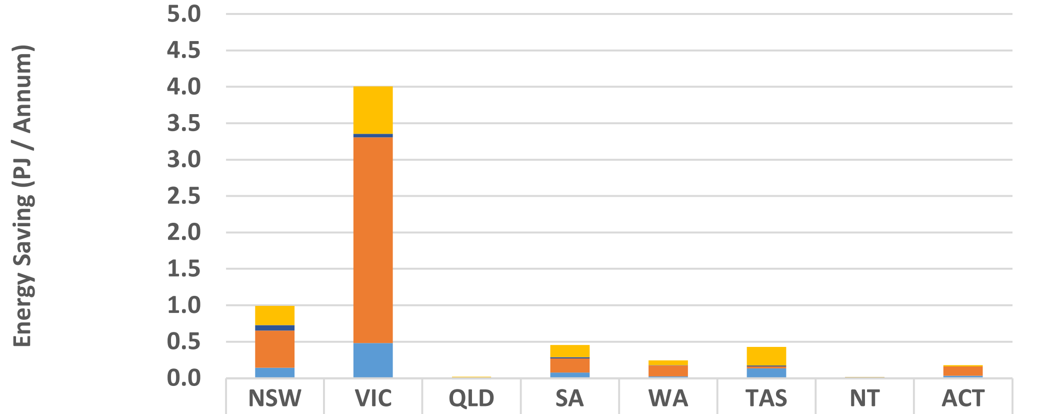
8 Modelled Benefits and Costs – Floor Insulation

8.1 State Level Benefits and Costs

8.1.1 Scope for energy savings

Insulating a previously uninsulated floor space provides scope for an estimated 2.3 million such upgrades across Australia (see Table 8). In terms of national energy savings, this represents a potential for saving a total of 6.3 PJ per annum, primarily in relation to electricity and natural gas (see Figure 28).

Figure 28: State level scope for energy savings - Floor insulation (PJ)

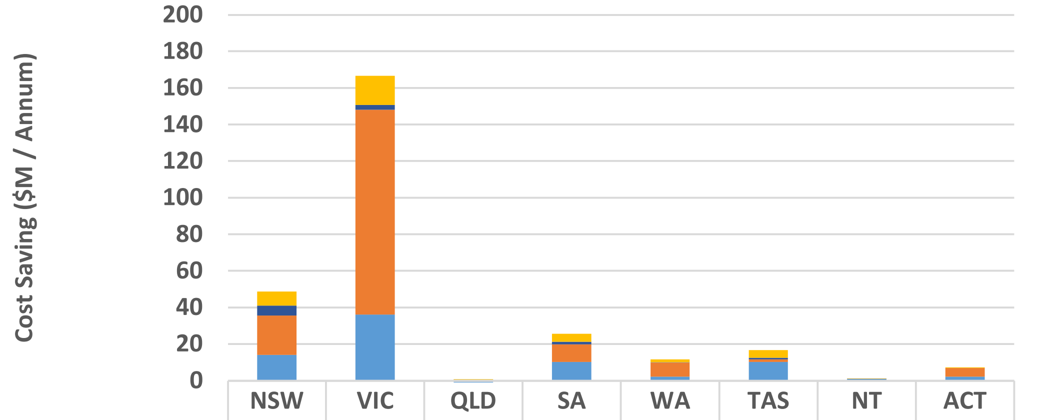


	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	0.99	4.00	0.01	0.45	0.24	0.43	0.01	0.18
Wood	0.263	0.652	0.013	0.168	0.066	0.256	0.000	0.015
LPG	0.074	0.046	0.001	0.018	0.005	0.011	0.000	0.000
Gas	0.509	2.827	0.005	0.192	0.149	0.030	0.000	0.131
Electricity	0.144	0.480	-0.012	0.077	0.023	0.132	0.011	0.031

8.1.2 Scope for cost savings

In terms of national fuel cost savings, the savings in energy use represent a monetary saving nationally of approximately 277 million dollars per annum primarily in relation to electricity and natural gas (see Figure 29). Note that in hotter climates such as Queensland, the statewide benefit can be a negative value as floor insulation offers little benefit in such climates (sometimes even a disbenefit). In the climate level breakdown data for Queensland there is in fact an observable benefit in the “average” climate zone areas, but this is outweighed by the disbenefit in the “hot” climate zone areas.

Figure 29: State level scope for cost savings - Floor insulation ($M)

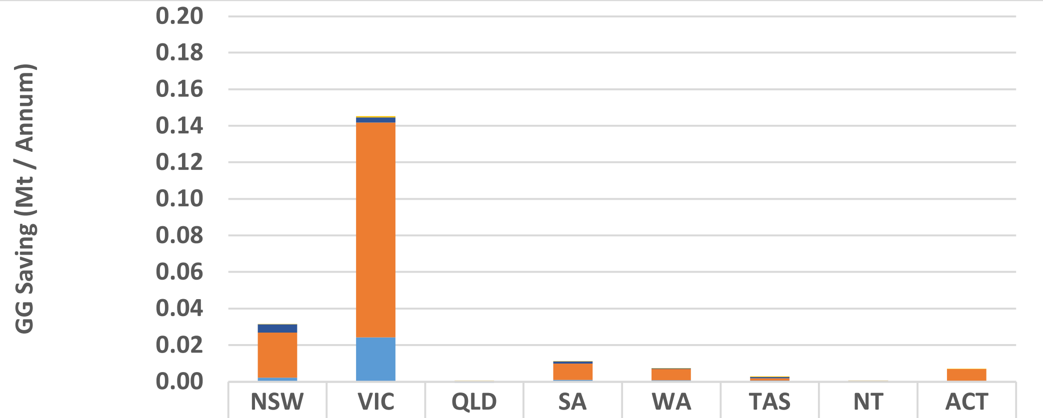


	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	48.7	166.6	-0.4	25.6	11.5	16.7	0.9	7.2
Wood	7.8	16.0	0.3	4.5	1.4	4.3	0.0	0.4
LPG	5.4	2.6	0.1	1.3	0.3	0.8	0.0	0.0
Gas	21.5	112.1	0.3	9.6	7.6	1.4	0.0	4.7
Electricity	14.0	36.0	-1.1	10.2	2.1	10.2	0.9	2.2

8.1.3 Scope for greenhouse gas savings

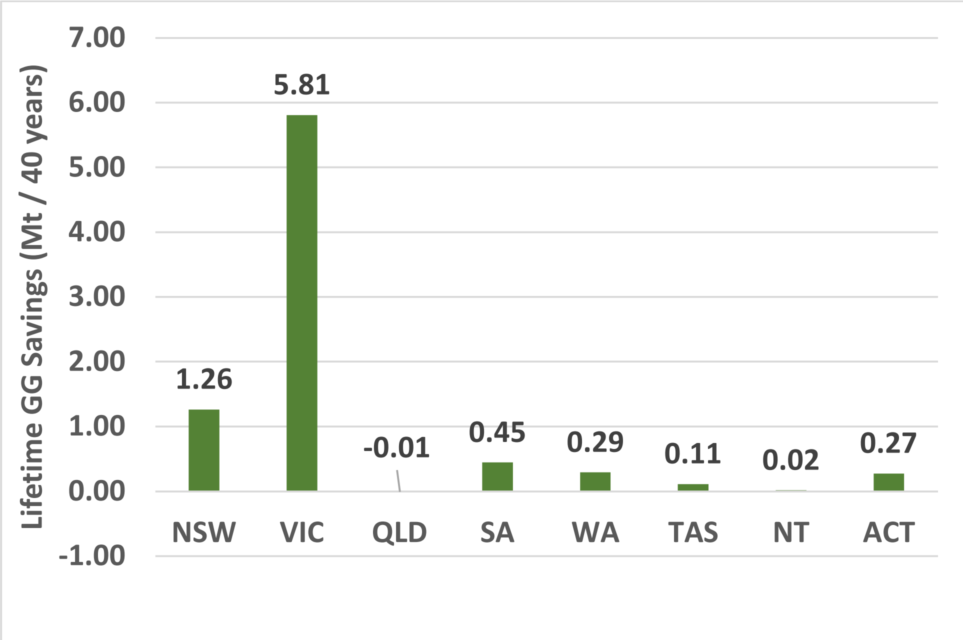
In terms of national greenhouse gas emissions savings, the savings in energy use represent a saving nationally of approximately 0.21 Mt $CO_{2\text{-}e}$ per annum primarily in relation to electricity and natural gas (see Figure 30) and lifetime savings nationally of approximately 6.2 Mt $CO_{2\text{-}e}$ (see Figure 31).

Figure 30: State level scope for annual greenhouse gas savings - Floor insulation (Mt CO2-e)



	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	0.032	0.145	0.000	0.011	0.007	0.003	0.000	0.007
Wood	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
LPG	0.004	0.003	0.000	0.001	0.000	0.001	0.000	0.000
Gas	0.025	0.118	0.000	0.009	0.006	0.001	0.000	0.006
Electricity	0.002	0.024	-0.001	0.001	0.001	0.001	0.000	0.000

Figure 31: State level scope for lifetime greenhouse gas savings - Floor insulation (Mt CO2-e)



8.1.4 State Level Costs

Costs to insulate all dwellings without floor insulation are estimated as shown in Table 30 based on the unit rates described in Section 4. These costs are split by jurisdiction and by climate zone within each jurisdiction with overall jurisdictional costs shown in the far-right hand column.

Table 30 : State Level Costs by Jurisdiction and Climate Zone – Floor Insulation ($M)

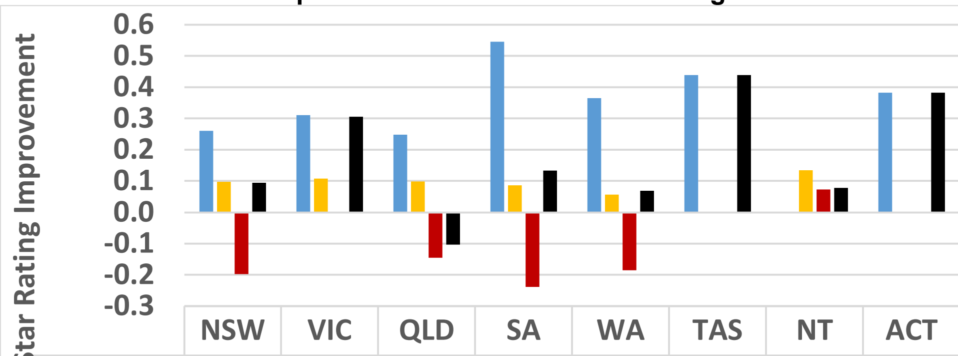
JURISDICTION	GEMS CLIMATE ZONE			OVERALL
	Cold	Average	Hot	
NSW	713	2684	441	**3837**
VIC	2436	56	N/A	**2493**
QLD	2	263	1261	**1526**
SA	113	811	10	**935**
WA	131	791	101	**1023**
TAS	353	N/A	N/A	**353**
NT	N/A	7	76	**82**
ACT	184	N/A	N/A	**184**

8.2 Household Level Benefits and Costs

8.2.1 Improvement in NatHERS star rating

Insulating a previously uninsulated floor space raises the average NatHERS thermal; performance rating between 0.1 to 0.4 stars depending upon jurisdiction. The outcome also varies according to the climate zone in which the dwelling is situated – see Figure 32 (Note: zero values in this figure do not indicate zero improvement in star rating, rather, they indicate that the particular climate type is not applicable to the state or territory). As can be seen from this figure, floor insulation is generally not beneficial in any of the GEMS hot climate zones but does provide benefits in the other two climate zones, particularly the GEM cold zones in each jurisdiction.

Figure 32: Household level improvement in NatHERS star rating - Floor insulation (Stars)

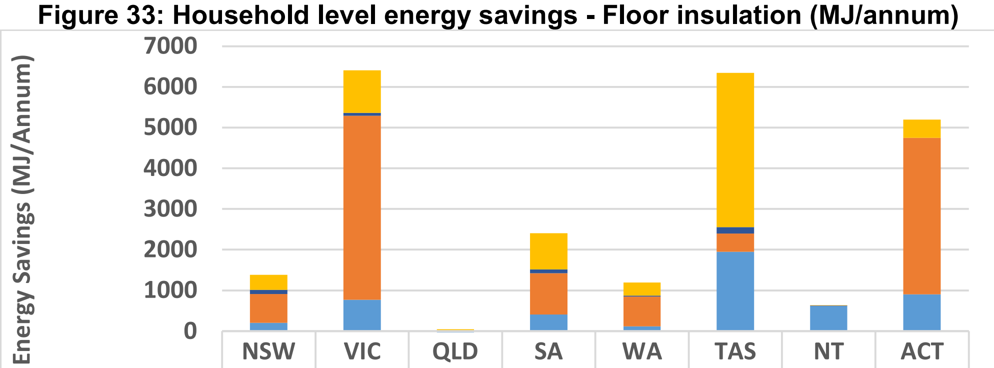


	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	0.3	0.3	0.2	0.5	0.4	0.4	0.0	0.4
Average	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.0
Hot	-0.2	0.0	-0.1	-0.2	-0.2	0.0	0.1	0.0
Overall	0.1	0.3	-0.1	0.1	0.1	0.4	0.1	0.4

8.2.2 Energy savings

In terms of household energy savings, insulating a previously uninsulated Floor space is estimated to save a state average ranging from virtually no savings in the case of Queensland to as much as 6.4 GJ of energy per household per annum in colder climates such as Victoria and Tasmania (see Figure 33).

Figure 33: Household level energy savings - Floor insulation (MJ/annum)

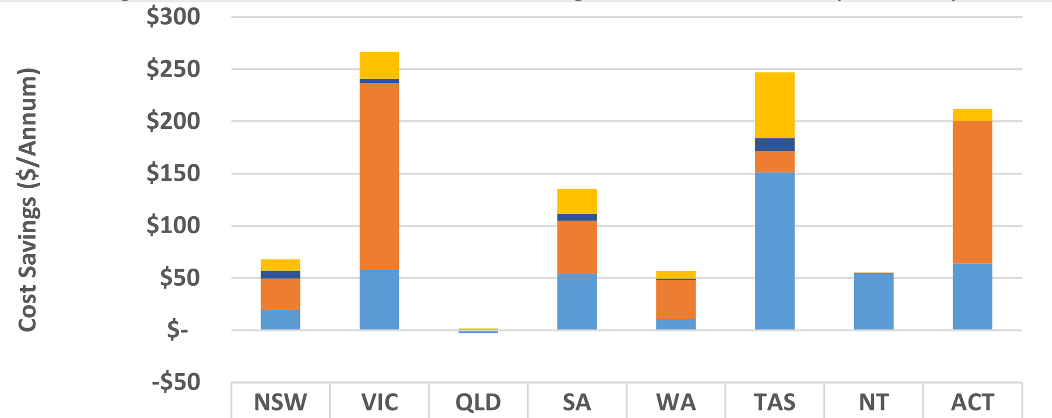


	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	1379	6402	18	2403	1197	6346	626	5195
Wood	366	1042	32	886	327	3789	1	446
LPG	103	74	3	96	23	162	4	0
Gas	709	4519	13	1012	732	443	0	3846
Electricity	201	767	-31	409	115	1952	620	903

8.2.3 *Cost savings*

In terms of fuel cost savings, the savings in energy use represent a state average monetary saving per household ranging from virtually no savings in the case of Queensland to as much as $266 per household per annum in colder climates such as Victoria and Tasmania (see Figure 34).

Figure 34: Household level cost savings - Floor insulation ($/annum)

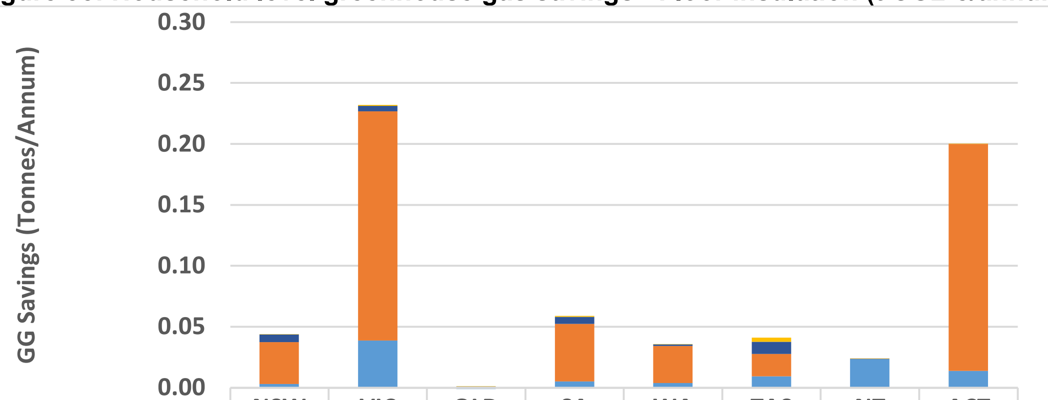


	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	$68	$266	-$1	$135	$57	$247	$55	$212
Wood	$11	$26	$1	$24	$7	$63	$0	$12
LPG	$8	$4	$0	$7	$1	$12	$0	$-
Gas	$30	$179	$1	$51	$38	$21	$0	$136
Electricity	$20	$58	-$3	$54	$11	$151	$54	$64

8.2.4 *Greenhouse Gas savings*

In terms of greenhouse gas emissions savings, the savings in energy use represent a state average greenhouse gas saving per household ranging from virtually no savings in the case of Queensland to as much as 0.23 t CO_{2-e} per annum in the case of Victoria (see Figure 35).

Figure 35: Household level greenhouse gas savings - Floor insulation (t CO2-e/annum)



	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Total	0.04	0.23	0.00	0.06	0.04	0.04	0.02	0.20
Wood	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LPG	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.00
Gas	0.03	0.19	0.00	0.05	0.03	0.02	0.00	0.19
Electricity	0.00	0.04	0.00	0.00	0.00	0.01	0.02	0.01

8.2.5 Household Level Costs

Average costs to insulate per dwelling without floor insulation are estimated as shown in Table 31 based on the unit rates described in Section 4. These costs are split by jurisdiction and by climate zone within each jurisdiction with overall average jurisdictional costs shown in the far-right hand column.

Table 31 : Average Costs per House by Jurisdiction and Climate Zone – Floor Insulation ($)

JURISDICTION	GEMS CLIMATE ZONE			OVERALL AVERAGE
	Cold	Average	Hot	
NSW	5345	5345	5345	**5345**
VIC	4007	3209	N/A	**3985**
QLD	4378	3747	3747	**3748**
SA	5412	4879	4879	**4938**
WA	5403	4985	4985	**5034**
TAS	5215	N/A	N/A	**5215**
NT	N/A	4833	4833	**4833**
ACT	5391	N/A	N/A	**5391**

8.3 Cost Effectiveness

Insulating a previously uninsulated floor space is a cost-effective insulation option in a wide range of jurisdictions but generally confined to GEMS cold and average climate zones (not hot).

Cost effectiveness was gauged at both a 7% and a 3% discount rate and also with and without a price on carbon. The results of this analysis are shown below as follows:

- **Table 32**– 7% discount rate without a price on carbon: The insulation measure is on average cost effective only in the cold climate region of SA where electrical energy prices are particularly high.
- **Table 33–** 3% discount rate without a price on carbon: The insulation measure is on average cost effective in Victoria and Tasmania and the cold climate region of South Australia.
- **Table 34**– 7% discount rate with a price on carbon: The insulation measure is on average cost effective in Victoria and the cold climate region of South Australia.
- **Table** 35– 3% discount rate with a price on carbon: The insulation measure is on average cost effective in Victoria, Tasmania and the ACT. The measure is also cost effective in the cold climate zones of SA and WA.

Table 32: Cost effectiveness: w/o carbon price - Floor insulation (B/C – 7% Discount Rate)

Climate (GEMS)	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	0.5	0.9	0.4	1.1	0.5	0.6	N/A	0.5
Average	0.1	0.4	0.1	0.3	0.1	N/A	0.0	N/A
Hot	0.0	N/A	0.0	-0.1	0.0	N/A	0.2	N/A
State Average	0.2	0.9	0.0	0.4	0.1	0.6	0.2	0.5

Table 33: Cost effectiveness: w/o carbon price - Floor insulation (B/C – 3% Discount Rate)

Climate (GEMS)	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	0.9	1.6	0.6	1.9	0.9	1.1	N/A	0.9
Average	0.2	0.8	0.2	0.5	0.2	N/A	0.0	N/A
Hot	-0.1	N/A	0.0	-0.1	0.0	N/A	0.3	N/A
State Average	0.3	1.5	0.0	0.6	0.3	1.1	0.3	0.9

Table 34: Cost effectiveness: with carbon price - Floor insulation (B/C – 7% Discount Rate)

Climate (GEMS)	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	0.6	1.1	0.4	1.2	0.6	0.7	N/A	0.7
Average	0.1	0.6	0.1	0.3	0.1	N/A	0.0	N/A
Hot	0.0	N/A	0.0	-0.1	0.0	N/A	0.2	N/A
State Average	0.2	1.1	0.0	0.4	0.2	0.7	0.2	0.7

Table 35: Cost effectiveness: with carbon price - Floor insulation (B/C – 3% Discount Rate)

Climate (GEMS)	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Cold	0.9	1.8	0.7	2.0	1.0	1.1	N/A	1.1
Average	0.2	0.9	0.2	0.5	0.2	N/A	0.0	N/A
Hot	-0.1	N/A	0.0	-0.1	0.0	N/A	0.3	N/A
State Average	0.3	1.8	0.0	0.7	0.3	1.1	0.3	1.1

9 Co Benefits

9.1.1 Overview

Apart from the obvious benefit of insulation-based energy savings measures in terms of reduced energy costs for the householder there are a number of other co-benefits likely to arise from this measure, these include:

- Reductions in greenhouse gas emissions
- Improved health outcomes for householders
- Improved property values
- Employment – Green Jobs
- Improved productivity
- Reduced air pollution
- Energy security
- Poverty alleviation

Greenhouse gas emission reduction benefits have been explicitly quantified in this study (see Section 5). Of the other potential co-benefits, improved health outcomes and property value are probably the most significant and tangible, these are examined in the following two sub-sections.

9.1.2 Co Benefits - Health

There is a significant body of evidence on the adverse health impacts of houses with poor thermal performance. Excess seasonal mortality is prevalent in climates with very cold winters and/or very hot summers, as are respiratory and circulatory disorders. The very young and the elderly are particularly at risk. Improving thermal performance is associated with improved health outcomes and reduced seasonal mortality. The main health risks arise from extended periods of extreme temperatures (a forecast outcome from climate change models), and extended periods of internal temperature extremes. (AGO 2007, Williamson et al 2009)

Until recently, houses in Australia have been constructed to quite poor energy efficiency standards. Such houses experience greater extremes of internal temperatures. A study of Victorian houses undertaken to explore the impact of the 1990 Victorian regulation to install ceiling insulation in new houses showed an average performance of 0.9 stars in 1991 and 2.2 stars in 1999 (EES 2000).

It is generally acknowledged that at temperatures below 16°C there is an increased risk of respiratory disease, and below 12°C increased risk of cardiovascular problems. The World Health Organisation recommends that temperatures in living areas should be maintained above 18°C, and at 20-21°C for the elderly or very young (Collins 1986).

The World Health Organisation has stated that if house temperatures fall below 16 degrees the occupants potentially face a number of health issues such as an increased incidence of respiratory illness. Low indoor temperatures can also lead to mould growth, particularly in conjunction with poor ventilation as often occurs in cold weather. Mould is acknowledged as a contributor to allergies and respiratory conditions. Insulation greatly reduces the chance of mould growth (WHO 2009). A 5-star NatHERS rated house in

Melbourne will be below 16°C for only 28% of the time and predominantly during sleeping hours. The same house without ceiling insulation will be below 16°C for 42% of hours. Similar results are observed in other climates. In warmer climates the reduction of hot temperatures through insulation retrofit will help to relieve heat stress for the aged, young or infirm.

A recent study of particular relevance was The Victorian Healthy Homes Program Research findings (SV 2022). This study used a randomised controlled trial designed to measure the impact of an energy efficiency and thermal comfort home upgrade on temperature, energy use, health and quality of life. The upgrades included both ceiling and floor insulation options. The study found that:

> *Householders in the intervention group reported less condensation over winter. Importantly, the upgrade was associated with benefits in health, with reduced breathlessness, and improved quality of life, particularly its mental health and social care aspects. Health benefits of the upgrade were reflected in cost savings, with $887 per person saved in the healthcare system over the winter period. Cost-benefit analysis indicated that the upgrade would be cost-saving within 3 years – and would yield a net saving of $4,783 over 10 years – due to savings in both energy and health. Savings were heavily weighted towards healthcare: for every $1 saved in energy, more than $10 is saved in health.*

A study conducted in New Zealand, examined the benefits of retrofitting insulation to houses with respect to health, energy and the environment (MED 2012). The underlying study relating to health benefits associated with insulation was conducted by way of a cluster randomised trial for retrofitting insulation in low-income communities in New Zealand (Chapman et al 2009). The health effects as a result of installing insulation were quantified and valued by measuring the number of visits to GPs, the number of hospitalisations, and the number of days of school and off work. Although the focus of the study was an economic cost-benefit analysis of these benefits rather than energy benefits, the conclusion was that the value for money of improving housing quality by retrofitting insulation is compelling.

9.1.3 Co Benefits – Improved Property Value

To evaluate the impact of improved thermal performance and therefore star rating of a house really requires the underpinning of a mandatory disclosure system as exists in the ACT and is currently proposed for national application. A study by the ABS for the Commonwealth using hedonic pricing analysis to model the relationship between energy efficiency rating and house price, found that the association on average between price and energy rating for detached dwellings built prior to 1996 (when 4 star energy performance standards were introduced in the ACT) was 1.23 percent of price for each 0.5 EER star in 2005 and 1.91 percent of price in 2006, holding all other variables constant. (DEWHA 2008). The total sample over the two years was over 5,000 dwellings, generally with energy ratings in the range 0 – 3 stars. In approximate terms, this means each energy rating star added about 3% to sales prices, or about $11,000 for a house at the median price.

As shown above (Section 5.2.1), ceiling insulation for instance adds about 2 stars to the dwelling energy rating. While there can be no guarantee that the ACT results would be replicated in all States, particularly those with milder climates and lower conditioning energy requirements, the recent rises in energy costs could be expected to improve market responses to energy ratings. In the ACT, the cost of a 2-star improvement through the retrofit of ceiling insulation is of the order of just 20% of the expected return on investment (i.e. higher sale price).

The report acknowledged how difficult it is to exactly allocate how much the improved rating is worth as the improvements can have both thermal and non-thermal benefits. For example, double glazing is valued for more than just its contribution to thermal performance (e.g. noise reduction) and eaves deliver more than shading (e.g. protection of walls against water damage).

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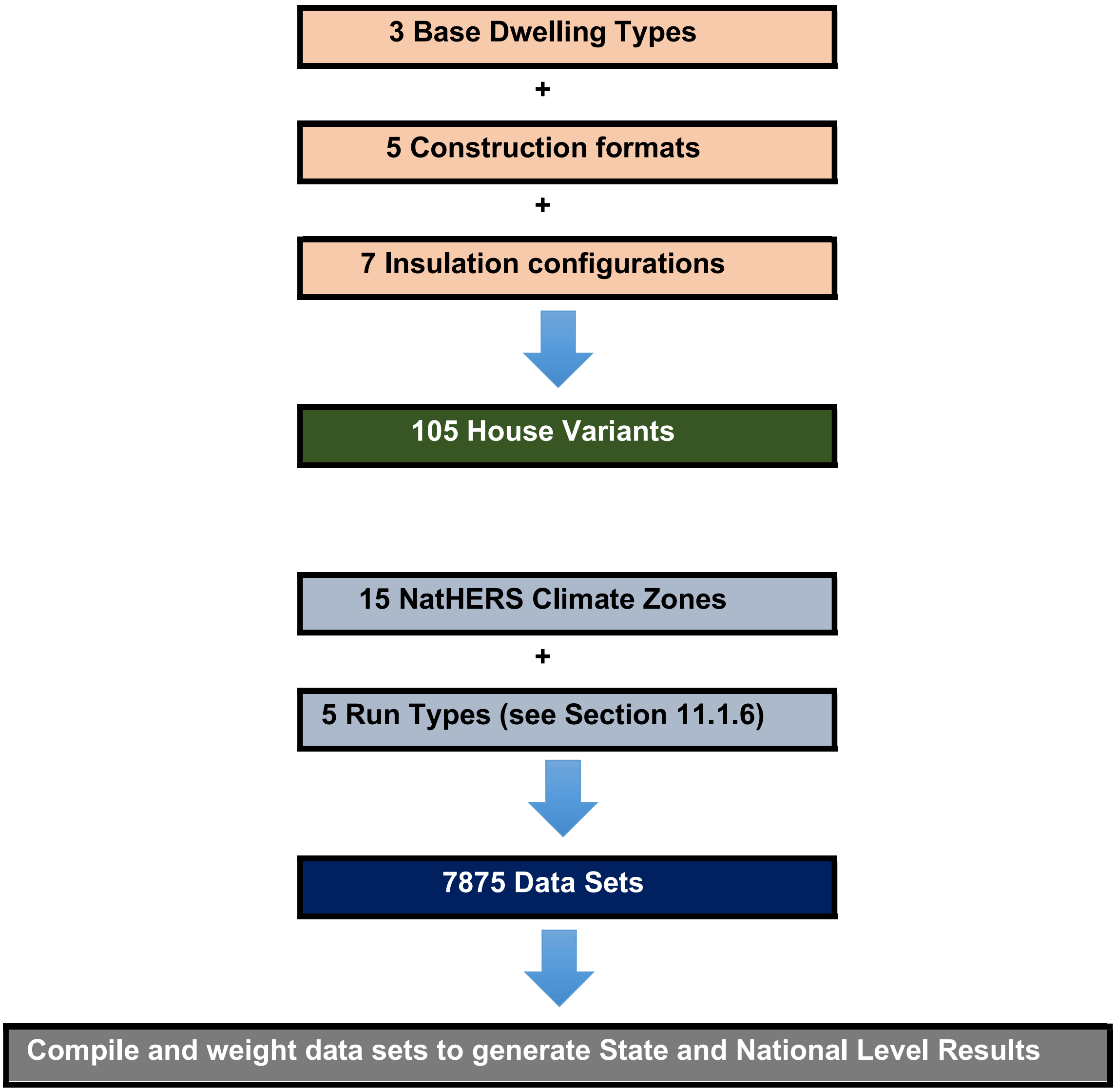
11 Appendix 1 Modelling Methods and Assumptions Details

11.1 Thermal Performance modelling Method

11.1.1 Overview

As noted previously, thermal performance modelling was undertaken using the accredited NatHERS tool AccuRATE. Modelling was conducted on 3 base dwelling types (see Section 11.1.2) through 5 construction formats and 7 insulation configurations designed to represent before and after improvement measure conditions. The below diagram summarises the permutations modelled to generate the necessary datasets from which to compile both State and National level results

Figure 36: Thermal performance permutations modelled



Note: An initial assessment of each dwelling was undertaken at each of the 4 ordinal orientations (North, East, South and West) and the orientation that provided the closest thermal load match to the average thermal load across all 4 orientations was then used for modelling purposes.

11.1.2 Representative housing stock

Three main dwelling types were selected to represent class 1 dwellings:

- Single storey detached dwelling with a pitched roof
- Two storey detached dwelling with a pitched roof
- Semi-detached dwelling

These three base dwelling types were selected and then configured to represent an average pre-regulation house by Tony Isaacs Consulting. Plans of the sample house types used are shown in Appendix 2 Sample House Types.

Each of the three sample dwellings was modelled across 5 construction formats that represent the most common formats found in Australia (noting that the various typologies present in differing proportions according to the jurisdiction in which they are present).

Whilst a potential 6th type (lightweight construction on a concrete floor) is becoming more popular in recent years, pre regulation there were very few dwellings of this format built. For the purposes of this study the very small number of lightweight constructions on a concrete floor were aggregated with brick veneer construction on a concrete floor which has similar thermal performance characteristics in any case.

The assumed propensities of each of the dwelling variants noted above were based on analysis undertaken in the study Energy Use in the Australian Residential Sector 1986-2020 (EES 2008) and are detailed in Table 36 below.

Table 36: Propensities of dwelling types by jurisdiction (EES 2008)

Type	Construction	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Detached Single Storey	Brick Veneer / Concrete	15.3%	13.7%	18.1%	10.5%	4.5%	8.2%	7.2%	30.1%
	Brick Veneer / Timber	12.2%	9.2%	13.1%	0.2%	3.8%	12.9%	4.3%	6.6%
	Heavyweight/ Concrete	2.8%	1.3%	1.8%	5.6%	23.7%	1.1%	13.3%	0.8%
	Heavyweight / Timber	14.5%	12.6%	3.5%	51.6%	23.6%	9.3%	17.6%	2.5%
	Lightweight/Timber	26.6%	27.7%	38.0%	7.0%	13.2%	43.0%	18.5%	0.4%
Detached Double Storey	Brick Veneer / Concrete	4.8%	4.3%	5.8%	3.6%	1.1%	2.0%	2.4%	9.7%
	Brick Veneer / Timber	1.9%	2.0%	2.0%	0.1%	0.4%	1.9%	0.6%	2.0%
	Heavyweight/ Concrete	0.7%	0.3%	0.6%	0.3%	7.9%	0.3%	4.6%	0.2%
	Heavyweight / Concrete	1.7%	1.4%	0.5%	0.0%	2.8%	1.1%	4.3%	0.3%
	Lightweight/Timber	3.4%	3.5%	4.7%	0.3%	1.6%	5.1%	3.4%	0.1%

Type	Construction	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Semi Detached	Brick Veneer / Concrete	4.4%	2.9%	4.5%	3.1%	0.9%	1.6%	1.5%	21.3%
	Brick Veneer / Timber	3.8%	9.9%	1.8%	1.0%	0.9%	5.7%	2.7%	21.5%
	Heavyweight/ Concrete	1.5%	0.4%	1.0%	1.8%	7.3%	0.2%	4.2%	0.6%
	Heavyweight / Concrete	2.7%	3.3%	0.6%	12.8%	5.7%	1.7%	10.3%	3.3%
	Lightweight/Timber	3.8%	7.5%	3.9%	2.3%	2.5%	6.0%	5.1%	0.5%

11.1.3 Base Cases (before retrofit)

For each of the energy savings measures examined in this study an assumption was required to be made regarding the base case conditions of the dwellings considered to be eligible for the application of the insulation-based energy savings measure. These assumptions are detailed below:

Retrofit of ceiling insulation to previously uninsulated ceilings.
It was assumed that the subject dwellings would have no wall insulation. Generally, for existing dwellings, ceiling insulation would have been applied preferentially to wall insulation both during construction and as a retrofit option. This means that for the subject dwellings, given that they had no ceiling insulation the likelihood of them having wall insulation is very low.
No floor insulation was assumed either as less than 1% of existing dwellings in 2003-2005 (when performance requirements were introduced into the BCA that effectively require both ceiling and wall insulation) were recorded as having floor insulation fitted – ABS 4602:2005.

Retrofit of top up ceiling insulation to less than optimally insulated ceilings
It is assumed that the dwelling subject to this energy savings measure has less than optimal ceiling insulation installed. It is assumed that the dwelling was constructed prior to the mid-1990s when the first regulations regarding ceiling insulation were introduced in selected states such as Victoria. Prior to the introduction of regulations, the voluntary installation of ceiling insulation typically included for 50mm to 75mm thick glass-wool insulation batts (or equivalent) with an R value of approximately R1.0 – R1.5. Insulation of this age is typically found to be in poor condition and often displaced to some degree which can have a marked impact on its performance (see Figure 37 which shows an analysis of the impact of an incomplete coverage of ceiling insulation on the effective R-value of that insulation) , consequently, for the purposes of this study an assumed average ceiling insulation performance of R1.0 has been assumed.

As the cohort of dwellings considered eligible for retrofit for this energy savings measure were constructed prior to the mid 1990's they are assumed to have:

- R1.0 ceiling insulation (see above)
- No wall insulation (less than 20% of all Australian dwellings in 1994 were recorded as having wall insulation fitted – ABS 4602:2005)
- No floor insulation (only 0.3% of dwellings in 1994 were recorded as having floor insulation fitted – ABS 4602:1994)

Figure 37: Impact of Gaps in Continuity of Insulation Coverage (ICANZ 2024)

Effective R-value table Batts: Glasswool

Thickness	Gap size with Batt Glasswool (% of ceiling area shown below)			
	No Gap/ no missing insulation across entire ceiling	Slight Gap/Poor Fit	Obvious Gaps/ Loose fit	Large Gaps / Missing Insulation
	0%	3%	6%	12%
50mm	R0.87	R0.77	R0.70	R0.57
100 mm	R1.79	R1.47	R1.24	R0.92
150 mm	R2.84	R2.14	R1.70	R1.17
200 mm	R3.85	R2.70	R2.05	R1.34
250 mm	R5.21	R3.33	R2.40	R1.49
300 mm	R7.50	R4.16	R2.83	R1.65

Retrofit of wall insulation to previously uninsulated external walls.
It is assumed that the dwellings subject to this energy savings measure have no pre-existing wall insulation installed. This applies to each of the 3 wall types examined, i.e. lightweight, brick veneer and heavyweight (assumed to be cavity brickwork).

Since performance regulations were introduced in the mid-2000s almost all new dwellings now have wall insulation fitted. This means that the cohort of dwellings considered as eligible for retrofit for this energy saving measure will have been constructed pre 2005 and as such are assumed to have:

- An average of R1.5 insulation fitted in the ceiling (as adopted as a stock average in the study Energy Use in the Australian Residential Sector 1986-2020 (EES 2008))
- No floor insulation (less than 1% of dwellings in 2005 were recorded as having floor insulation fitted – ABS 4602:2005

Retrofit of floor insulation to previously un-insulated suspended timber floors
It is assumed that the dwelling subject to this energy savings measure has no floor insulation installed. This applies only to those dwellings with suspended timber floors.

Since performance regulations were introduced in the mid 2000's an increasing number of new dwellings now have floor insulation fitted. This means that the cohort of dwellings considered eligible for retrofit for this energy savings measure will have been constructed pre 2005 and as such are assumed to have:

- An average of R1.5 insulation fitted in the ceiling (as adopted as a stock average in the study Energy Use in the Australian Residential Sector 1986-2020 (EES 2008))
- No wall insulation (less than one quarter of all Australian dwellings in 2005 were recorded as having wall insulation fitted – ABS 4602:2005)

11.1.4 Representative Insulation levels – before and after retrofit

Table 37 details the insulation levels modelled for this study. Cases P01 P02 and P03 represent insulation levels found in existing dwellings that are considered suitable for upgrading. Cases P03 to P08 inclusive represent the proposed upgrades to be applied to cases P01 and P02. The particular base and improved cases applied for each of the insulation activities examined in this study are detailed in Table 38.

Table 37: Insulation levels modelled

Case No.	Description	Ceiling	Wall	Floor
P01	Uninsulated Case	R0	R0	R0
P02[1]	Stock Base Case	R1.5	R0	R0
P03[1]	Base Case Ceiling Top-up	R1.0	R0	R0
P04[2]	Ceiling upgrade 1	R4.0	R0	R0
P05[3]	Ceiling upgrade 2	R5.0	R0	R0
P06[4]	Wall upgrade	R1.5	R2.5 / R1.3*	R0
P07	Floor upgrade 1	R1.5	R0	R2.0[5]
P08	Floor upgrade 2	R1.5	R0	R2.5[5]

1. Whilst insulation levels in the ceilings of pre-regulation houses could be higher than this (R2.0 or R2.5), poor installation practices, deterioration with age and disturbances to the continuity of the insulation over time (e.g. with the installation of new downlight fittings) means that the insulation levels are expected to be closer to an equivalent of R1.5 generally and in cases where top up insulation is indicated R1.0.
2. Ceiling upgrade 1 level apply to the milder NCC climate zones: 2,4 and 5 and are broadly in line with levels as prescribed in NCC 2022 (prescribed levels in NCC 2022 vary to some degree according to the colour and format of the roof)
3. Ceiling upgrade 2 level apply to the more severe NCC climate zones 1,3,.6,7 and 8. and are broadly in line with levels as prescribed in NCC 2022 (prescribed levels in NCC 2022 vary to some degree according to the colour and format of the roof)
4. The level of insulation which can be achieved depends on the type of wall construction and the width of the cavity.
    a. For cavity brick walls an overall installed R-value of R1.3 to R1.5 is expected assuming a cavity of 40mm to 50mm and the use of silicone coated rockwool fill.
    b. For weatherboard walls an overall installed R-value of R2.5 could be achieved by the installation of batts (if linings are removed or the use of blown-in of silicone coated rockwool fill)
    c. For brick-veneer walls the insulation level which can be achieved will depend on the width of the wall studs, the width of the cavity between the brickwork and the framing, and on whether sarking has been fixed to the outside of the wall frame. In this case installed R-values of between R1.9 to R3.4 would be expected using silicone coated rockwool fill. The highest value will be achieved where there is no sarking, and the overall cavity width is around 130 mm. The lowest value will be achieved where sarking is fixed to the outside of the frame and the top half of the wall (e.g. above the nogging) filled to the full cavity width via the roof while in the lower half only the cavity between the brickwork and sarking (around

40 to 50 mm) is filled. For the purposes of this study, it has been assumed that for brick veneer construction an average R value of R-2.5 will be achieved.

5. floor upgrade 1 level will be applied to NCC climates zones 1 – 6 inclusive and floor upgrade 2 level will be applied to NCC climates zones 7 and 8

Table 38: Base case and improved case by insulation activity

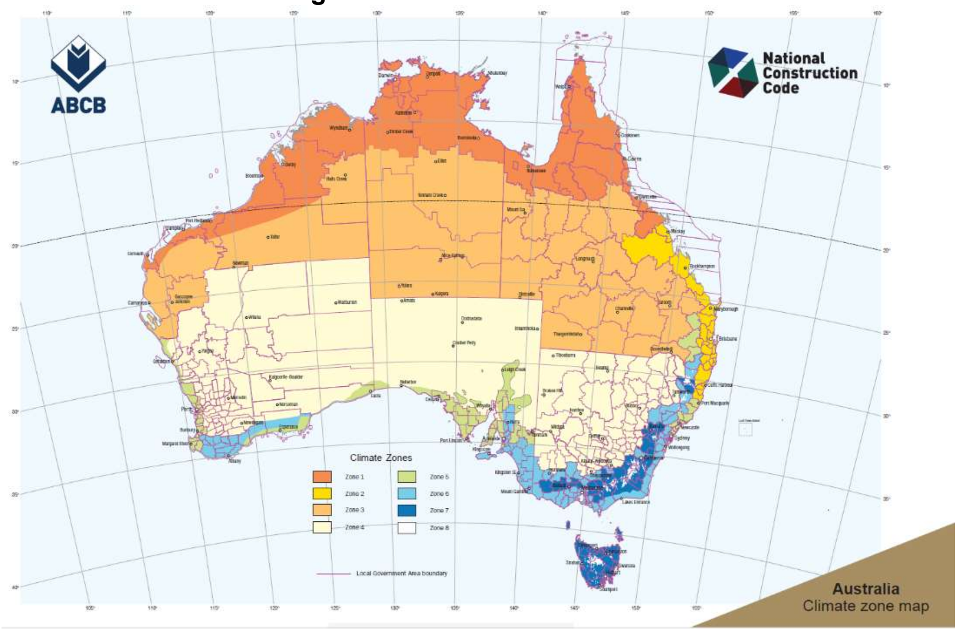
Insulation Activity	Assumed base insulation case (see cases above)	Upgrade case (see cases above)
1. Retrofit Ceiling insulation	P01	P04 or P05[1]
2. Top up ceiling insulation	P03	P04 or P05[1]
3. Retrofit Wall insulation	P02	P06
4. Retrofit floor insulation	P02	P07 or P08[1]

1. Level of upgrade depends on climate zone – see table above

11.1.5 Climates Modelled

Similar to the methodology used in the analysis undertaken for NCC 2022, a total of 15[7] NatHERS climate zones were modelled (see Table 39). One of the representative NatHERS climate zone from the 15 modelled was used to represent each of the NCC climate categories found in differing proportions in each jurisdiction (see Figure 38).

Figure 38: NCC Climate Zones



[7] In NCC 2022 only 12 climate zones were modelled. For this study additional zones were modelled to improve both the coverage and accuracy of the analysis.

Table 39: NatHERS climate zones modelled (Matches those modelled for NCC 2022)

NCC Climate Zone	NatHERS Climate Zone	Population centre	GEMS Climate Zone
Climate zone 1	1	Darwin	Hot
Climate zone 1	5	Townsville	Hot
Climate zone 2	10	Brisbane	Hot
Climate zone 4	27	Mildura	Average
Climate zone 5	16	Adelaide	Average
Climate zone 5	13	Perth	Average
Climate zone 5	28	Sydney	Average
Climate zone 5	56	Mascot	Average
Climate zone 5	21	Melbourne RO	Cold
Climate zone 6	60	Tullamarine	Cold
Climate zone 6	62	Moorabbin	Cold
Climate zone 7	24	Canberra	Cold
Climate zone 7	26	Hobart	Cold
Climate zone 7	65	Orange	Cold
Climate zone 7	66	Ballarat	Cold

The propensity of each of the 15 modelled NatHERS climate zones according to jurisdiction is shown in Table 40. These propensities were derived from the study Energy Use in the Australian Residential Sector 1986-2020 (EES 2008).

Table 40:Propensity of NatHERS climate zones applied as representative in each jurisdiction

CZ	Population Centre	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
1	Darwin	0%	0%	0%	0%	1%	0%	79%	0%
5	Townsville	0%	0%	22%	0%	3%	0%	13%	0%
10	Brisbane	11%	0%	60%	1%	7%	0%	0%	0%
13	Perth	0%	0%	0%	0%	75%	0%	0%	0%
16	Adelaide	0%	0%	13%	87%	0%	0%	0%	0%
21	Melbourne RO	10%	9%	0%	0%	3%	0%	0%	0%
24	Canberra	3%	0%	0%	0%	0%	0%	0%	100%
26	Hobart	0%	0%	0%	0%	0%	80%	0%	0%
27	Mildura	0%	3%	0%	0%	3%	0%	0%	0%
28	Richmond	30%	0%	0%	0%	0%	0%	0%	0%
56	Mascot	40%	0%	4%	1%	0%	0%	8%	0%
60	Tullamarine	1%	35%	0%	2%	8%	0%	0%	0%
62	Moorabbin	0%	44%	0%	0%	0%	9%	0%	0%
65	Orange	4%	2%	0%	9%	2%	11%	0%	0%
66	Ballarat	0%	7%	0%	0%	0%	0%	0%	0%

11.1.6 Thermal Performance Settings

Thermal modelling was undertaken using the latest version of NatHERS rating tools, including updated weather files as applied to the NCC 2022 analysis.

For building shell star rating analysis purposes, the standard (default rating mode) NatHERS thermostat and occupancy schedule settings were used.

However, for energy calculations, in line with the approach taken in whole of house modelling under NatHERS, modelling was undertaken using two separate (weighted) occupancy schedules:

- Home all day schedule (60%)
- Workday Schedule (40%)

Thermostat settings were applied as per the latest agreed levels used for Whole of house modelling undertaken for NCC 2022 (generally these tend to have lower cooling thermostat set points than the previous NatHERS settings)

Finally, separate runs were undertaken for a centrally conditioned case and a room only conditioned case (typically main living/kitchen area).

Overall, a total of 5 runs were undertaken:

1. Standard building shell rating run (default rating mode)
2. Central Zoning – All day occupancy schedule
3. Central Zoning – Workday occupancy schedule
4. Room Zoning – All day occupancy schedule
5. Room Zoning – Workday occupancy schedule

11.2 Class 1 Heating and Cooling Equipment profile

11.2.1 Stock

Heating and cooling equipment types modelled in this study were selected as representative of the majority of equipment types in the current housing stock. Heater options modelled included:

- Mains Gas non-ducted
- LPG Gas non-ducted
- Mains Gas ducted
- Resistive Electric slab
- Resistive Electric ducted
- Resistive Electric panel+room
- Reverse Cycle AC non-ducted
- Reverse Cycle AC ducted
- Wood Closed Combustion
- Wood Open Fires
- No Main Space Heating

Propensities were derived via reference to available published ABS data plus some limited BIS Oxford data. The derived values were as follows:

Table 41: Estimated Propensities of Heating Equipment in Class 1 Housing - 2023

Equipment type	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Mains Gas non-ducted	22.0%	16.7%	2.7%	17.0%	23.6%	1.4%	0.2%	8.4%
LPG Gas non-ducted	3.6%	1.0%	0.7%	2.0%	0.8%	1.5%	4.5%	0.0%
Mains Gas ducted	2.2%	33.2%	0.2%	3.3%	2.0%	1.9%	0.0%	28.8%
Resistive Electric slab	0.5%	0.7%	0.0%	0.1%	0.0%	0.5%	0.0%	0.2%
Resistive Electric ducted	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.4%
Resistive Electric panel+room	8.6%	8.4%	10.8%	6.2%	4.7%	11.3%	3.9%	3.3%
Reverse Cycle AC non-ducted	30.8%	22.8%	31.9%	40.2%	33.8%	49.9%	6.1%	41.3%
Reverse Cycle AC ducted	6.0%	2.9%	3.2%	10.6%	5.4%	5.7%	0.3%	12.2%
Wood Closed Combustion	9.6%	11.2%	4.1%	14.8%	9.1%	26.5%	1.2%	4.4%
Wood Open Fires	0.3%	0.1%	0.7%	0.1%	0.2%	0.3%	0.0%	0.0%
No Main Space Heating	16.3%	2.6%	45.7%	5.7%	20.2%	1.0%	83.6%	0.8%

Cooling options included:

- Ducted Reverse Cycle (or cooling only) Air Conditioner
- Ducted Evaporative Cooler
- Non-ducted Reverse Cycle (or cooling only) Air Conditioner
- Nil

Propensities were derived via reference to available published ABS data plus some limited BIS Oxford data. The derived values were as follows:

Table 42: Estimated Propensities of Cooling Equipment in Class 1 Housing - 2023

Equipment type	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Evaporative cooling	5.7%	23.1%	2.4%	19.4%	18.4%	0.8%	7.3%	16.8%
Ducted reverse cycle	16.0%	9.0%	4.9%	21.1%	15.1%	7.0%	1.1%	16.3%
Ducted cooling only	0.9%	2.8%	1.6%	4.1%	3.6%	0.0%	2.3%	0.2%
Non-ducted reverse cycle	50.1%	44.7%	58.1%	43.6%	50.0%	49.9%	52.6%	37.8%
Non-ducted cooling only	5.9%	6.2%	9.8%	4.7%	4.0%	0.7%	34.6%	7.7%
No cooling	21.4%	14.2%	23.2%	7.0%	8.9%	41.6%	2.2%	21.2%

11.2.2 Equipment Performance

The assumed efficiency levels for the stock of heating and cooling equipment were derived from a range of data sources including GfK survey data collected by the Commonwealth as well as the GEMS registration database. In the case of air-conditioners, performance varies according to the particular GEMS climate (Cold, Mixed or Hot/Humid) into which the unit is to be installed. The assumed performance levels (conversion efficiencies) are shown in Table 43 (heaters) and Table 44 (coolers).

Table 43: Assumed Stock Heater Efficiencies

Equipment type	Cold	Mixed	Hot	Losses
Mains Gas non-ducted	78%	78%	78%	0%
LPG Gas non-ducted	78%	78%	78%	0%
Mains Gas ducted	71%	71%	71%	22%
Resistive Electric slab	100%	100%	100%	22%
Resistive Electric ducted	100%	100%	100%	22%
Resistive Electric panel+room	100%	100%	100%	0%
Reverse Cycle AC non-ducted	373%	426%	488%	0%
Reverse Cycle AC ducted	337%	383%	438%	22%
Wood Closed Combustion	60%	60%	60%	0%
Wood Open Fires	18%	18%	18%	0%
No Main Space Heating	NA	NA	NA	NA

Table 44: Assumed Stock Cooler Efficiencies

Equipment type	Cold	Mixed	Hot	Losses
Evaporative cooling*	1500%	1500%	1500%	22%
Ducted reverse cycle	417%	408%	456%	22%
Ducted cooling only	417%	408%	456%	22%
Non-ducted reverse cycle	515%	498%	547%	0%
Non-ducted cooling only	515%	498%	547%	0%
No cooling	NA	NA	NA	NA

* In the case of evaporative coolers, the rating is an equivalent COP value based on default settings used in NatHERS tools. These values are based on the energy consumption per unit cooling associated with evaporative coolers. Note however that these values are not directly comparable to refrigerative cooler efficiencies because evaporative coolers provide a different form of service.

11.3 Fuel cost Data

Analysis of retail fuel costs leveraged off an unpublished study completed by EES in late 2023. That study used a range of sources which varied according to the type of fuel and to a lesser extent the jurisdiction. Sources included:

- Published surveys of fuel costs (government and non-government
- Comparator websites)
- Web sites of major suppliers
- Direct phone contact with supply companies (mainly in relation to LPG and firewood costs but occasionally for clarifications in relation to electricity and gas)
- Relevant advertising (e.g. advertisements on-line for direct delivery of firewood)

Actual sources used in in relation to each fuel type are detailed in the following sub-sections:

11.3.1 Electricity Tariffs

Key Sources:

- Comparator tool – Victoria: https://compare.switchon.vic.gov.au/
- Comparator tool – Other Jurisdictions: https://www.energymadeeasy.gov.au/
- Major supplier websites as required (varies by jurisdiction)

In addition to the above noted sources, reference was also made to the 2022-2023 projections contained in The Australian Energy Market Commission (AEMC)-Residential-Electricity-Price-Trends report 2021. This provides a convenient summary of electrical tariffs in most jurisdictions. However, this survey only reports peak rate residential electricity prices and not controlled load (off peak) or feed-in tariff prices.

In the case of Victoria, the comparator tool was of reduced value as typically retailers offered discounted tariffs for the first year which then revert to standard (undiscounted) default rates after 12 months. This meant that the quoted rates at https://compare.switchon.vic.gov.au/ are generally lower than the average. Efforts by the Victorian Government in recent times have reduced this effect to the extent that at present only 400,000 households (about 15%) are on the default rate which currently sits at about 32c/kWh. To allow for this, the average comparator tool rates were weighted as representing 85% of the stock with those on the default rate (assumed to be 32c/kWh) were weighted at 15%.

11.3.2 Natural Gas Tariffs

Applicable tariffs for natural gas were primarily derived from comparator tools including:

- Comparator tool – Victoria: https://compare.switchon.vic.gov.au/
- Comparator tool – Other Jurisdictions: https://www.energymadeeasy.gov.au/

11.3.3 LPG Tariffs

LPG gas for residential use is typically supplied in one of three forms:

- Replacement 45kg tanks
- 90 kg tank – filled on site
- 190-210 kg tank – filled on site

Applicable tariffs were derived from the three main suppliers:

- Elgas http://www.elgas.com.au
- Origin https://www.originenergy.com.au/for-home/lpg/lpg-plans/pricingfees.html
- Supagas Supagas | Leading LPG and Gas Bottle Suppliers

Prices are not always quoted on supplier's websites, in such cases prices were obtained via phone calls to each supplier. 45kg tanks are priced per tank delivered. 90kg and 190-210 kg tanks are priced per litre of refill on site. Prices generally reflect those applicable in and around townships, more remote rural locations are likely to attract higher delivery charge components.

11.3.4 Firewood Costs

There are two main types of firewood supply:

- Pre-packaged (e.g. 20kg plastic wrapped available from service stations etc.)
- Bulk delivery (typically per tonne or per m^3)

In reality, those that heat using firewood as their primary heater are unlikely to use pre-packaged firewood as the cost is somewhat prohibitive.

Bulk delivery costs can vary greatly often by a factor of three in the same jurisdiction. Only suppliers that quoted per m^3 or per tonne were considered. Many offer firewood by the “ute” or “trailer” load but the actual quantity supplied in these cases is less certain. Suppliers identified were commercial operators (firewood merchants and garden supplies) rather than backyard type operations, so cost estimates are probably conservative (backyard operators tend to be less expensive).

11.3.5 General Notes

Conventions applied were as follows:

- All prices include GST
- Electricity tariffs are quoted in cents/kWh
- Gas tariffs are quoted in cents/MJ
- LPG tariffs are quoted in cents/MJ
- Firewood costs are quoted in cents/MJ
- Feed in tariffs are all assumed to be net feed in tariffs

Where jurisdictions offer two levels of controlled load, generally, Controlled load 1 provides overnight off-peak electricity only. Controlled load 2 provides both overnight off-peak electricity plus several hours during the daytime (ripple controlled). In NSW approximately two-thirds[8] of residential customers that use controlled loads use controlled load 1. For the purposes of this study, tier1 controlled load tariffs were used.

In determining the various tariff values the following constants were applied as required:

Table 45: Constants used in the fuel tariff analysis

Constant	Assumed Value
Litres LPG / kg	**1.96**
MJ per litre of LPG	**25**
kg per m^3 of firewood	**600**
MJ/kg of firewood	**16**

11.3.6 Fuel cost Estimates

The results of the above noted analysis is presented in Table 46 below. These values were for 2023. For the analysis undertaken in this study (commencing 2025) these values were adjusted by the inflation rate (approx. 3.6% in 2023-2024).

[8] Based on unpublished data sets held by EES

Table 46: Fuel Tariffs 2023

Tariff type	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Electricity (c/kWh)	33.87	25.64	30.92	44.8	30.81	26.27	29.51	23.84
Electricity Controlled (c/kWh)	16.95	20.29	21.5	21.72	12.86	17.38	25.28	21.1
Gas (c/MJ) [1]	3.94	3.705	5.53	4.68	4.79	4.33[2]	4.33[2]	3.315
LPG (c/MJ)	6.83	5.18	6.93	6.8	6.05	7	9.24	7.04
Firewood (c/MJ)	2.76	2.29	1.98	2.5	2.03	1.56	2.19[3]	2.49

Table Notes:

1. Gas Tariffs are set at the average of tier 1 usage and tier 2 usage in line with the approach taken in NCC 2022. Typically, the following tiers would be applicable:
    a. Cooking only – tier 1
    b. Water heating only – tier 1 and part tier 2 depending on load.
    c. Heating only – varies from tier 1 to tier 3 depending on season and location.
    d. Water heating and heating – tier 2 to tier 3 depending on season and location.
2. Natural gas prices for Tas and NT were not readily available so the average of all other jurisdictions with gas was used as per the method used for NCC 2022.
3. Firewood prices for NT were not readily available so the average of all other jurisdictions was used.

11.4 Greenhouse Gas intensity of Fuels data

The greenhouse gas intensity of fuels was derived from two sources:

- Electricity and Natural Gas: Economic Parameters for technical work (NCC), prepared for the ABCB by Nicki Hutley, Rovingstone Advisory Pty Ltd, April 2023. Note: These values are projected to decline over time – see Table 47.
- All other fuels: The Australian National Greenhouse Accounts Factors 2023 as published in August 2023 by the Department of Climate Change, Energy, the Environment and Water, see Table 48

Table 47: Electricity, Indirect scope 2 and 3 combined emissions factors, projected, tonnes CO_2-e per MWh (Hutley 2023)

Year	NSW/ACT	QLD	SA	VIC	TAS	WA (SWIS)	NT
2022	0.78	0.88	0.33	0.92	0.18	0.55	0.61
2023	0.75	0.81	0.31	0.82	0.03	0.52	0.57
2024	0.64	0.77	0.26	0.78	0.06	0.5	0.53
2025	0.53	0.61	0.23	0.72	0.02	0.44	0.5
2026	0.42	0.58	0.15	0.72	0.06	0.41	0.48
2027	0.36	0.54	0.16	0.67	0.05	0.38	0.47
2028	0.25	0.54	0.11	0.59	0.04	0.34	0.45
2029	0.22	0.5	0.08	0.44	0.03	0.31	0.42
2030	0.13	0.46	0.02	0.4	0.03	0.26	0.38
2031	0.12	0.42	0.02	0.38	0.02	0.25	0.38
2032	0.11	0.36	0.02	0.35	0.02	0.24	0.36
2033	0.13	0.29	0.02	0.37	0.02	0.24	0.35

Year	NSW/ACT	QLD	SA	VIC	TAS	WA (SWIS)	NT
2034	0.02	0.26	0.1	0.41	0.02	0.23	0.32
2035	0.02	0.24	0.11	0.39	0.02	0.22	0.23
2036	0.02	0.22	0.1	0.35	0.02	0.2	0.21
2037	0.02	0.2	0.09	0.32	0.02	0.19	0.19
2038	0.02	0.19	0.09	0.29	0.02	0.17	0.18
2039	0.02	0.17	0.08	0.27	0.02	0.16	0.16
2040	0.02	0.16	0.07	0.24	0.02	0.14	0.15
2041	0.02	0.15	0.07	0.22	0.02	0.13	0.14
2042	0.02	0.13	0.06	0.2	0.02	0.12	0.13
2043	0.02	0.12	0.06	0.18	0.02	0.11	0.12
2044	0.02	0.11	0.05	0.17	0.02	0.1	0.11
2045	0.02	0.1	0.05	0.15	0.02	0.1	0.1
2046	0.02	0.1	0.04	0.14	0.02	0.09	0.09
2047	0.02	0.09	0.04	0.13	0.02	0.08	0.08
2048	0.02	0.08	0.04	0.11	0.02	0.07	0.08
2049	0.02	0.07	0.03	0.1	0.02	0.07	0.07
2050+	0.02	0.07	0.03	0.09	0.02	0.06	0.07

Table 48: Greenhouse Gas Intensity of Other Fuels (kg $_{CO2-e}$/GJ) – 2025

Tariff type	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Natural Gas[2]	64.6	55.5	60.3	62.2	55.6	55.5	55.6	64.6
LPG[3]	80.8	80.8	80.8	80.8	80.8	80.8	80.8	80.8
Firewood[4]	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2

Table Notes:

1. Includes both Scope 2 and 3 emissions.
2. Includes Scope 2 and 3 emissions (assumes Metropolitan values for Scope 3 emissions). Scope 3 Emissions for Tas and NT not published due to confidentiality constraints, but the National Greenhouse Accounts report recommends use of Vic values for Tas and use of WA values for NT.
3. Includes both Scope 1 and 3 emissions.
4. Includes both Scope 1 and 3 emissions.

11.5 The cost of Carbon

The NCC 2022 Decision RIS adopted a carbon cost for the purposes of cost benefit analysis based upon the social cost of carbon.

The social cost of carbon (SCC) is an estimate of the marginal impact of an additional tonne of carbon based on the future costs associated with those emissions. Typically, the SCC is given as a very high, high, medium, and low value — deriving from different measures of the applicable discount rate.

For the NCC 2022 Decision RIS, carbon costs based on, the United States (US) Government's Interagency Working Group (IWG) on Social Cost of Greenhouse Gases 2021, medium scenario. For this study the same values have been used – see bolded values in Table 49. It should be remembered that for this study, effectively these values were discounted by 25% to account for expected rebound effects (see Section 2.10).

Table 49: Carbon Price (AUD) – As applied in NCC 2022 (based on US IWG – Medium Scenario)

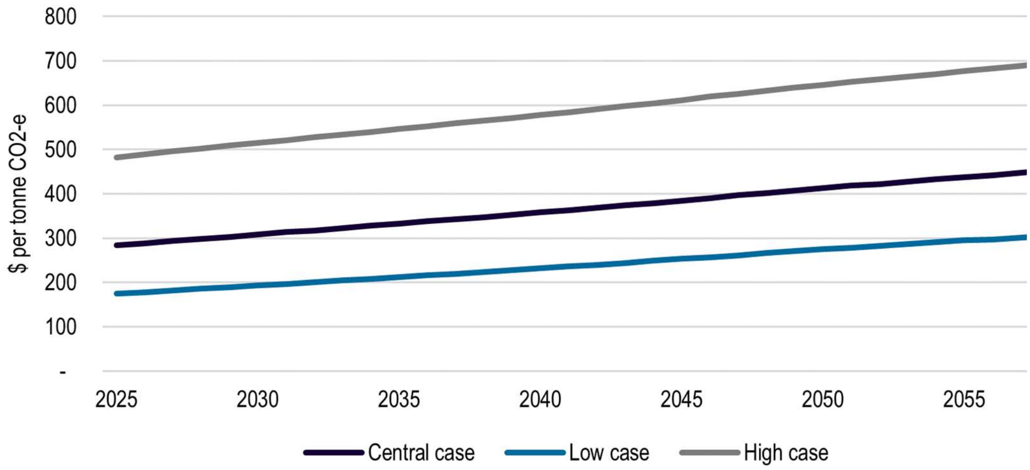
Year	Low (5%)	Medium (3%)	High (2.5%)
2020	22	**78**	116
2021	24	**80**	118
2022	24	**81**	121
2023	25	**83**	122
2024	25	**84**	124
2025	27	**87**	127
2026	27	**88**	128
2027	28	**90**	130
2028	28	**91**	131
2029	29	**93**	134
2030	31	**94**	136
2031	31	**96**	139
2032	32	**97**	140
2033	32	**99**	142
2034	34	**102**	145
2035	34	**103**	146
2036	35	**105**	147
2037	37	**106**	150
2038	37	**108**	152
2039	38	**109**	153
2040	38	**111**	156
2041	40	**114**	158
2042	41	**115**	159
2043	41	**116**	162
2044	43	**118**	164
2045	44	**119**	165
2046	44	**121**	168
2047	46	**124**	170
2048	47	**125**	171
2049	22	**78**	116
2050	24	**80**	118

These carbon costs as used in the NCC 2022 RIS are now considered to be very conservative. In September 2022, the United States (US) EPA released updated estimates of the social cost of carbon to be used when monetising the value of changes in GHG emissions resulting from regulatory changes (see Figure 39 below).

These more recent US SCC estimates are now in the order of $300 - $400 per tonne over the next 25 years (using the medium scenario i.e. equivalent to that used in NCC 2022).

It is also worth noting that many notable economists now estimate that the market value (or “resource cost”) of carbon in Australia (which is a far more conservative measure than the social cost of carbon) will soon rise to a carbon price similar to that assumed in NCC 2022. – see https://www.ey.com/en_au/sustainability/australia-s-carbon-market-is-changing-gears-are-you-ready and also Hutley 2023.

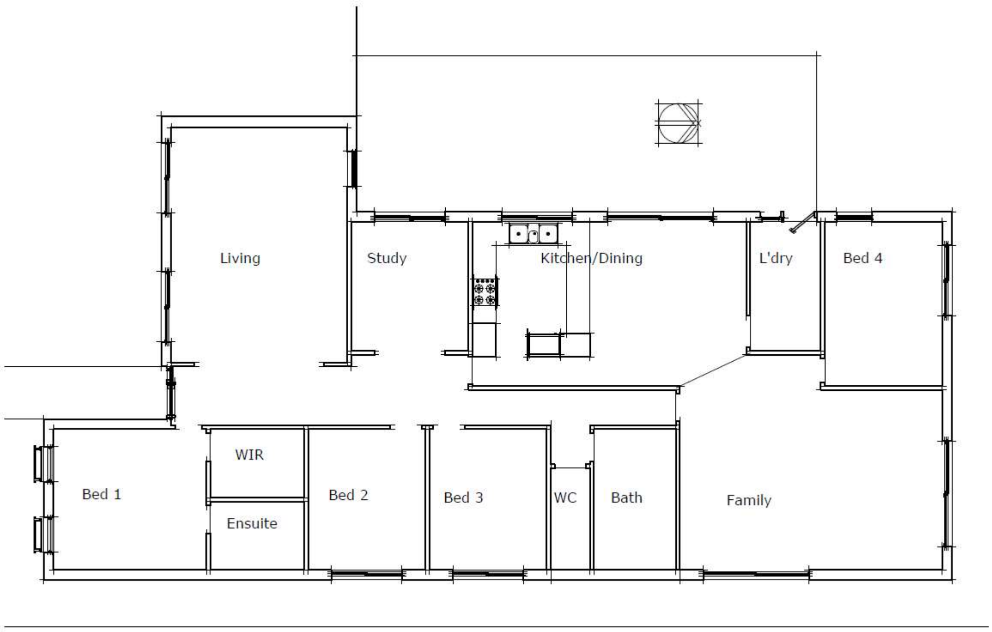
Figure 39: Societal Cost of Carbon – US EPA Values September 2022



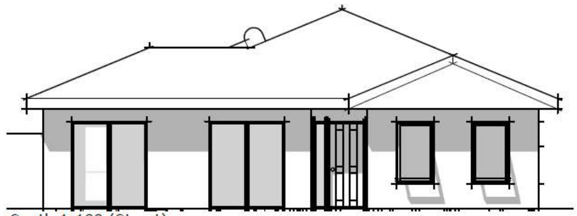
Note: Converted to Australian dollars using an exchange rate of 0.75 AUD/USD (calculated based on a 10 year monthly exchange rate average from April 2013 to April 2023 sourced from the Reserve Bank of Australia). The central case scenario shows the average estimate of the future social cost of climate change discounted using a discount rate of 2%, the low case scenario shows the SCC using a discount rate of 2.5% and the high scenario uses a discount rate of 1.5%.

12 Appendix 2 Sample House Types

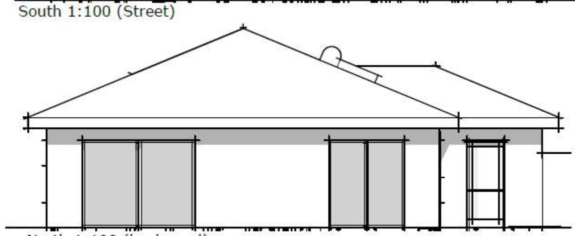
Figure 40 : Class 1 Detached House Single Storey – Sample House Schematic Plans



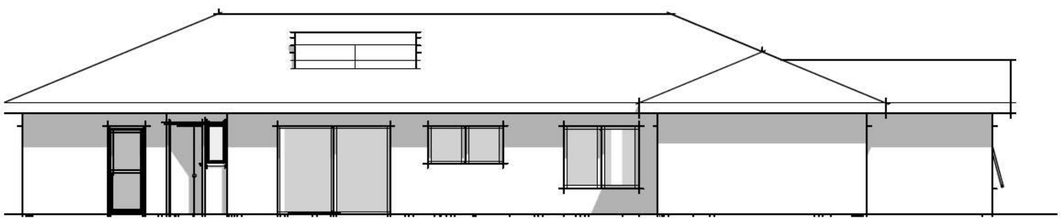
Plan 1:100



South 1:100 (Street)



North 1:100 (back yard)

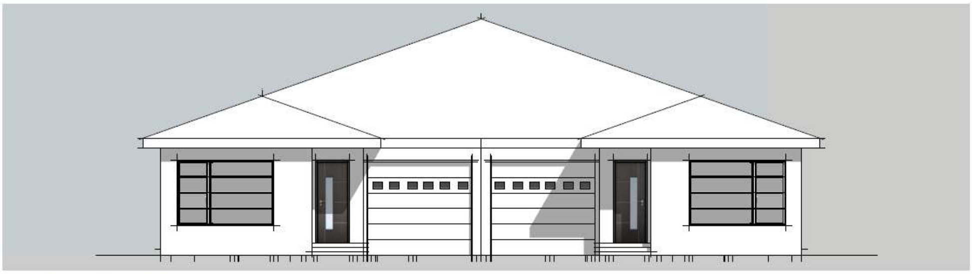


West 1:100 (side yard)

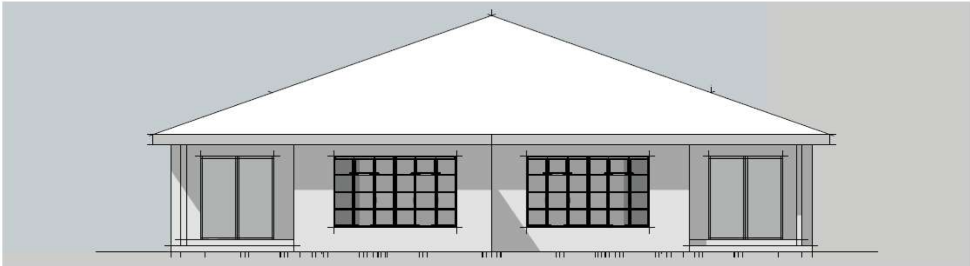
Figure 41 : Class 1 Detached House Two Storey – Sample House Schematic Plans

Figure 42 : Class 1 Semi Detached House – Sample House Schematic Plans

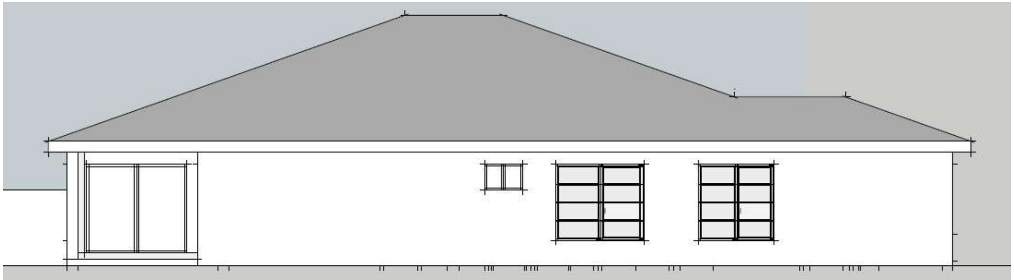
Semi Detached House H03 Plan 1:100



Street Elevation 1:100 (South)



Rear Elevation 1:100 (North)



Side Elevation 1:100 (West)

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