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Report for ICANZ

Version 4.0 (Final)

The Value of Ceiling Insulation

Impacts Of Retrofitting Ceiling Insulation To Residential Dwellings In Australia

Prepared by Energy Efficient Strategies

FOREWORD

This study was undertaken by Energy Efficient Strategies (Victoria), with assistance from Pitt & Sherry under commission from The Insulation Council of Australian and New Zealand (ICANZ). ICANZ is a leading voice for the insulation industry. Its members represent 70% of the insulation sold in Australia and New Zealand and is the leading advocate promoting the proper use of effective building insulation. Member companies include Fletcher Building and CSR.

A number of organisations were contacted during the project and their cooperation and assistance is gratefully acknowledged. We would like to particularly thank staff of:

- Commonwealth Department of Climate Change and Energy Efficiency
- ICANZ members
- Tony Isaacs Consulting for significant contributions to estimates in relation to the "Rebound effect" detailed in Appendix 5

Modelling for this study was undertaken by Robert Foster of Energy Efficient Strategies. This report was prepared by Robert Foster with assistance from Dr Tony Marker of Pitt & Sherry.

Notwithstanding the individuals and organisations that have assisted during this project, the content and form of this report, and all of the views, conclusions and recommendations expressed therein, are those of Energy Efficient Strategies P/L

While the authors have taken every care to accurately report and analyse the data, the authors are not responsible for the source data, nor for any use or misuse of any data or information provided in this report, nor any loss arising from the use of this data.

In relation to the data supplied by the Commonwealth Department of Climate Change and Energy Efficiency for the purposes of this study, that Department has advised that the data is derived from information provided by householders and installers for the purposes of the Home Insulation Program. The Commonwealth cannot guarantee the accuracy of the data and does not accept responsibility for any loss, damage or liability arising from the use of the data.

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ABBREVIATIONS

General Abbreviations

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
AC	Air-conditioner
BOM	Bureau of Meteorology, Australia
CBA	Cost Benefit Analysis
CLF	Conservation Load Factor
DCCEE	Department of Climate Change and Energy Efficiency
DEWHA	Department of Environment, Water, Heritage and the Arts
EES	Energy Efficient Strategies P/L
ESAA	Electrical Supply Association of Australia
GFC	Global Financial Crisis
HIP	Home Insulation Program
ICANZ	Insulation Council of Australia and New Zealand
MEPS	Minimum Energy Performance Standards
NatHERS	Nationwide House Energy Rating Scheme
TMY	Typical Mean Year

Space Conditioning Equipment Abbreviations

DuctC	Cooling – AC ducted (composite cooling only and reverse cycle types)
Ductgas	Heating – mains gas ducted
DuctRCH	Heating – AC reverse cycle ducted
El Resist	Heating – electric resistive (mostly portable units run from GPOs)
Evap	Cooling – evaporative (mostly central)
RCOC	Cooling – AC cooling only non-ducted (split and window wall)
Room Gas	Heating – mains gas non-ducted (room heater)
RoomLPG	Heating – LPG gas non-ducted (room heater)
RRCC	Cooling – AC reverse non-ducted (composite split and window wall)
RRCH	Heating – AC reverse cycle non-ducted
Wood C	Heating – wood - closed combustion
Wood O	Heating – wood - open combustion

EXECUTIVE SUMMARY

BACKGROUND

This report, commissioned by the Insulation Council of Australia and New Zealand (ICANZ) is intended to re-state the case for the retrofitting of ceiling insulation to the remaining stock of uninsulated residential buildings in Australia.

In 2009-10 the Commonwealth government, as part of its response to the GFC initiated the Home Insulation Program (HIP). The objective of the HIP was to retrofit ceiling insulation to the uninsulated dwellings of Australia. Unfortunately that program encountered difficulties and was terminated half way through leaving an estimated 0.8 – 1.4 million households without ceiling insulation.

In hindsight, it is little wonder that the program encountered difficulties. In an average year, approximately 200,000 new and existing dwellings are fitted with ceiling insulation (75% new dwellings and 25% retrofit of existing dwellings). In the first year of the HIP, 1.2 million existing dwellings were retrofitted – a six-fold increase in the level of delivery previously managed by the industry. The capacity of the industry was clearly overstretched and, unsurprisingly, less than optimal outcomes resulted. The rapid growth in demand for labour (a goal of the program in the context of the global financial crisis) led to some poor outcomes in terms of opportunistic business practices and reduced levels of staff training.

Whilst it is understandable that, in the aftermath of HIP, political sensitivities have meant that governments have baulked at any new programs to retrofit ceiling insulation, this report argues that a properly designed and paced program could deliver significant benefits with little risk. After all, every year all new dwellings in Australia (typically 160,000+ per annum) are fitted with ceiling insulation (with a further 40,000+ existing dwellings retrofitted) with little or no problem. The issues with the HIP related to the design of the program delivery and NOT the measure itself. The schools program (also a stimulus measure initiated in 2009) experienced similar shortcomings related to the pace of its delivery, including cost overruns and defects in roofs[1], despite this there is no suggestion that governments will abandon the building of new school facilities into the future.

Historically, both nationally and internationally a number of barriers have meant that the market has failed to significantly increase the proportion of insulated homes, despite considerable investment in marketing programs. ICANZ believes that all governments should therefore continue to include ceiling insulation retrofit as a key policy measure for reducing residential energy use. As state and territory governments continue to roll out programs such as the VEET scheme in Victoria and the REES scheme in South Australia and as new programs such as the proposed Residential Mandatory Disclosure scheme[2] are introduced, dwellings that could benefit from the

[1] Findings of the Commonwealth taskforce – The Melbourne Age Saturday 10 July 2011

[2] A RIS was released for this program in July 2011

retrofitting of ceiling insulation will continue to be identified by those programs. Despite the particular delivery issues that arose during the HIP, this study argues that retrofit of ceiling insulation should continue to be promoted as one of the best and most cost effective energy saving measures that should be supported at all levels of government.

WHY INSULATE CEILINGS ?

The thermal insulation of ceilings has long been recognised as one 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 the rate of retrofit of ceiling insulation prior to the HIP was in steady decline when measured as a percentage of the remaining stock without ceiling insulation, suggesting a significant market failure of householders to capitalize on the positive financial and health benefits associated with the retrofit of ceiling insulation.

WHAT OPTIONS WERE EXAMINED IN THIS STUDY?

Two options (post HIP) were examined with goals of insulating 50% and 100% of dwellings currently without ceiling by 2020. These goals relate to dwellings where the addition of ceiling insulation is a relatively low cost option, and therefore exclude a 10% allowance for existing uninsulated ceilings that are in accessible, noting that some of these can be insulated during roof replacement or major renovation exercises.

- Option 1 (HIP+50%) lifts ceiling insulation from approximately 200,000 to 250,000 pa (i.e. an additional 50K retrofits per annum, or 25% increase overall) from now until 2020, and will insulate half the remaining stock of uninsulated dwellings
- Option 2 (HIP+100%) lifts ceiling insulation from approximately 200,000 to 300,000 pa (i.e. an additional 100K retrofits per annum or 50% increase overall), and will insulate all of the remaining stock of uninsulated dwellings.

KEY STUDY FINDINGS

Benefits to the Householder

This study has found that the retro-fitting of ceiling insulation to the standard applied in the HIP (R3 – R4) to otherwise uninsulated dwellings will:

- Increase the star rating of the dwelling on average by 2.2 stars
- Reduce household energy consumption on average by almost 10 GJ per annum (ranges from 2GJ to 29GJ depending upon climate)
- Reduce Household energy costs on average by almost $300 per annum (in 2012) increasing to $375 by 2020 (assuming a "low carbon price" scenario)
- Provide a payback period on the investment in ceiling insulation of 5 years or less in all jurisdictions except WA and NT (7 – 8 years) and Qld (13 – 15 years). The weighted national average payback period will be 6 – 7 years at 5% discount rate and 7 – 8 years at a 7% discount rate
- Provide a positive benefit to cost ratio (B/C >1) over a 30 year payback period in all jurisdictions. The national average benefit to cost ratio ranges from 3.9 to 5.6 depending upon the discount rate and fuel price assumptions applied.
- Provide a national average annual reduction in greenhouse gas emissions of 0.93 tonnes (CO_2-e) per household in 2012 reducing to 0.83 tonnes in 2020 as the carbon intensity of electricity declines
- In the ACT, where mandatory disclosure of residential building energy performance has been required since 1999 when dwellings are advertised for sale, an improvement of 2 stars in energy rating would be expected to add significantly to the sale price.

These benefits are summarised in Table 1 including values for each jurisdiction. Financial analysis in this table is based on a "low carbon" price scenario (starting at $23/tonne) . For other scenarios refer to the results section of this report (section 4).

Table 1 : Summary of Benefits to the Householder

Benefit	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Star Rating (Additional Stars)	+2.2	+1.9	+2.3	+2.3	+2.7	+1.9	+2.1	+1.9	**+2.2**
Energy Savings (MJ/annum)	7942	29329	2017	10479	8481	19328	2600	23118	**9827**
$ Savings in 2012 ($/annum)	$254	$586	$105	$359	$279	$462	$187	$668	$299
Payback Period @ 7% Discount (Yr)	5	2	16	4	7	4	8	2	7
B/C ratio – 30 year payback @ 7%	3.4	9.2	1.4	4.6	2.8	4.7	2.4	12.0	4.3
Greenhouse. Gas Reduction in 2012 (TCO_2-e)	0.80	1.94	0.35	0.94	0.59	0.36	0.60	2.30	0.93

Benefits at the State/Territory and National Level

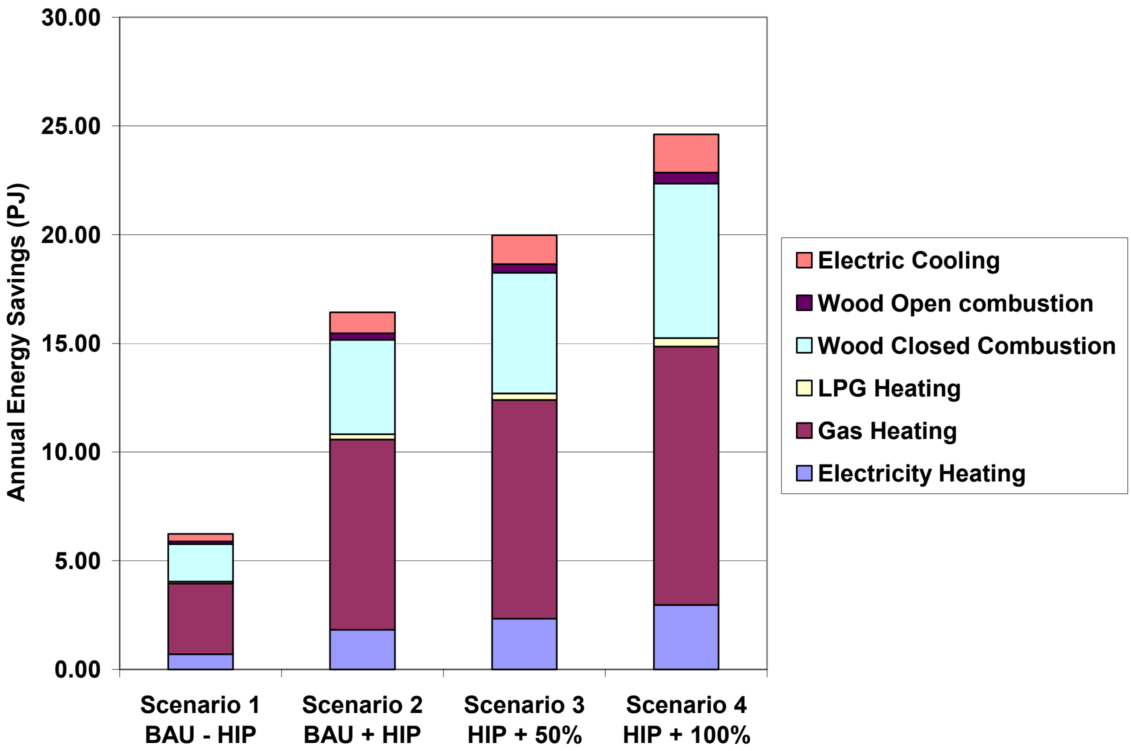
Energy

In terms of energy savings the Commonwealth Home Insulation Program is projected to be saving by 2020 an additional 9.4 – 10.2 PJ in national energy consumption.

If the (HIP+50%) option were to be adopted a further 1.8-3.6PJ could be saved, alternatively, if the (HIP+100%) option were to be adopted 4.0-8.2PJ could be saved.

The projected national energy savings in 2020 by scenario are shown in Figure 1, noting that Figure 1 shows the upper end of the estimates (in terms of number of potential retro-fits) and include a discount of 25% for expected rebound.

Figure 1 : National Energy Savings from Ceiling Insulation Retrofit in 2020 (By Scenario)



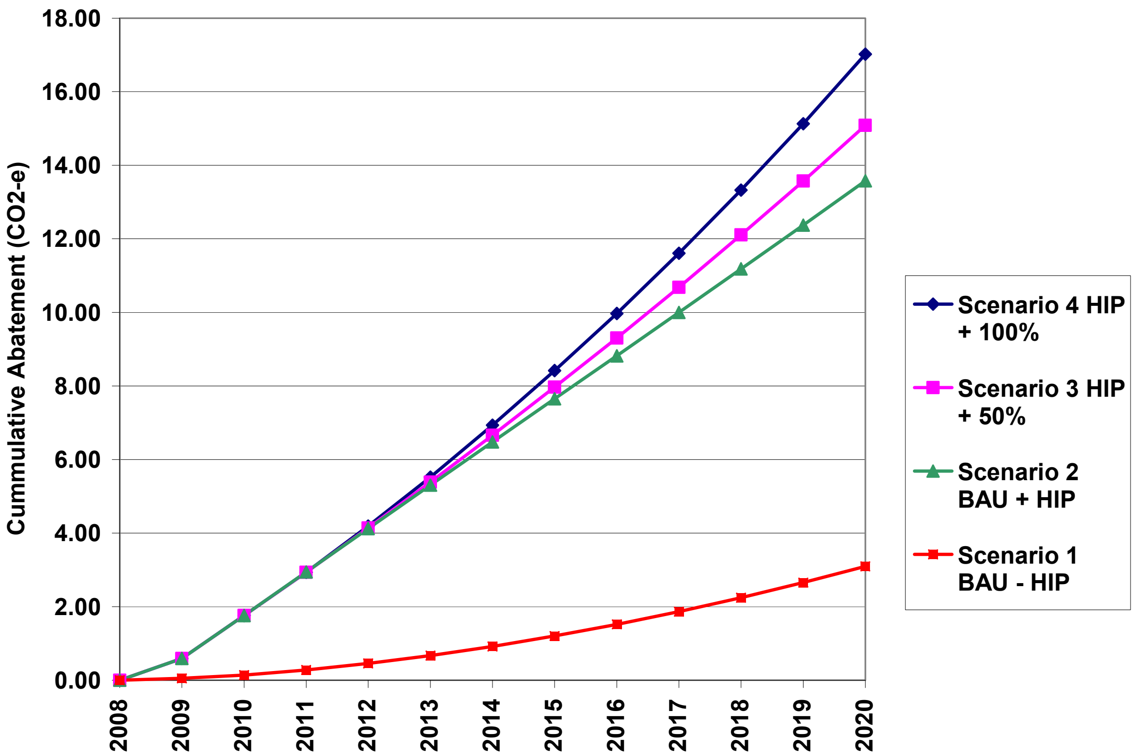
Greenhouse Gas

Nationally, by 2020 the 2009-10 HIP program (BAU + HIP) is projected to be saving 0.7 – 0.8 MT CO_2-e of greenhouse gas emissions per annum more than if that program had never been undertaken (BAU – HIP). If the HIP + 50% scenario were to be adopted then a further 0.2-0.3 MT CO_2-e of greenhouse gas emissions per annum could be avoided or if the HIP + 100% scenario were adopted a further 0.4-0.7 MT CO_2-e of greenhouse gas emissions per annum could be avoided.

Nationally, by 2020 the 2009-10 HIP program (BAU + HIP) is projected to have saved a cumulative total of approximately 10 MT CO_2-e of greenhouse gas emissions more than if that program had never been undertaken. If the HIP + 50% scenario were to be adopted (starting 2012) then a further 0.9 – 1.5 MT CO_2-e of greenhouse gas emissions could be avoided or if the HIP + 100% scenario were adopted (starting 2012) a further 1.9 – 3.4 MT CO_2-e of greenhouse gas emissions could be avoided.

The projected cumulative greenhouse gas savings by scenario are shown in Figure 2, noting that Figure 2 shows the upper end of the estimates (in terms of number of potential retro-fits) and include a discount of 25% for expected rebound.

Figure 2 : Cumulative National Greenhouse Gas Savings from Ceiling Insulation Retrofit (Upper)

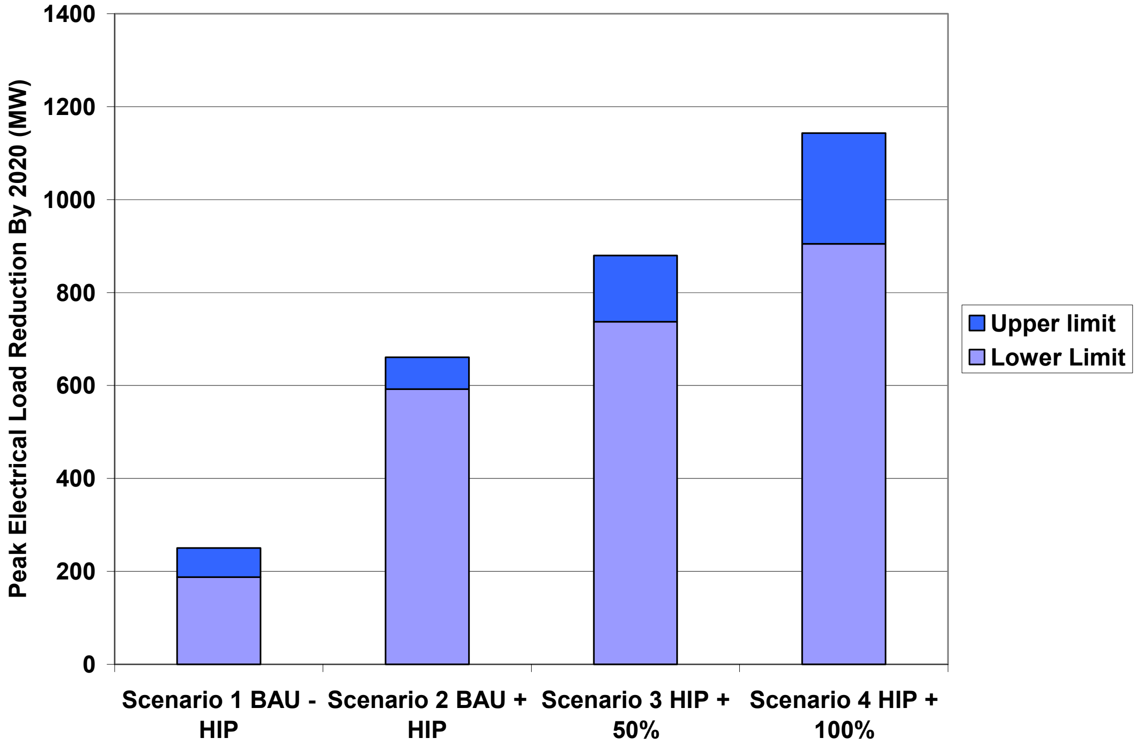


Peak Load

Nationally, by 2020 the 2009-10 HIP program (BAU + HIP) is projected to have saved a total of approximately 400 MW in required peak load capacity compared to the case where that program had never been undertaken (BAU – HIP). If the HIP + 50% scenario were to be adopted then a further 145 – 220 MW in required peak load capacity could be saved or if the HIP + 100% scenario were adopted a further 310 – 480 MW in required peak load capacity could be avoided. All these values include a discount of 25% for expected rebound. (see also Figure 3 below).

In terms of the estimated $ savings in peak load capacity attributable to the retrofit of ceiling insulation, nationally, by 2020 the 2009-10 HIP program (BAU + HIP) is projected to be saving approximately $130 million annually in infrastructure cost savings. If the HIP + 50% scenario were to be adopted then a further $48 – 72 million annually in infrastructure costs could be saved, or if the HIP + 100% scenario were adopted then a further $102 – 157 million annually in infrastructure costs could be saved. All these values include a discount of 25% for expected rebound. These savings add approximately a further 40% to the annual savings realised from avoided fuel cost alone.

Figure 3 National Electrical Peak load reduction by 2020 – Insulation to HIP Standard (MW)



Overview of Benefits at a State / National level (HIP + 100% Scenario)

If the HIP + 100% option were to be adopted, then by 2020 all dwellings that are practical to insulate would have ceiling insulation fitted (0.8 – 1.4 million dwellings). The state and national benefits that are projected to be realised by 2020 (compared to the business as usual case) under that scenario are summarised in Table 2.

Table 2 : Projected Benefits of HIP + 100% (Scenario 4) compared to BAU + HIP (Scenario 2) in 2020 (Upper)

Benefit	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Energy savings in 2020 (PJ)	3.74	2.14	0.69	0.43	0.72	0.24	0.06	0.19	**8.2**
Cumulative Greenhouse. Gas Reduction (MT CO_2-e)	1.71	0.64	0.55	0.17	0.22	0.02	0.05	0.08	**3.44**
Peak Load Reduction by 2020 (MW)	205	31	142	26	57	4	13	3	**482**
Cumulative Peak load savings $M / annum	399	34	190	66	58	2	14	5	**769**

Summary of Findings

This report, commissioned by ICANZ, demonstrates not only the value and cost effectiveness of the Home Insulation Program (HIP) but also the additional benefits that could be realised by completing the retrofit of the estimated 0.8 – 1.4 million remaining dwellings yet to be fitted with ceiling insulation. By responsibly pacing a retrofit program between now and 2020 to insulate approximately 100,000 additional dwellings per annum (rather than the 1.2 million retrofits per annum attempted under the HIP) the benefits associated with the HIP program could be extended to the remaining stock of uninsulated Australian dwellings.

For the householder, this study found those benefits to be numerous:

- Average energy savings of almost 10 GJ per annum which equates to a reduction in energy costs of almost $300/annum now, rising to $375 by 2020.
- An average payback on investment period of less than 7 years (at 5% discount). The payback period is significantly less in the cooler climates.
- An average reduction in household greenhouse gas emissions of almost 1 tonne CO2-e per household per annum.
- An increase in the average NatHERS star rating of each insulated dwelling of more than 2 stars.
- Improvements in comfort, energy bill control, noise, maintenance costs, property values and health outcomes for the householder that some studies have found can outweigh the savings in energy costs alone.

For the nation too the benefits are significant. By 2020 the HIP program will have delivered nationally:

- Cumulative savings in space heating and cooling energy costs of $3.88 billion by 2020. This could be increased by a further $1.47 billion if the remaining uninsulated dwellings were to be insulated.
- Cumulative savings in greenhouse gas emissions of 10 million tonnes of CO2-e. This could be increased further by as much as 3.4 million tonnes if the remaining uninsulated dwellings were to be insulated by 2020.
- A reduction in peak electrical load by 2020 of 400 MW. This could be doubled if the remaining uninsulated dwellings were to be insulated.
- A cumulative saving in capital investment in infrastructure required to meet that peak load demand of $1.7 billion. This could be increased further by as much as $750 million if the remaining uninsulated dwellings were to be insulated.

The retrofit of ceiling insulation to existing residential buildings remains one of the most cost effective and beneficial energy saving investment strategies, particularly for low income households where energy costs are significant and co-benefits such as improved health outcomes are of particular value. Program delivery issues associated with the HIP should not dissuade individuals or governments from embracing this key residential energy saving measure.

1. Project Overview

1.1 Background

The thermal insulation of ceilings has long been recognised as one 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

The insulation of the ceilings of all new dwellings in Australia has effectively been mandatory since 2005 (longer in some jurisdictions such as Victoria and the ACT). Such practice is common throughout the developed world.

Whilst ceiling insulation is now standard for all new housing in Australia, there remains a significant number of existing dwellings with little or no ceiling insulation.

In 2008 an ICANZ commissioned a report[3] that found that

> *Historically, both nationally and internationally a number of barriers have meant that the market has failed to significantly increase the proportion of insulated homes, despite considerable investment in marketing programs.*

In 2009 the Commonwealth introduced the Home Insulation Program (HIP) as part of its economic stimulus package designed to mitigate the impacts of the Global Financial Crisis (GFC). Between 2009 and 2010 that program resulted in the retrofit of ceiling insulation to approximately 1.2 million Australian dwellings. The HIP encountered several problems relating to its delivery (although as this study will show these problems have at times been overstated) and as a consequence it was terminated early leaving an estimated 0.8 – 1.4 million dwellings without ceiling insulation.

ICANZ have commissioned this report, largely to re-state the case for ceiling insulation post the 2009–10 House Insulation Program. ICANZ believes that governments of all

[3] Submission to the Victorian Energy Efficiency Target Scheme by the Insulation Council Of Australia And New Zealand (ICANZ) 2008

persuasions should continue to include ceiling insulation retrofit as a key residential energy saving measure. As state and territory governments continue to roll out programs such as the VEET scheme in Victoria and the REES scheme in South Australia and as new programs such as the proposed Residential Mandatory Disclosure scheme are introduced, dwellings that could benefit from the retrofitting of ceiling insulation will continue to be identified by those programs. Despite the particular delivery issues that arose during the HIP, this study argues that retrofit of ceiling insulation should continue to be promoted as one of the best and most cost effective energy saving measures that should be supported at all levels of government.

This report is effectively an update of earlier insulation studies undertaken by ICANZ, that now takes into account the impact of the HIP and also, significant changes in actual energy costs (up to 2011) and projected energy costs (up to 2020) that are being driven both by network cost increases and the upcoming price on carbon. These impacts will be shown in this report to make the case for ceiling insulation retrofit even more compelling than in previous studies.

1.2 Aim of this study

The aims for this study were to, at a State / Territory level :

- Demonstrate the benefits associated with the HIP program in terms of energy savings and greenhouse gas abatement.
- Estimate the remaining potential for retrofitting of ceiling insulation to Australian residential dwellings
- Quantify the energy, greenhouse gas and peak load reduction potential of ceiling insulation retrofits to residential buildings post the House Insulation Program
- Undertake a cost benefit analysis of this particular energy saving measure at the householder level, taking into account recent and planned increases to the cost of fuels.

1.3 Scope and Structure of this Report

1.3.1 Scope of Analysis Undertaken

There are 3 main strands to this study

- A review of the comparative value and cost effectiveness of ceiling insulation as a means of improving the energy efficiency of existing Australian residential building stock (section 2).
- An analysis of the potential scope for retrofitting of ceiling insulation to the existing residential building stock at a jurisdictional level (section 3).

- An analysis of energy, financial, greenhouse gas emission and peak load benefits associated with the retrofitting of ceiling insulation to the existing residential building stock at a jurisdictional level (section 4).

1.3.2 Scenarios Modelled

This study included the examination of 4 different scenarios as a means of illustrating the potential benefits that have resulted from ceiling insulation, and could continue to flow from a program that accelerates ceiling insulation retrofitting.

Scenario 1 - BAU in the absence of the HIP program (BAU-HIP)

This scenario assumes that the HIP had never been undertaken at that the retrofit of ceiling insulation to existing residential dwellings from 2008 onwards simply followed the trend based on regression analysis of past trends for such retrofitting. The main purpose of this scenario is to establish a base case against which estimates of the benefits stemming from the HIP can be assessed.

Scenario 2 - BAU including the HIP program (BAU+HIP)

This is the actual business as usual case that takes into account the impact of the HIP and assumes that the retrofit of ceiling insulation to existing residential dwellings from 2010 onwards simply follows the trend based on regression analysis of past trends for such retrofitting. It should be noted, however, that following the HIP it is expected that whilst the proportion of retrofits in relation to the number of remaining dwellings left uninsulated will remain the same, the total number of annual retrofits will be significantly reduced as a result of the HIP intervention, compared to the number of retrofits undertaken before the HIP (i.e. a smaller pool of dwellings will left without ceiling insulation compared to before the HIP – see section 3.4).

Scenario 3 - HIP program plus an intervention to insulate half of the remaining uninsulated stock by 2020 (HIP+50%)

This scenario takes into account the impact of the HIP but then assumes that the retrofit of ceiling insulation to existing residential dwellings from 2012 onwards will be such that by 2020, 50% of the uninsulated stock (as at 2011) shall be retrofitted with ceiling insulation.

Scenario 4 - HIP program plus an intervention to insulate all of the remaining uninsulated stock (that is practical to insulate) by 2020 (HIP+100%)

This scenario takes into account the impact of the HIP but then assumes that the retrofit of ceiling insulation to existing residential dwellings from 2012 onwards will be such that by 2020, 100% of the uninsulated stock (as at 2011) that is practical to insulate shall be retrofitted with ceiling insulation. It is recognised that some currently existing uninsulated ceilings (as of 2011) are inaccessible (flat roofs, cathedral ceilings), and for the purpose of modelling it has been assumed that such ceilings represent 10% of the existing stock in 2011 and these dwellings would not be included in the retrofitting undertaken under this scenario. Note that some of these ceilings can be insulated during roof replacement or major renovation exercises.

1.3.3 Dwelling Types Examined

For this study, the scope of housing types examined were 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 – the majority of ceilings in these dwellings are bounded above by another occupancy and as such there is no value in applying ceiling insulation. These types of dwellings were also largely excluded from the HIP.

A range of dwelling designs was used to build a representative housing profile. These dwellings were sourced from the detached and semi detached sample dwellings used in the study Energy Use in the Australian Residential Sector 1986-2020 (EES 2008) – see section 8.3.1. Whilst the plans are generic, they are modelled through a representative range of construction types (see following section).

1.3.4 Construction Types Examined

The construction type of the floor, walls and to a lesser degree the roof affects both the insulating characteristics and the thermal mass of the building shell. For the purposes of modelling and based on ABS data, a set of the most common floor/wall combinations were selected to represent the full range of major construction types (see Table 3). The proportions of the various wall construction types in the existing stock were determined through reference to the ABS National Energy Surveys for 1980 (ABS8212.0, 1981), 1983 (ABS8212.0, 1984), 1985-6 (ABS8212.0, 1987) and 1994 (ABS 4602.0, 1994) and to ABS building Approvals data from 1996 to 2005 (ABS 2006). For complete details relating to construction type assumptions refer to the study *Energy Use in the Australian Residential Sector 1986-2020* (EES 2008) – see section 7.2.4.

As outlined in Appendix 1, energy modelling is undertaken on a State-by-State basis with appropriate stock numbers and proportions of the construction types for each State.

Table 3 : Construction Types Examined

Construction*	Description
Lightweight/Timber Floor	Timber or metal framed walls with sheet cladding and suspended timber floor
Lightweight/Concrete Floor	Timber or metal framed walls with sheet cladding and a concrete raft slab floor**
Brick Veneer/Timber floor	Brick or block veneer walls, internal timber or metal wall frame and a suspended timber floor. Category also Includes pre-cast concrete walls with internal framing
Brick Veneer/Concrete floor	Brick or block veneer walls, internal timber or metal wall frame and a concrete raft slab floor. Category also includes pre-cast concrete walls with internal framing
Heavy Weight/Timber floor	Cavity Brick or block or pre-cast concrete and suspended timber floor
Heavy Weight/Concrete floor	Cavity Brick or block or pre-cast concrete and a concrete raft slab floor

Notes:

* Variations in Roof types were not considered in this study, as generally speaking roof type (as distinct from roof insulation) has a comparatively small effect upon thermal performance.

** Note: Combinations of lightweight structure with concrete floor were found to be relatively uncommon.

1.3.5 Retrofit Options Examined

Sample dwellings were modelled without ceiling insulation (base case) then re-modelled using 4 different levels of improvement. The improvements were in the form of added ceiling insulation. The level of insulation applied was set to one of two options. The first option aligned with the values specified in the HIP program as shown in Table 2 and the second option assumed that all ceilings were retrofitted with R5 insulation (in line with increasingly common practice in new dwellings).

Option 1 – As per HIP program

- R3 ceiling insulation as mandated for BCA climate zones 1 – 3
- R3.5 ceiling insulation as mandated for BCA climate zones 4 - 6
- R4 ceiling insulation as mandated for BCA climate zones 7 & 8

Option 2 – R5 to entire area of ceiling below the roof

Table 4 : Home Insulation Program R Value Requirements by Climate Zone (DEWHA 2009)

Table 1: Program R-Value Requirements by Climate Zone

Climate zone (see climate maps at www.environment.gov.au/ energyefficiency)	1	2 At less than 300m altitude	2 At 300m altitude or more	3	4	5	6	7	8
Minimum R-Value requirements The R-Value can be either: 1. Material R-Value OR 2. Total R-Value approach outlined in the Building Code of Australia[8]	3.0	3.0	3.0	3.0	3.5	3.5	3.5	4.0	4.0
Direction of heat flow	Down		Down and Up		Up				

Notes on Table 1:

- Material R-Value is the declared R-Value of the insulation product as tested according to AS/NZS4859.1. This value should be marked on the insulation packaging.
- Material R-Value is not the same as Total R-Value. Total R-Value includes the Material R-Value plus the thermal value of building elements and reflective air spaces.
- The assistance of up to $1,600 is available for a variety of insulation materials, provided the other requirements listed above are met.

The modelling assumed that the entire ceiling space was insulated except for any attached garages. For two storey dwellings insulation was only applied to the ceiling of the upper floor – insulation between storeys has very limited benefit and is not cost effective.

The modelling also 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. All new dwellings currently require wall insulation under BCA requirements.

1.3.6 Financial Options Examined

Cost benefit analysis is necessarily based on a number of financial assumptions. Primarily, these assumptions were as follows.

Discount Rates

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 (ceiling insulation) For this study two different levels of discount rate were examined:

- 5% representing what is considered a reasonable return on a long term investment
- 7% representing the level commonly mandated by governments when assessing the viability of a proposed market intervention

Maximum Acceptable Payback Period

The maximum acceptable payback period is the maximum period of time deemed acceptable in which the discounted return on the initial investment (i.e. annual savings in fuel costs) matches the value of that initial investment (in this case the cost of insulating the ceiling). In other words the Benefit to Cost ratio is equal to one.

Based on the known longevity of ceiling insulation, the maximum acceptable payback period was set at 30 years, noting however that in most jurisdictions the payback period was found to be significantly less (typically less than 10 years)

Fuel Costs

Estimates of likely future fuel costs (primarily electricity, gas, LPG and wood) are required in order that estimates of future space conditioning fuel cost savings can be made. For this study three scenarios for fuel costs were modelled:

- BAU
- BAU + Low carbon price
- BAU + Medium carbon price

The residential electricity and gas price estimates for the future are based on detailed work undertaken by pitt&sherry in the first half of 2011, prior to the announcement of an interim carbon price by the Commonwealth. The prices have been separately developed for all capitals, and the generally higher non-capital tariffs have not been taken into account.

Prices for electricity and gas have been constructed as the sum of major cost components, comprising wholesale costs, network (transmission and distribution) costs, retail operating costs, and retail margin.

The modelling from which the wholesale market costs were derived was for a 'without carbon price' case. A carbon price was therefore added on a cost pass-through basis. The BAU case has no carbon price. In the BAU + Low Carbon Price case the carbon price starts at $23 per t CO_2-e (2011 prices) in 2012-13 and increases at 4% per year for the whole projection period. In comparison, the carbon price subsequently announced by the Commonwealth was $23 increasing at 2.5% pa until the introduction of emissions trading in 2015. We believe the uncertainty surrounding the future price path of carbon means the price estimate used is reasonable - for electricity the carbon price will represent 10 – 15% of current prices (depending on jurisdiction) so that small changes in the assumed path of the carbon price will have very little impact on the NPV of future prices. For the BAU + Medium Carbon Price the carbon price starts at $23 and rises by $3 per year, which means the annual percentage price increase falls over time. Such price 'glide paths' are used as an alternative to a higher initial price with a constant percentage increase over time. By 2020, the Low and Medium price paths would result in carbon prices of $30 and $44, respectively.

Prices for the lesser fuels, LPG and firewood were based on estimates made by the Allen Consulting Group for the Residential Mandatory Disclosure project. The cost (2011 prices) of LPG ranged from 4.4 to 5.2 cents /MJ depending upon the jurisdiction and the cost (2011 prices) of firewood ranged from 0.5 to 1.0 cents /MJ ($80 to $160 per tonne) depending upon the jurisdiction.

Refer Appendix 2 for further details relating to the financial modelling undertaken in this study.

1.4 Energy Modelling Methodology Overview

The modelling method used in this study is based on that used in the study *Energy Use in the Australian Residential Sector 1986-2020* (EES 2008). A schematic of that model is shown in Figure 18. This is believed to be the most comprehensive “bottom up” model of residential energy use available and has been verified against top down (ABARE) data.

Further details regarding the methodology are contained in Appendix 1: Modelling Methodology – Energy

This study also considered those factors that are likely to constrain the economic and greenhouse abatement benefits arising form the particular ESM (e.g. Rebound effects). These are detailed in Appendix 5 : Review of Factors Likely to Constrain Benefits. 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 energy greenhouse gas emission savings and peak load were discounted to 75% of the modelled value in consideration of the rebound effect.

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.

1.5 Financial Modelling Methodology Overview

Primarily the financial 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 (ceiling insulation) was determined by ICANZ for each jurisdiction via reference to its key members.

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

- Projected savings in space conditioning energy usage following the application of ceiling insulation (i.e. based on the analysis outlined in section 1.4)
- Assumed payback period (see section 1.3.6)
- Applied Discount rate (see section 1.3.6)
- Projected fuel costs (see section 1.3.6 and Appendix 2 : Modelling Methodology – Financial)

1.6 Greenhouse Gas Abatement Modelling Methodology Overview

Modelled space conditioning energy use (see section 1.4) on a State basis was aggregated into each of the four fuel types as follows:

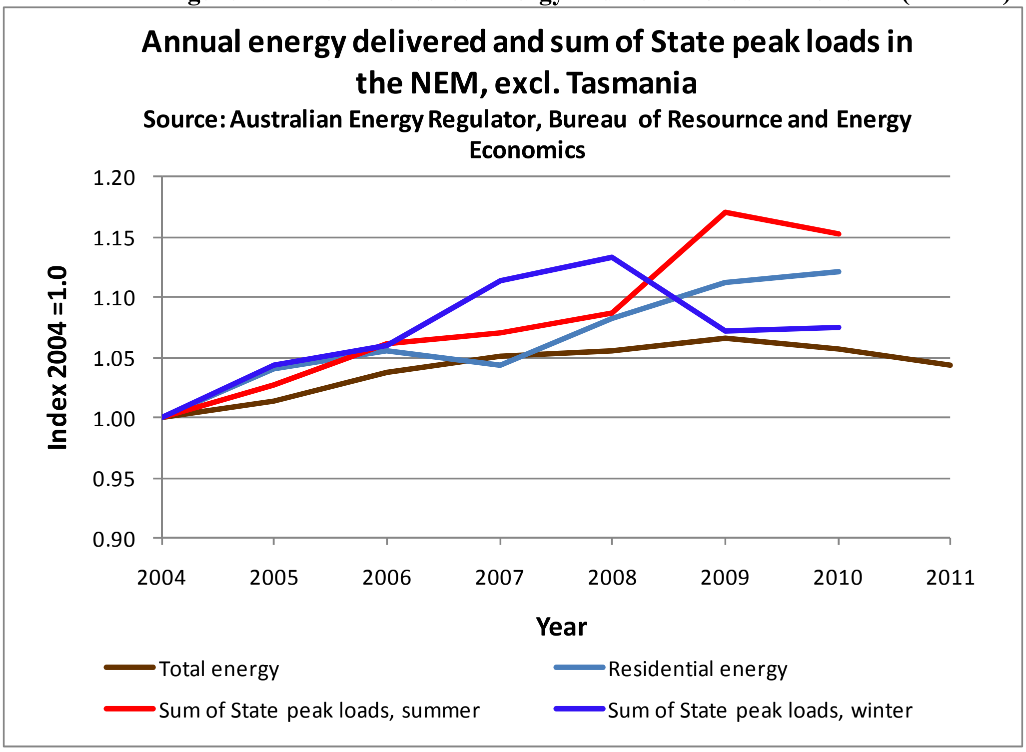
- Electricity
- Gas
- LPG
- Firewood (modelled separately for both open and closed combustion[4])

Greenhouse gas coefficients are then applied to each fuel type to determine estimated total greenhouse gas emissions per household by state and territory, recognising that the carbon intensity of electricity varies by jurisdiction. By comparing the estimated greenhouse gas emissions before and after the application of insulation to the sample dwelling ceilings an estimate of the abatement potential can be made.

1.7 Peak Load Reduction Modelling Methodology Overview

In recent years peak load has grown much faster than electricity demand, as shown in Figure 4.

Figure 4: Annual Delivered Energy and Peak Loads in the NEM (ABARE)



[4] Firewood is separately tracked according to the equipment type it is burnt in, either closed combustion or open combustion, this is important because the type of combustion significantly affects the greenhouse gas intensity of this fuel type.

This strong growth in peak load has had a big impact on residential electricity prices, with transmission and distribution costs now amounting to about 50% of tariffs. Proposed total annual electricity network CAPEX over the period 2011-2014 averages $9.5 billion, and will contribute to further increases in electricity prices. Therefore, the ability of energy efficiency contributions such as ceiling insulation to contribute to the reduction of peak loads needs to be quantified in order to make better energy policy decisions. The ultimate goal should be to incorporate the economic benefits of peak load reduction (supply side) into benefit/cost analysis of energy efficiency policies and programs (demand side).

In 2004 Energy Efficient Strategies developed a model of Victoria's electrical peak load for VENCORP (Victorian Energy Networks Corporation) and for the Australian Greenhouse Office (now DCCEE). The study that accompanied the model was entitled "Electrical Peak Load Analysis – Victoria 1999-2003" (EES 2004). In that study it was established that provided appropriate and representative input data is used, AccuRate thermal simulation software can be used to infer summer electrical peak loads associated with the space cooling of dwellings to an accuracy of +/- 3%.

The VENCORP study used actual weather data to test and prove the model's accuracy against actual state electrical load. A similar study was repeated by EES for Energy SA and DEWHA including some refinements to the AccuRate software to improve the curve fit of the modelled load. This same methodology has been applied in this study. For further details refer to Appendix 4 : Modelling Methodology – Peak Load.

The modelling undertaken in this study provides estimates of both annual energy and peak load savings by State, and together with the earlier peak load modelling studies undertaken by EES there is a strong basis for linking annual energy and peak load reductions through what is known as a Conservation Load Factor (Koomey 1990). The Conservation Load Factor (CLF) was introduced in the United States in order to estimate the financial benefit of the reduction in peak load. The CLF is defined as the average annual load savings divided by the peak load savings, where both are based on measured data or the output of an hourly simulation model.

For further details refer to Appendix 4 : Modelling Methodology – Peak Load.

2. Why Ceiling Insulation?

2.1 General Principles

Insulation fundamentally acts to reduce the rate of heat flow from areas of higher temperature (e.g. the heated interior of a dwelling) to areas of lower temperature (e.g. the exterior of a dwelling during a cold winter's day). By limiting such heat flows, either out of a building in the winter or into the building in the summer it is possible to reduce the need for space conditioning (i.e. energy) as a means of maintaining acceptable internal comfort conditions for the dwellings occupants.

Ceiling insulation is particularly effective in limiting heat flow from inside a dwelling to outside, as natural convective currents mean that the highest internal temperatures (and hence the site for potentially the greatest heat flows) are at the ceiling. Furthermore, because roof spaces can become exceedingly hot in the summer (>50^{0}C), ceiling insulation is also effective in limiting heat flow from the roof space down into the dwelling.

Whilst it is true that wall and to a lesser extent floor insulation will also have a beneficial effect on heat flows into and out of the dwelling, ceiling insulation typically offers the greatest benefit for the least cost. This is in part a result of the fact that the retrofitting of ceiling insulation to a ceiling space is typically a simpler and therefore cheaper process (particularly in the case of the most common form of roof the attic style roof) than is the case for either wall or floor insulation retrofit.

2.2 Benefits Compared to Other Energy Saving Measures

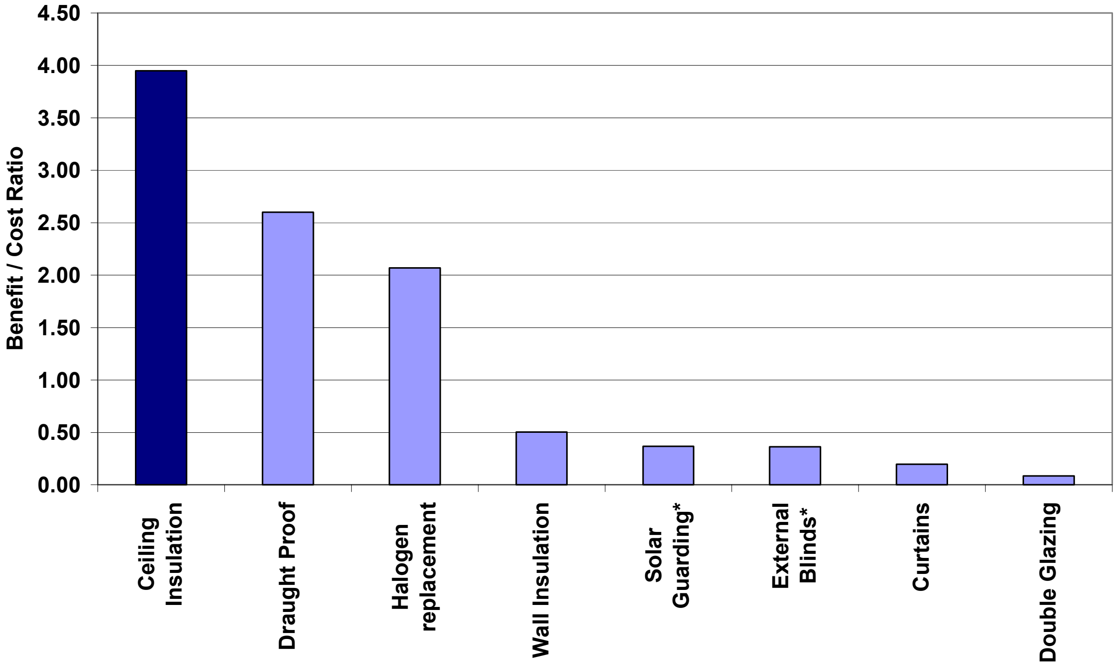
Compared to other forms of residential energy saving measures (ESM) ceiling insulation consistently demonstrates one of the highest benefit to cost ratios. EES undertook some analysis of various energy saving measures as part of the study undertaken by Allen Consulting Group (ACG) into the proposed Residential Mandatory Disclosure (RMD) Scheme. Average weighted national results[5] from that analysis can be seen in Figure 5. The results shown in Figure 5 are for a 10 year payback period with 0% discount rate[6]. These results are approximately equivalent to the results obtained in this study (for ceiling insulation) using a 30 year payback period with a 7% discount rate and the no carbon price for fuel costs.

[5] Note : The weighting applied per state and territory was based on projected stock of housing in each state by 2020 (ABS3236-2010 Series III). In reality the appropriate weightings for each ESM is likely to vary from that suggested by the housing stock numbers , nevertheless using a common weighting scheme gives a reasonable basis for comparing the cost effectiveness of various ESM's

[6] The analysis for the RMD scheme undertaken by EES did not include for a discount rate (applied later by ACG).

As can be seen from this analysis, ceiling insulation is clearly one of the most cost effective energy saving measures that can be applied to a residential dwelling. It should be noted that the cost effectiveness of each measure shown in Figure 5 is an average value only and the cost effectiveness will vary according to the particulars of an individual household (e.g. occupancy levels, space conditioning equipment types installed, occupant behaviour etc).

Figure 5 : Comparative National Average Benefit Cost Ratios for Various ESMs



* Comparisons for solar guarding and external blinds are based on results for Queensland and Northern Territory only where such ESM are most beneficial

For a typical dwelling it is easy to demonstrate that ceiling insulation is the single most important element for delivering building shell energy efficiency. In the absence of ceiling insulation, it can be shown that elaborate additional efforts to improve thermal performance such as high performance wall and floor insulation and very high performance glazing (timber frames, low-e double glazing with argon fill) struggle to deliver even a 2 Star energy performance. With the addition of ceiling insulation, performance levels as high as 7 Stars become possible. Table 5 below demonstrates the impact of ceiling insulation in the context of overall thermal performance, and shows the results of AccuRate modelling of a single storey brick veneer/concrete slab on ground dwelling[7] in the Melbourne climate zone.

[7] The house used was house H4 of the AccuRate Protocol Set

Table 5 : Sample Building Shell Performance – Various Design Strategies (Climate 21)

Iteration	Design Features	Conditioning Energy (MJ/m^2 per annum)	Star Rating
1	No ceiling or wall insulation Basic single glazing/aluminium frame	522	**1.2**
2	#1 plus R2.5/foil wall insulation	470	**1.4**
3	#1 plus very high performance (low-e, argon) double glazing (U=1.7)	467	**1.4**
4	#1 plus R3 ceiling insulation	186	**4.2**
5	#1 plus R5 ceiling insulation	173	**4.4**
6	#5 plus wall insulation (#2) and very good glazing (#3)	71	**7.4**

In most circumstances, ceiling insulation is the critical first step for reducing space conditioning energy consumption and greenhouse gas emissions and improving comfort and health.

Fortunately and conveniently, ceiling insulation (along with good weather stripping/draught-proofing) is the lowest cost and most cost effective means to reduce energy consumption and improve comfort.

The benefits of a wider variety of other measures can be modelled or estimated, but as can be seen in Table 5, unless the ceiling (or roof) is insulated other measures have limited impact on the star rating. The 'step size' of AccuRate energy stars decline in a geometric progression (the step size declines by about 30% per star for Melbourne from 1 star to 4 stars), so unless the important ceiling insulation is applied first (benefit of 3 stars ~ $340MJ/m^2$), the more expensive ESMs (wall insulation and very good glazing both ~ $50MJ/m^2$) have limited impact on energy saving or star rating.

2.3 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 to achieve 3 star energy performances 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^oC there is an increased risk of respiratory disease, and below 12^oC increased risk of cardiovascular problems. The World Health Organisation recommends that temperatures in living areas should be maintained above 18^oC, and at 20-21^oC for the elderly or very young (Collins 1986).

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 study of particular relevance conducted in New Zealand, examined the benefits of retrofitting insulation to houses with respect to health, energy and the environment. The study 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.

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. A 5 star house in Melbourne will be below 16^oC for only 28% of the time and predominantly during sleeping hours. The same house without ceiling insulation will be below 16^oC for 42% of hours. Similar results are observed in other climates. In warmer climates the reduction of hot temperatures will help to relieve heat stress for the aged, young or infirm.

Considerable international research has also shown multiple spin-off benefits to the health and well being and productivity for people living in thermally comfortable housing, which directly reduced the demand on burdened health systems. Additionally, a longer tenancy period for retrofitted insulated properties, delivers reductions in property management costs, and increases rental income are also achieved.

2.4 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. A study by the ABS for DEWHA 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 below (Section 4.2), ceiling insulation 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 10% 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).

3. What is the Scope for Retrofitting?

3.1 Introduction

The potential for cost effective energy and greenhouse savings to be derived from the retrofitting of ceiling insulation to residential buildings is naturally dependent upon the actual number of dwellings remaining without ceiling insulation. This study attempts to make estimates of both the current and future potential for ceiling insulation retrofit via reference to various data sources, primarily the ABS and DCCEE.

The ABS has undertaken several surveys in the ABS4602 series that has examined this particular aspect of dwellings and this data is analysed in Section 3.2. In addition the Commonwealth Department of Climate Change and Energy Efficiency (DCCEE) has kindly provided data from the home Insulation program (HIP) that ran from February 2009 until February 2010, and which has fitted ceiling insulation to more than 1.2 million Australian households. The impact of the program is examined in Section 3.3. Finally, in Section 3.4, based on the available data, estimates for the future potential for ceiling insulation retrofitting are made.

3.2 ABS Data

In its 4602 series of surveys the ABS undertook surveys of the following:

- whether insulation was installed in respondents dwellings
- where insulation was installed (ceiling, wall and or floor)
- in the case of ceiling and wall insulation, the type of insulation installed

These surveys were undertaken in 1994, 1999, 2002, 2005 and the last survey reported was undertaken in 2008 (i.e. immediately prior to the Commonwealth Home Insulation Program).

The percentage of dwellings reported to be insulated is shown in Table 6. This includes all locations for insulation including ceilings, walls and floors. Whilst ceiling insulation is the most common form of insulation not all dwellings reported as being insulated in the ABS surveys indicated that such insulation included ceiling insulation. Approximately 2 – 3% of insulated dwellings were reported as having no ceiling insulation (Table 7). By discounting the number of dwellings reported as insulated (Table 6) by the percentage of those dwellings reported as being insulated with ceiling insulation a value for the number of dwellings with ceiling insulation can be derived (Table 8). The number of dwellings reported as being insulated with ceiling insulation is also shown graphically in Figure 6. What is particularly notable from this figure is that the curved trend-line (with an R^2 value = 1) based on ABS data indicates that the rate of retrofit prior to the HIP was in steady decline when measured as a percentage of the remaining stock without ceiling insulation, suggesting a significant market failure of householders to capitalize on the positive financial benefits associated with the retrofit of ceiling insulation.

Table 6 : Percentage of dwellings reported to be insulated by year (ABS)

Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1994	44.5	69.5	28.5	72.2	52	62.7	43.9	79.5	52.1
1999	47.6	71.3	33	70.8	57.3	64.1	44.8	75.8	54.5
2002	50.5	72.1	36.2	75.7	64.5	68.2	42.3	80.4	57.5
2005	54.4	72.3	43.2	78.2	65.6	74.6	49.2	78.5	60.5
2008	53.4	73.8	46.9	76.6	69.4	74.6	48.4	77.3	61.5

Table 7 : Percentage of Insulated dwellings reported to have ceiling insulation by year (ABS)

Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1994	96.6	98.6	91.8	97.3	99.1	96.9	98	97	97.1
1999	97.4	98.7	93.3	98.4	99.3	97.2	98.3	98.8	97.7
2002	98.2	98.6	94.5	99.3	99.2	97.6	97.1	99	98.1
2005	97.1	98.7	94.4	99	99.7	98.1	98.3	99.2	97.8
2008	97.2	98.7	95.9	99.4	99.3	97.8	98.6	97.9	98

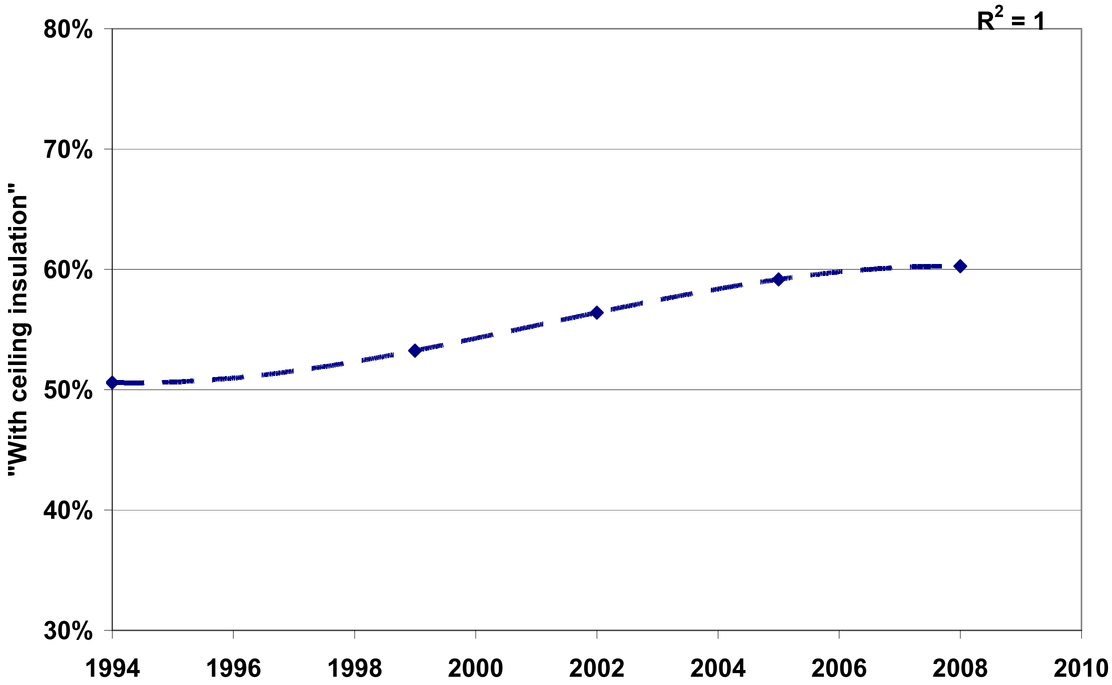
Table 8 : Percentage of dwellings reported to be insulated with ceiling insulation by Year (ABS)

Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1994	43.0	68.5	26.2	70.3	51.5	60.8	43.0	77.1	50.6
1999	46.4	70.4	30.8	69.7	56.9	62.3	44.0	74.9	53.2
2002	49.6	71.1	34.2	75.2	64.0	66.6	41.1	79.6	56.4
2005	52.8	71.4	40.8	77.4	65.4	73.2	48.4	77.9	59.2
2008	51.9	72.8	45.0	76.1	68.9	73.0	47.7	75.7	60.3

Table 9 : Percentage of dwellings reported with unknown insulation status by Year (ABS)

Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1994	16.1	13.5	17.9	12	11.3	8.5	27.6	10.8	14.7
1999	20.9	16.3	18.4	16.7	13.7	13.6	23.6	14.8	17.9
2002	21.5	15.8	18.9	11.5	12.6	10.6	30.3	11.7	17.5
2005	20.7	18.5	21.3	13.1	14	13.2	34.4	17.9	18.9
2008	21	17.7	23.1	14.7	14.3	14.5	30.4	18.2	19.3

Figure 6: National Percentage of Dwellings Reported as "Having Ceiling Insulation" (ABS 2008)



In addition to the number of dwellings reported as having insulation (of one form or another) in the ABS survey data, a significant number of respondents indicated that the insulation status was unknown (see Table 9). This means that there is a relatively high level of uncertainty as to the exact number of dwellings fitted with ceiling insulation.

To address this uncertainty it was decided that an upper and lower boundary be established for the number of dwellings without ceiling insulation based on the available data. The lower boundary of uninsulated ceilings (i.e. the least number of uninsulated ceilings) would be based on an assumption that the rate of ceiling insulation for those that responded as "unknown" matched the rate for those that responded as "known". The upper boundary of uninsulated ceilings (i.e. the assumed highest number of uninsulated ceilings) would be based on an assumption that the rate of ceiling insulation for those that responded as "unknown" was half the rate for those that responded as "known". .

The upper boundary assumption may appear somewhat extreme (i.e. it would normally be expected that the rate of insulation in the unknown category would match that in the known category), however this upper boundary has been set taking into account the very high likelihood that a proportion of those dwellings, where the respondent indicated that their dwelling was insulated, were in fact not insulated. Some that responded that their dwelling was insulated are likely to have simply been guessing or were possibly ill informed, others are likely to have given a response that they assumed the interviewer wanted to hear (i.e. the "environmentally responsible" response). A further consideration is the fact that the ABS study also found that a proportion of respondents indicated that the type of ceiling insulation installed was "foil" type" (5 – 6% on average across Australia, although higher in some states). In many cases the effectiveness of this form of insulation will be limited (particularly in draughty attic spaces, where upwards facing foil is covered in dust, or where the material has degraded to the point that the trapped air space can no longer be considered unventilated) and the ceiling could reasonably be considered to be close to being un-insulated.

The results of these estimates for the upper and lower boundaries for the number of dwellings without ceiling insulation are shown in Table 10 and Table 11 respectively. By 2008 it is estimated that between 25% and 32%, or between 2 and 2.6 million Australian dwellings were without ceiling insulation.

Table 10 : Upper limit of dwellings estimated to have no ceiling insulation by year (%)

Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1994	52.9	26.1	71.0	25.0	45.2	36.4	48.8	18.2	45.1
1999	47.5	22.8	65.7	23.3	38.6	32.8	49.2	18.6	40.9
2002	43.6	22.2	61.8	19.9	31.4	29.5	50.0	15.1	37.6
2005	40.3	20.5	53.7	16.7	29.3	21.3	39.0	13.6	33.9
2008	41.2	19.3	48.3	17.3	25.3	20.9	41.9	15.9	32.5

Table 11 : Lower limit of dwellings estimated to have no ceiling insulation by year (%)

Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1994	48.8	20.8	68.1	20.2	41.9	33.6	40.6	13.5	40.7
1999	41.4	15.9	62.3	16.4	34.1	27.9	42.4	12.1	35.1
2002	36.8	15.6	57.8	15.1	26.8	25.5	41.1	9.9	31.6
2005	33.4	12.4	48.2	10.9	23.9	15.7	26.3	5.1	27.0
2008	34.3	11.5	41.5	10.7	19.6	14.7	31.4	7.5	25.3

It should be noted that whilst these percentage changes over time shown in Table 10 and Table 11 appear to be significant, these are percentages of the stock of households in the particular year noted. With strong growth in the number of households between 1994 and 2008 (6.56 to 8.08 million or 23% growth) the reality is that prior to the HIP program the rate of ceiling insulation retro-fit was in fact quiet low. During this period and particularly since 2003, an increasing share of new dwellings were required to have ceiling insulation as jurisdictions adopted the increasingly stringent energy requirements of the Building Code of Australia. The percentages noted in Table 10 and Table 11 can be converted into actual numbers of households without ceiling insulation by multiplying these values by the total number of households as reported by the ABS in ABS3236-2010 (see Table 12 for the upper limit and Table 13 for the lower limit).

Table 12 : Upper limit of dwellings estimated to have no ceiling insulation by year (000's)

Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1994	1169	424	844	143	282	67	26	19	2956
1999	1141	397	886	139	267	62	29	22	2927
2002	1083	408	881	122	230	57	31	18	2807
2005	1020	391	801	104	224	42	25	17	2613
2008	1081	387	769	111	207	42	28	21	2628

Table 13 : Lower limit of dwellings estimated to have no ceiling insulation by year (000's)

Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1994	1078	337	810	115	262	62	21	14	2670
1999	993	278	839	98	236	53	25	14	2512
2002	914	286	824	92	196	49	25	12	2361
2005	845	237	718	68	183	31	17	6	2083
2008	900	230	661	69	160	29	21	10	2046

It is notable that for the upper limit estimates the trend over time in the number of dwellings without ceiling insulation appears to be static or even slightly upwards in the ACT and NT[8]. For the lower limit estimates (i.e. the assumed highest rate of retrofit) the trend is generally downwards, even so the total reduction in uninsulated ceilings between 1994 and 2008 was just over 600,000 households or just 45,000 per annum.

3.3 HIP Program

The Commonwealth Home Insulation Program (HIP) commenced in February 2009 and ended in February 2010, and involved the insulation of ceilings in approximately 1.2 million Australian households.

Phase 1 of the Program ran from 3 February 2009 to 30 June 2009. The owner occupier element of this phase was known as the Homeowner Insulation Program and allowed eligible owner occupiers to source an installer, pay them directly for installing ceiling insulation and then seek re-imbursement from the Government of up to $1,600. In addition, the Low Emission Assistance Plan for Renters provided up to $1,000 assistance to eligible landlords and tenants for the installation of ceiling insulation. On 1 September 2009 the Low Emission Assistance Plan for Renters and the Homeowner Insulation Program were rolled into the Home Insulation Program allowing owner occupiers as well as landlords and tenants access to up to $1,600 in assistance for the installation of ceiling insulation.

[8] The slight upward trend is unlikely to have occurred in reality (particularly given that the ACT effectively had mandatory ceiling insulation requirements for new dwellings throughout this period) and is most probably a result of the relatively high degree of uncertainty in relation to the available data. Even so, clearly the rate of retrofit to existing dwellings must have been low.

Phase 2 of the Program ran from 1 July 2009 until closure of the Program on 19 February 2010. Under this phase, the householder arranged for the installation of ceiling insulation by an installer on an Installer Provider Register. On completion of the work both the installer and householder signed a work order form verifying compliance with program requirements and that the householder was satisfied with the work. The installer was then able to lodge a claim for payment with the Government.

For this project DCCEE provided data regarding the number of "claims" (i.e. claims for payment for the installation of ceiling insulation) by postcode. By cross matching postcodes to NatHERS climate zones an estimate could be made of the number of retrofits per climate zone. Almost all claims (98%) could be successfully matched via their postcodes to NatHERS climate zones. The remaining 2% generally could not be matched because.[9]

The results of this analysis are shown in Table 14. DCCEE figures suggest a total of 1.24 million retrofits of ceiling insulation but after matching claims to identifiable postcodes and or NatHERS climate zones this figure was reduced to 1.21 million retrofits. Table 15 and Table 16 provide a breakdown of ceiling insulation retrofits by NatHERS climate zone. This breakdown is used in Appendix A as part of the basis for estimating the impact of the HIP program.

Table 14 : Number of Claims (Retrofits of Ceiling Insulation) under the HIP program

Jurisdiction	DCCEE Estimates	Number Matched to Climate Zones	% Match
NSW	489259	486840	99.5
VIC	279941	276837	98.9
QLD	339186	319907	94.3
SA	41115	39297	95.6
WA	67965	66591	98.0
TAS	15304	15198	99.3
NT	2728	2725	99.9
ACT	5761	5739	99.6
AUS	**1241259**	**1213134**	**97.7**

It should be noted that some industry sources have suggested that there is a degree of uncertainty regarding the actual number of retrofits achieved under the HIP and that in fact actual numbers of retrofits may be fewer than suggested in Table 14. Whilst this study makes no claim in this respect this possibility suggests that the true remaining

[9] DCCEE advise that the data supplied for this study was derived from information provided by householders and installers when submitting claims for reimbursement or payment. In the case of installers the information was supplied by entering required fields on an on-line claim form. Accordingly, DCCEE advise that they cannot guarantee the accuracy of the data.

scope for future retrofit of ceiling insulation may be closer to the "upper" estimates made in this study rather than the "lower" estimates.

Table 15 : Percentage of Claims (Retrofits) under the HIP program by Jurisdiction (Part 1)

Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
01 Darwin	0.00	0.00	0.00	0.00	0.00	0.00	63.63	0.00	0.14
02 Port Hedland	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.01
03 Longreach	0.00	0.00	0.61	0.00	0.00	0.00	0.00	0.00	0.16
04 Carnarvon	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.01
05 Townsville	0.00	0.00	2.73	0.00	0.00	0.00	0.00	0.00	0.72
06 Alice Springs	0.00	0.00	0.00	0.00	0.00	0.00	34.68	0.00	0.08
07 Rockhampton	0.00	0.00	2.20	0.00	0.00	0.00	0.00	0.00	0.58
08 Moree	0.77	0.00	0.20	0.12	0.00	0.00	0.00	0.00	0.36
09 Amberley	0.72	0.00	17.03	0.00	0.00	0.00	0.00	0.00	4.78
10 Brisbane	3.22	0.00	58.71	0.00	0.00	0.00	0.00	0.00	16.78
11 Coffs Harbour	3.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.48
12 Geraldton	0.00	0.00	0.00	0.00	3.64	0.00	0.00	0.00	0.20
13 Perth	0.00	0.00	0.00	0.00	59.68	0.00	0.00	0.00	3.28
14 Armidale	1.48	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.61
15 Williamtown	12.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.10
16 Adelaide	0.00	0.00	0.00	87.13	0.00	0.00	0.00	0.00	2.82
17 Sydney RO	7.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.18
18 Nowra	3.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.44
19 Charleville	0.01	0.00	1.59	0.00	0.00	0.00	0.00	0.00	0.42
20 Wagga	1.93	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.82
21 Melbourne RO	0.00	8.07	0.00	0.00	0.00	0.00	0.00	0.00	1.84
22 East Sale	0.00	3.17	0.00	0.00	0.00	0.00	0.00	0.00	0.72
23 Launceston	0.00	0.00	0.00	0.00	0.00	12.81	0.00	0.00	0.16
24 Canberra	1.80	0.31	0.00	0.00	0.00	0.00	0.00	99.97	1.27
25 Cabramurra	0.27	0.37	0.00	0.00	0.00	6.05	0.00	0.02	0.27
26 Hobart	0.00	0.00	0.00	0.00	0.00	47.78	0.00	0.00	0.60
27 Mildura	0.93	1.66	0.00	3.37	0.00	0.00	0.00	0.00	0.86
28 Richmond	23.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.43
29 Weipa	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.01
30 Wyndham	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
31 Willis Island	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.01
32 Cairns	0.00	0.00	2.69	0.00	0.00	0.00	0.00	0.00	0.71
33 Broome	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.01
34 Learmonth	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
35 MacKay	0.00	0.00	2.23	0.00	0.00	0.00	0.00	0.00	0.59

Continued over page

Table 16 : Percentage of Claims (Retrofits) under the HIP program by Jurisdiction (Part 2)

Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
36 Gladstone	0.00	0.00	6.88	0.00	0.00	0.00	0.00	0.00	1.81
37 Halls Creek	0.00	0.00	0.00	0.00	0.16	0.00	1.35	0.00	0.01
38 Tennant Creek	0.00	0.00	0.12	0.00	0.00	0.00	0.34	0.00	0.03
39 Mt Isa	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.06
40 Newman	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41 Giles	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42 Meekathara	0.00	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.02
43 Oodnadatta	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44 Kalgoorlie	0.00	0.00	0.00	0.00	4.12	0.00	0.00	0.00	0.23
45 Woomera	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.02
46 Cobar	0.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31
47 Bickley	0.00	0.00	0.00	0.00	3.32	0.00	0.00	0.00	0.18
48 Dubbo	1.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58
49 Katanning	0.00	0.00	0.00	0.00	1.52	0.00	0.00	0.00	0.08
50 Oakey	0.01	0.00	4.65	0.00	0.00	0.00	0.00	0.00	1.23
51 Forrest	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
52 Swanbourne	0.00	0.00	0.00	0.00	14.34	0.00	0.00	0.00	0.79
53 Ceduna	0.00	0.00	0.00	1.66	0.00	0.00	0.00	0.00	0.05
54 Mandurah	0.00	0.00	0.00	0.00	6.34	0.00	0.00	0.00	0.35
55 Esperance	0.00	0.00	0.00	0.00	0.46	0.00	0.00	0.00	0.03
56 Mascot (Airport)	33.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.41
57 Manjimup	0.00	0.00	0.00	0.00	1.37	0.00	0.00	0.00	0.07
58 Albany	0.00	0.00	0.00	0.00	4.23	0.00	0.00	0.00	0.23
59 Mt Lofty	0.00	0.00	0.00	2.61	0.00	0.00	0.00	0.00	0.08
60 Tullamarine	0.00	32.74	0.00	0.00	0.00	0.00	0.00	0.00	7.47
61 Mt Gambier	0.00	0.17	0.00	4.50	0.00	0.00	0.00	0.00	0.18
62 Moorabbin	0.00	43.45	0.00	0.00	0.00	0.00	0.00	0.00	9.91
63 Warrnambool	0.00	1.51	0.00	0.00	0.00	0.00	0.00	0.00	0.35
64 Cape Otway	0.00	1.34	0.00	0.00	0.00	0.00	0.00	0.00	0.31
65 Orange	1.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.70
66 Ballarat	0.00	6.95	0.00	0.00	0.00	0.00	0.00	0.00	1.59
67 Low Head	0.00	0.00	0.00	0.00	0.00	13.80	0.00	0.00	0.17
68 Launceston	0.00	0.00	0.00	0.00	0.00	13.51	0.00	0.00	0.17
69 Thredbo Village	0.10	0.07	0.00	0.00	0.00	6.05	0.00	0.02	0.13

The impact of the HIP program on the number of households without ceiling insulation can be determined by applying the HIP claims shown in Table 14 with the assumed numbers of uninsulated ceilings immediately prior to the HIP in 2008, i.e. as reported in Table 12 (upper limit) and Table 13 (lower limit). The results are shown graphically in Figure 7 and Figure 8. Figure 7 shows the estimate of dwellings without ceiling insulation immediately prior to the HIP (2008) and Figure 8 shows the estimate of dwellings without ceiling insulation immediately after the HIP (2010).

Figure 7: Estimated number of dwellings without ceiling insulation – Pre HIP (2008)

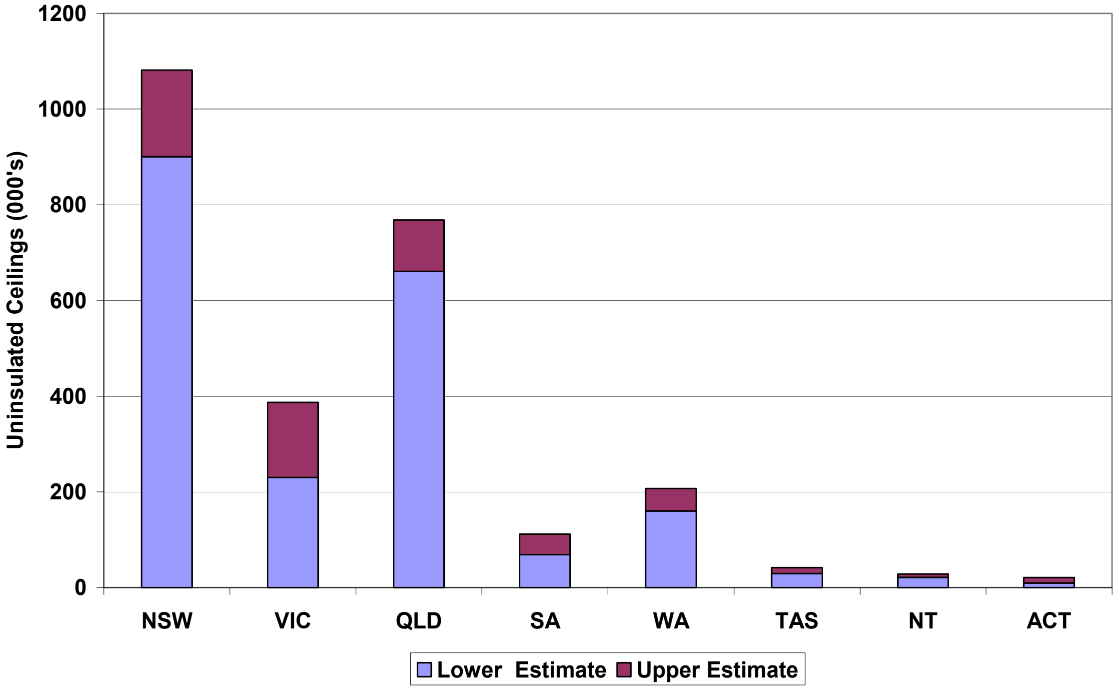
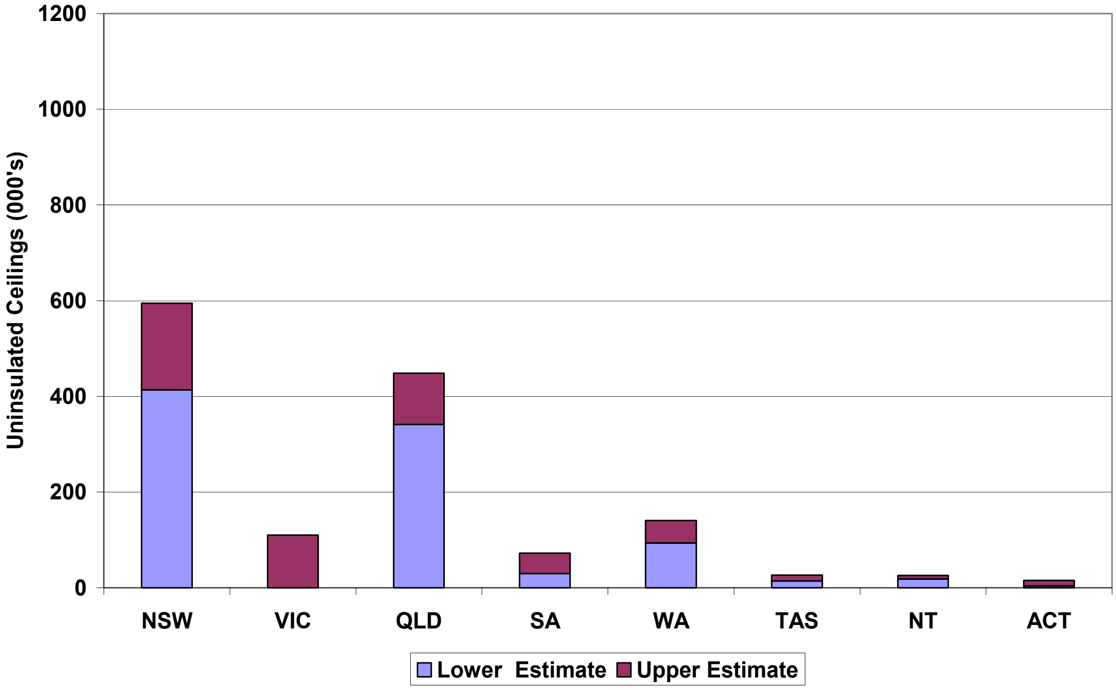


Figure 8: Estimated number of dwellings without ceiling insulation – Post HIP (2010)



Overall there were estimated to be between 2 and 2.6 million Australian dwellings without ceiling insulation in 2008 and after the HIP in 2010 there were estimated to be between 830,000 and 1.4 million Australian dwellings without ceiling insulation, this data is shown in tabular form in Table 17.

Table 17 : Estimate of dwellings estimated to have no ceiling insulation by year (000's)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Pre HIP (2008)									
Lower Estimate	900	230	661	69	160	29	21	10	2046
Upper Estimate	1081	387	769	111	207	42	28	21	2628
Post HIP (2010)									
Lower Estimate	413	0	341	30	94	14	19	4	833
Upper Estimate	595	110	449	72	141	27	26	15	1415

3.4 Forward projections

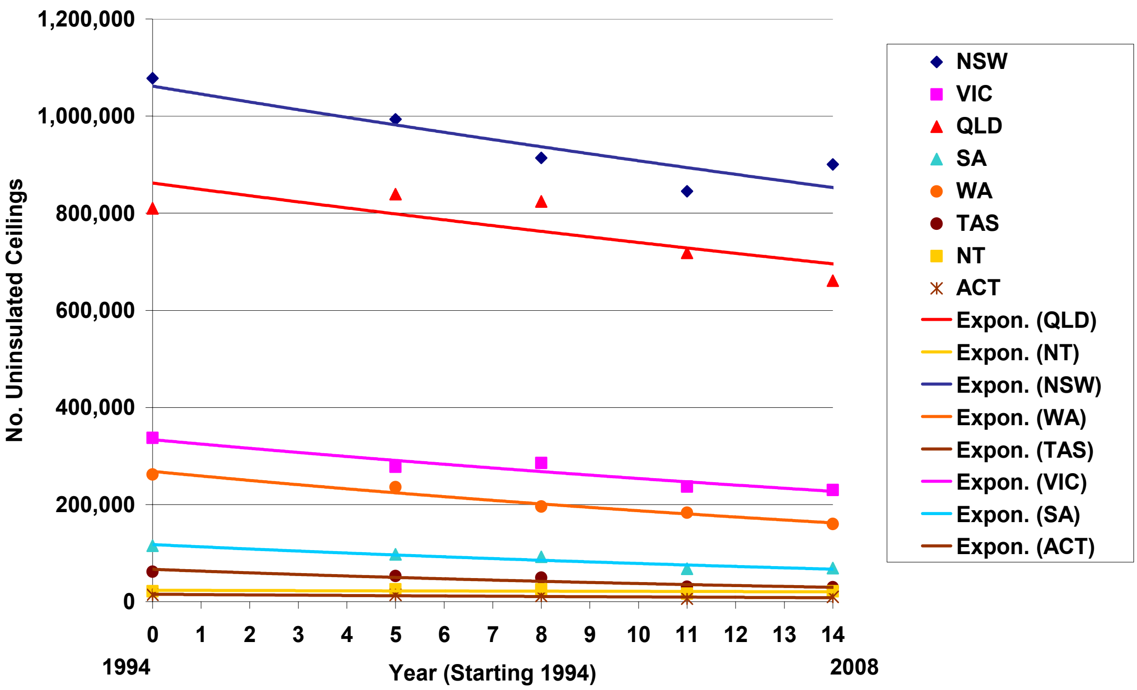
As noted in section 1.3.2, in this study 4 main scenarios are examined as follows:

- Scenario 1 - BAU in the absence of the HIP program (BAU-HIP, hypothetical)
- Scenario 2 - BAU including the HIP program (BAU+HIP)
- Scenario 3 - HIP program plus an intervention to insulate half of the remaining uninsulated stock by 2020 (HIP + 50%)
- Scenario 4 - HIP program plus an intervention to insulate all of the remaining uninsulated stock (that is practical to insulate) by 2020 (HIP + 100%)

In all of the above scenarios it is assumed that new dwellings entering the stock (i.e. post 2010) will have ceiling insulation fitted in order that they can meet the current performance requirements in the BCA. This means that the only stock to be insulated with ceiling insulation post 2010 should be the stock as identified in Table 12 and Table 13. This stock will have been constructed generally pre 2006 (earlier in the case of the ACT, Victoria [insulation requirements since 1991] and possibly NSW).

To estimate the historical rate of insulation retrofit (pre HIP), the available data points from 1994 to 2008 were plotted using the "lower boundary estimates" (i.e. Table 13). This "lower boundary estimate" assumes the higher rate of retrofit of ceiling insulation between 1994 and 2008 (compared with the upper boundary estimates), and is therefore the more conservative case in terms of any projections made in relation to the number dwellings that could potentially be fitted with ceiling insulation. This analysis is shown in Figure 9 and includes an exponential regression line through the available data points for each jurisdiction.

Figure 9: Historical trends in number of dwellings with uninsulated ceilings (1994 – 2008)



The exponential regression assumes that the rate of retrofit (in the absence of any incentive program) will be proportional to the number of dwellings that remain in the stock without ceiling insulation (i.e. as the pool of uninsulated dwellings decreases over time the absolute number of retrofits shall also decrease proportionally over the same period). The regression data derived from Figure 9 is shown in Table 18

Table 18 : Historical annual rate of decline in number of dwellings without ceiling insulation

Jurisdiction	Annual rate of decline in number of dwellings without ceiling insulation*
NSW	1.2%
VIC	2.7%
QLD	1.5%
SA	3.9%
WA	3.5%
TAS	5.6%
NT	1.0%
ACT	4.3%
AUS	**1.9%**

* Note: This is a percentage reduction of the number of remaining dwellings without ceiling insulation (i.e. a compounding rate)

For this study, in developing the 4 scenarios noted it has been assumed that in the absence of any market intervention that the rate of retrofit of ceiling insulation to the remaining stock of uninsulated dwellings will match the historical rates as detailed in Table 18 and Figure 9. The scenarios 1 - 4 are shown graphically at a national level in Figure 10 to Figure 13 respectively.

Figure 10 : Scenario 1 – No HIP – Projected number of dwellings without ceiling insulation (000's)

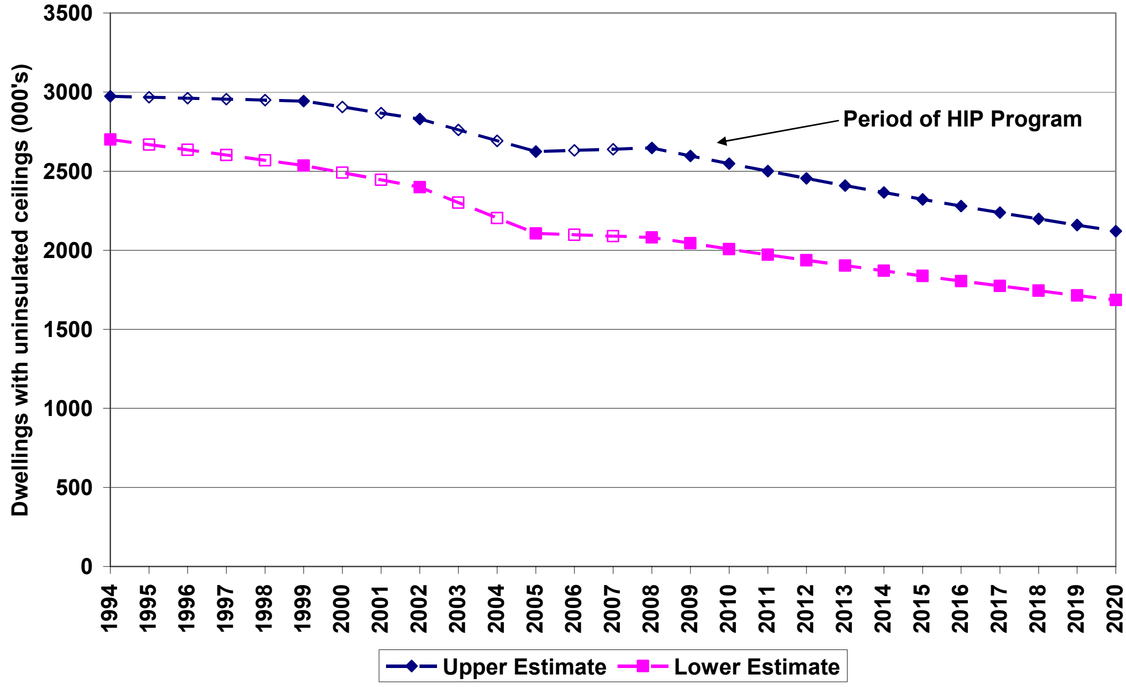


Figure 11 : Scenario 2 – With HIP – Projected number of dwellings without ceiling insulation (000's)

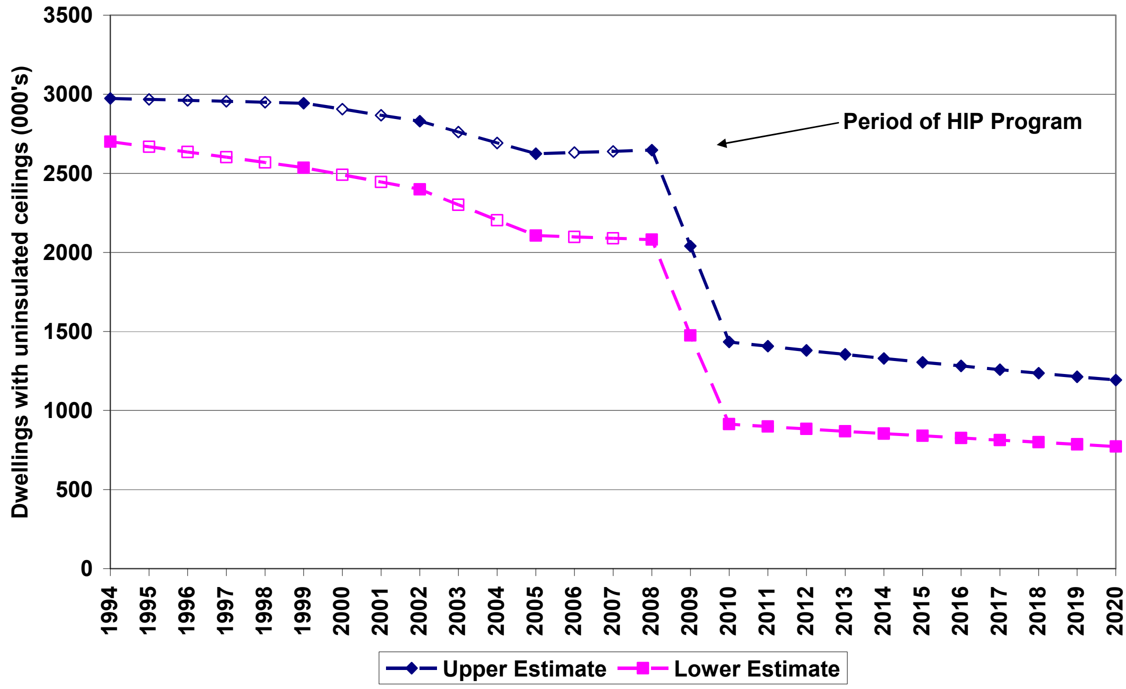


Figure 12 : Scenario 3 – HIP + 50% – Projected number of dwellings without ceiling insulation (000's)

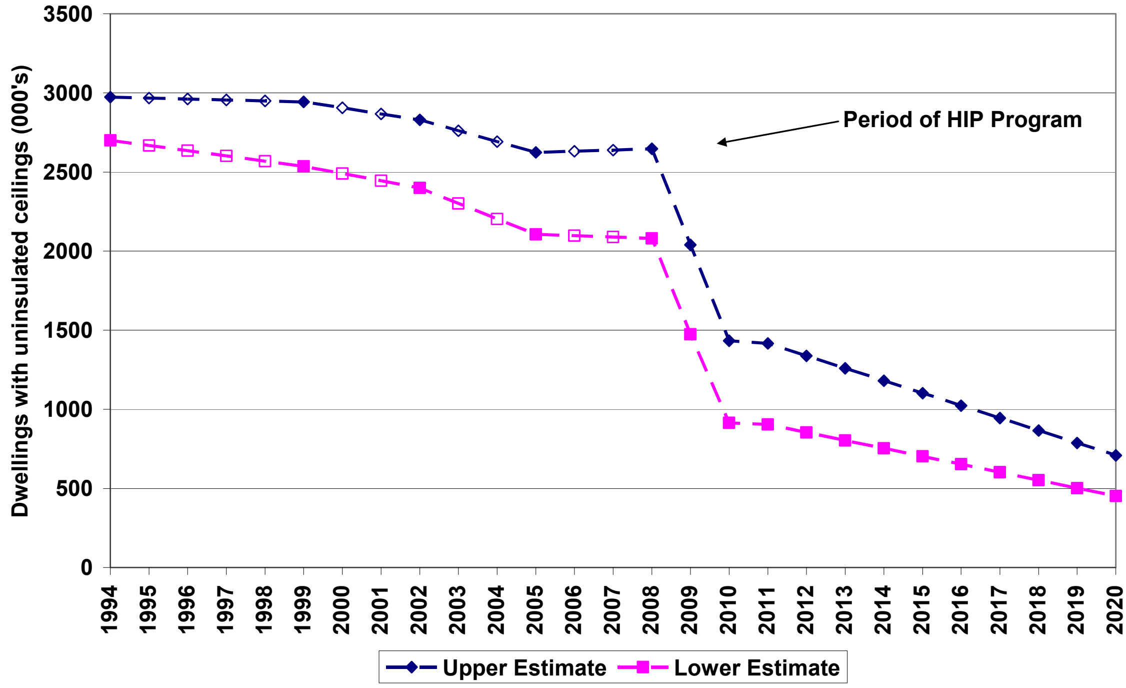
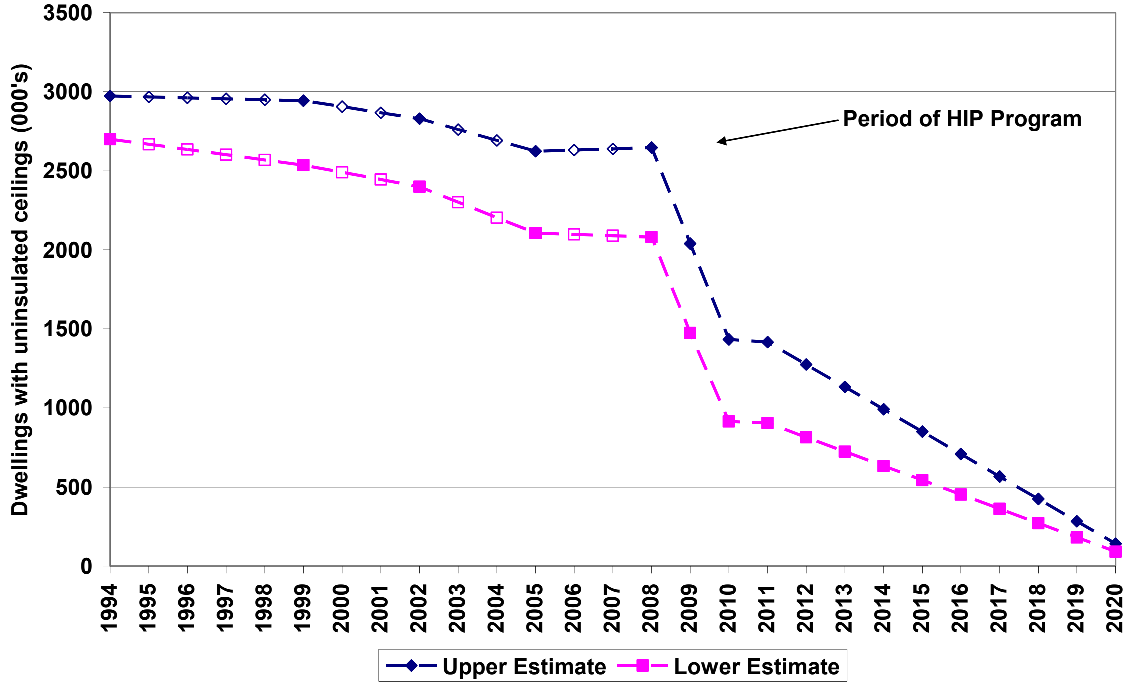


Figure 13 : Scenario 4 – HIP + 100% – Projected number of dwellings without ceiling insulation (000's)



Points to note in relation to these four figures are as follows:

- In the absence of the HIP, it is projected that by 2020 there would have been between 1.7 and 2.1 million households without ceiling insulation (Scenario 1).
- Between now and 2020 in the absence of the HIP it is estimated that the rate of retrofit (in the absence of any government incentives) would have been in the range of 30 – 45 thousand dwellings per annum
- During the approximate 12 month duration of the HIP, approximately 1.2 million residential ceilings were insulated. This represents an approximate 600% increase in total number of dwellings (new and existing) insulated per annum, above the background level of approximately 200,000 new and existing dwellings insulated per annum.
- The HIP is projected to have reduced the number of households without ceiling insulation by 2020 down to between 770,000 and 1.2 million dwellings. This projection takes into account the projection that between now and 2020 following the HIP it is estimated that the rate of retrofit (in the absence of any further government incentives) will be between 12 – 25 thousand dwellings per annum. (Scenario 2)
- If a program were undertaken to halve the number of households without ceiling insulation (as of 2011) by 2020 then by 2020 the number of households without ceiling insulation would be down to between 450,000 and 710,000 dwellings (Scenario 3). This would require that between 2012 and 2020 an additional (above BAU) 35-55 thousand households per annum[10] would require retrofitting of ceiling insulation (Scenario 3). This rate of retrofit is approximately 1/20th the rate applied during the HIP and represents an approximate 25% increase in the total number of dwellings (new and existing) insulated per annum.
- If a program were undertaken to insulate all households without ceiling insulation that are practical to insulate[11] (as of 2011) by 2020 then this would require that between 2012 and 2020 an additional (above BAU) 75-120 thousand households per annum would require retrofitting of ceiling insulation (Scenario 4). This rate of retrofit is approximately 1/10th the rate applied during the HIP and represents an approximate 50% increase in the total number of dwellings (new and existing) insulated per annum.

[10] Note this number of retrofits is in addition to the expected number that would take place under the business as usual scenario (Scenario 2) i.e. in addition to the expected 12 – 25 thousand retrofits.

[11] Generally only dwellings with flat or skillion roofs or cathedral ceilings are not practical to insulate unless the roofing material is being replaced or major renovations are being undertaken (which may occur for some of these dwellings during the study period up to 2020). It has been assumed for the purposes of this analysis that 90% of remaining dwellings without ceiling insulation will be practical to insulate. This value is an estimate only of the maximum potential for retrofit.

4. Modelling Results

4.1 Overview

This section of the report details the results from the modelling undertaken as outlined in section 1.3. The modelling results are set out in the following sections:

- Section 4.2 details the benefits of ceiling insulation retrofit in terms of reduced space conditioning energy consumption.
- Section 4.3 details the benefits of ceiling insulation retrofit in terms of the financial returns to the householder.
- Section 4.4 details the benefits of ceiling insulation retrofit in terms of greenhouse gas abatement.
- Section 4.5 details the benefits of ceiling insulation retrofit in terms of reductions in Peak loads attributable to space conditioning and associated generation and network cost savings.

4.2 Energy Reduction Benefits

The results of the analysis of estimated star rating improvements for dwellings subject to ceiling insulation retrofit show that for the range of sample dwellings examined a wide range of performance outcomes resulted (see Table 19).

In the uninsulated (ceiling) state, the sample dwellings exhibited a range of performances from 0 stars (lightweight single storey detached dwelling on a timber floor in Queensland) to 2.9 stars (heavyweight semi detached dwelling on concrete floor in NSW, SA and WA). The weighted national average performance for dwellings with uninsulated ceilings was 1.1 stars.

After applying insulation to levels as prescribed in the HIP (R3-R4), the sample dwellings exhibited a range of performances from 2.3 stars (lightweight detached dwelling on a timber floor in Queensland or WA) to 5.2 stars (heavyweight semi detached dwelling on concrete floor in WA). The weighted national average performance following application of ceiling insulation was 3.3 stars. By increasing the standard of insulation to R5 the performance was raised to a national average of 3.4 stars.

The improvement in star rating by state, following the fitting of ceiling insulation to levels as prescribed in the HIP (R3-R4) ranged from 1.9 to 2.7 stars of improvement with a national average improvement of 2.2 stars. By increasing the standard of insulation to R5 the level of improvement was raised to a national average of 2.3 stars (see Table 19). These estimates of star ratings improvement are based on modelling undertaken using AccuRate set in “Ratings” mode.

Table 19 : Estimated Star Rating Improvement due to Retrofit of ceiling Insulation

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Star Rating Performance of Dwellings with no Ceiling Insulation									
Detached	0.1-2.3	0.5-2.3	0-2.5	0.4-2.3	0.1-2.3	0.6-2.3	0.1-2.8	0.3-2.3	0.2-2.4
Semi Detached	1.8-2.9	2-2.8	1.5-2.8	1.8-2.9	1.6-2.9	2.1-2.8	1.7-2.6	2-2.7	2.4-1.8
Average All	**1.0**	**1.3**	**0.8**	**1.6**	**1.4**	**1.1**	**1.6**	**1.7**	**1.1**
Star Rating Performance of Dwellings with ceiling insulation to HIP standard (R3.0 – R4.0)									
Detached	2.2-4.8	2.4-4.6	1.7-4.4	2.4-4.7	2.2-5.1	2.4-4.5	2.1-5.1	2.4-4.6	2.1-4.7
Semi Detached	3-5.2	3.2-4.6	2.9-4.7	3-5	2.8-5.7	3.3-4.5	3-4.3	3.3-4.7	4.7-3
Average All	**3.3**	**3.2**	**3.1**	**3.9**	**4.1**	**2.9**	**3.7**	**3.7**	**3.3**
Star Rating Performance of Dwellings with R5.0 Insulation									
Detached	2.3-4.9	2.5-4.7	1.8-4.6	2.5-4.9	2.2-5.3	2.5-4.6	2.2-5.2	2.5-4.7	2.2-4.8
Semi Detached	3-5.3	3.3-4.6	3-4.8	3-5	2.8-5.8	3.3-4.5	3-4.4	3.3-4.8	4.8-3.1
Average All	**3.4**	**3.2**	**3.2**	**4.0**	**4.3**	**3.0**	**3.8**	**3.7**	**3.4**
Average Star Rating Improvement due to Ceiling Insulation Retrofit									
R0 to HIP	**2.2**	**1.9**	**2.3**	**2.3**	**2.7**	**1.9**	**2.1**	**1.9**	**2.2**
R0 to R5	**2.3**	**2.0**	**2.4**	**2.4**	**2.9**	**1.9**	**2.2**	**2.0**	**2.3**

Estimates of actual savings in energy consumption resulting from the application of ceiling insulation based on the methodology detailed in Appendix 1: Modelling Methodology – Energy are detailed in Table 20.

In this table energy savings estimates are provided for each jurisdiction as well as a weighted national average. Separate results are provided for heating and cooling and for each of the four main fuel types examined in this study. The top half of the table provides estimates based on insulation levels in accordance with the HIP (i.e. ranging from R3 to R4 depending upon the particular climate zone). The lower half of the table provides estimates based on a common insulation level of R5.

It should be noted that the estimates shown in Table 20 allow for a discount of 25% due to factors such as the “Rebound effect” that are assumed to constrain benefits – refer Appendix 5 : Review of Factors Likely to Constrain Benefits for further details. Specifically, the energy savings by fuel type in Table 20 represent 75% of the modelled outcomes.

Table 20 : Estimated Average Retrofitted Household Energy Savings by Fuel Type in 2020 (MJ)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Retrofitted to HIP Standard (R3.0 to R4.0)									
Elec. Heating	1365	1828	403	1969	896	3757	19	3567	1186
Gas Heating	1997	22857	53	3187	2638	748	22	17325	4744
LPG Heating	191	286	47	213	62	346	78	0	154
Wood Closed	3384	3930	612	3986	3780	13542	70	1929	2834
Wood Open	264	209	70	313	206	904	4	20	203
Cooling	741	218	833	811	899	31	2409	276	707
Total	**7942**	29329	2017	10479	8481	19328	2600	23118	9827
Retrofitted with R5 insulation									
Elec. Heating	1398	1873	417	2017	918	3818	19	3659	1216
Gas Heating	2045	23431	55	3265	2701	760	22	17772	4862
LPG Heating	196	293	48	218	63	351	80	0	158
Wood Closed	3466	4029	633	4083	3870	13761	72	1979	2903
Wood Open	270	214	72	321	211	919	4	21	208
Cooling	758	223	856	832	924	31	2499	283	725
Total	8134	30065	2081	10736	8687	19640	2696	23714	10072

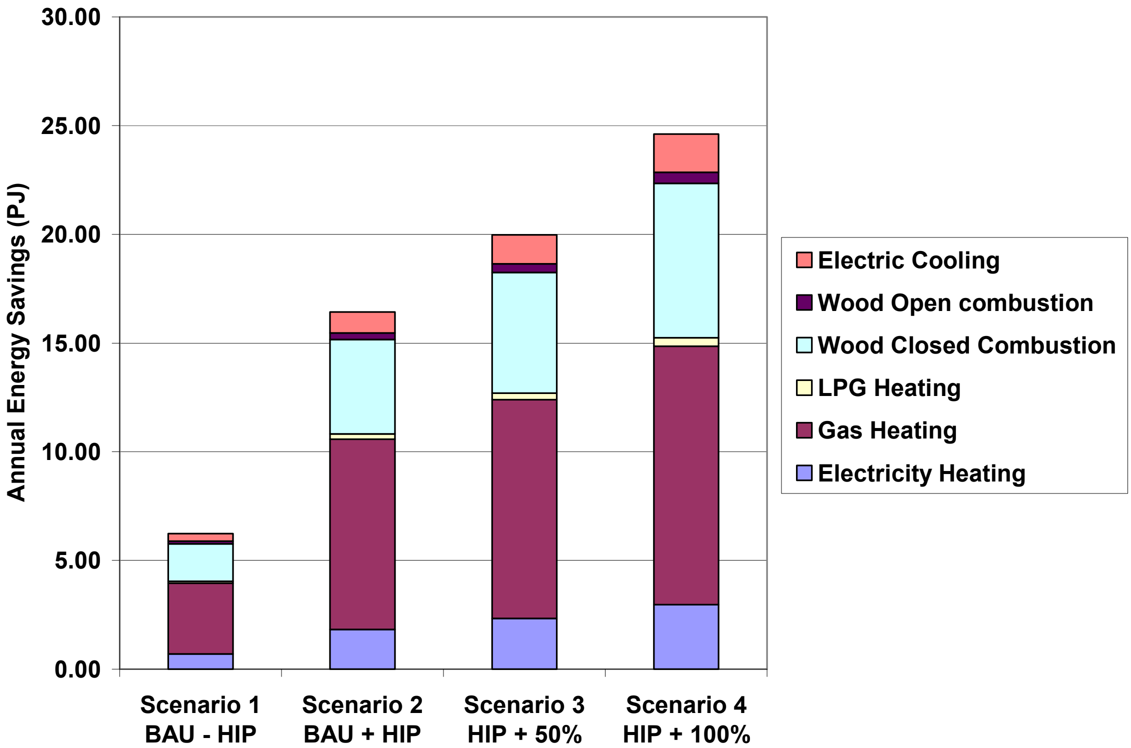
By applying the results from Table 20 to the various scenarios for retrofit (see sections 1.3.2 and 3.4 for details of these scenarios) an estimate of state and national energy savings was derived. These savings are detailed in Table 21. In this table the results presented are for 2020 for each of the 4 retrofit scenarios examined. The first value in each field represents to outcome if the lower limit of expected retrofit were to be achieved and the second value the upper limit. All reported values include a discount of 25% for expected rebound.

Figure 14 shows graphically the results at a national level for the upper limit of expected retrofit.

Table 21 : Estimated Range of State and National Level Energy Savings in 2020 (PJ)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Retrofitted to HIP Standard (R3.0 to R4.0)									
Scenario 1 BAU - HIP	0.93-1.12	1.89-3.18	0.22-0.26	0.28-0.45	0.48-0.61	0.29-0.41	0.01-0.01	0.09-0.2	**4.2-6.2**
Scenario 2 BAU + HIP	4.23-4.38	6.75-8.89	0.74-0.77	0.52-0.66	0.8-0.92	0.42-0.52	0.01-0.01	0.17-0.26	**13.6-16.4**
Scenario 3 HIP + 50%	5.53-6.25	6.75-9.75	0.99-1.1	0.57-0.79	0.97-1.17	0.43-0.55	0.03-0.04	0.18-0.31	**15.4-20**
Scenario 4 HIP + 100%	6.83-8.12	6.75-11.03	1.27-1.46	0.69-1.09	1.28-1.64	0.54-0.76	0.05-0.07	0.22-0.45	**17.6-24.6**
Retrofitted with R5 insulation									
Scenario 1 BAU - HIP	0.95-1.14	1.94-3.26	0.23-0.27	0.28-0.46	0.49-0.63	0.29-0.41	0.01-0.01	0.1-0.2	**4.3-6.4**
Scenario 2 BAU + HIP	4.33-4.49	6.92-9.12	0.77-0.8	0.53-0.68	0.82-0.95	0.42-0.53	0.01-0.01	0.17-0.26	**14-16.8**
Scenario 3 HIP + 50%	5.66-6.41	6.92-10	1.02-1.14	0.58-0.81	0.99-1.2	0.44-0.56	0.03-0.04	0.19-0.32	**15.8-20.5**
Scenario 4 HIP + 100%	6.99-8.32	6.92-11.3	1.31-1.51	0.71-1.12	1.31-1.68	0.55-0.77	0.05-0.07	0.22-0.46	**18.1-25.2**

Figure 14 : National Energy Savings from Ceiling Insulation Retrofit in 2020 (By Scenario – "Upper Estimate")



4.3 Financial Benefits to the Householder

Financial benefits (i.e. savings in fuel costs) associated with the retrofitting of ceiling insulation were estimated in accordance with the methodology outlined in section 1.5. The results of that modelling are detailed in Table 22. In this table savings are based on the "Low Carbon" fuel price scenario (see section 1.3.6).

Table 22 : Estimate of Average Annual Fuel Savings - Low Carbon Price (2011$)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Retrofitted to HIP Standard (R3.0 to R4.0)									
2009	243	563	103	352	244	474	189	655	**288**
2010	247	571	104	355	256	470	188	659	**292**
2011	251	579	104	357	268	467	188	664	**296**
2012	254	586	105	359	279	462	187	668	**299**
2013	279	651	115	390	294	490	185	736	**329**
2014	282	665	116	395	297	486	185	746	**333**
2015	285	684	116	399	303	483	185	753	**339**
2016	288	700	118	409	311	487	188	761	**345**
2017	292	721	120	420	320	494	190	772	**352**
2018	295	741	123	430	324	499	192	781	**359**
2019	298	764	124	438	328	501	195	799	**365**
2020	303	787	127	458	356	507	196	819	**375**
Retrofitted with R5 insulation									
2009	249	577	107	361	250	482	196	672	**295**
2010	253	585	107	363	262	478	195	676	**299**
2011	257	594	108	366	275	474	195	681	**303**
2012	260	601	108	367	286	469	194	685	**307**
2013	286	668	119	399	301	498	191	755	**337**
2014	289	682	119	404	304	494	192	765	**342**
2015	292	702	120	409	310	491	192	773	**347**
2016	295	718	122	419	318	495	195	781	**353**
2017	299	739	124	430	328	502	198	792	**361**
2018	302	759	126	440	332	507	199	801	**368**
2019	306	783	128	449	336	510	202	820	**375**
2020	310	807	131	469	365	515	203	840	**385**

In this table energy savings estimates from 2012 to 2020 (in terms of 2011$) are provided for each jurisdiction as well as a weighted national average (according to the projected number of retrofits by jurisdiction). The top half of the table provides estimates based on insulation levels in accordance with the HIP (i.e. ranging from R3 to R4 depending upon the particular climate zone). The lower half of the table provides estimates based on a common insulation level of R5.

It should be noted that unlike the estimates for energy or greenhouse gas savings the estimates of financial savings to the householder do not include a discount for any rebound effect that may occur. No discount is applied because for the householder, rebound or "comfort creep" (if it occurs) is discretionary behaviour. If such discretionary behaviour 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.

Table 23 provides similar detail to Table 22 except that the impact of each of the fuel cost scenarios is shown on the annual savings in fuel costs as at 2020.

Table 23 : Estimate of Average Household Fuel Savings in 2020 (2011$)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Retrofitted to HIP Standard (R3.0 to R4.0)									
No Carbon	279	714	116	426	340	473	173	744	345
Low Carbon	303	787	127	458	356	507	196	819	375
Med. Carbon	313	820	132	472	363	522	206	853	389
Retrofitted with R5 insulation									
No Carbon	286	732	119	436	349	481	180	763	353
Low Carbon	310	807	131	469	365	515	203	840	385
Med. Carbon	321	840	136	484	372	531	213	875	399

By applying the results from Table 23 to the various scenarios for retrofit (see sections 1.3.2 and 3.4 for details of these scenarios) an estimate of state and national fuel cost savings was derived. These savings are detailed in Table 24. In this table the results presented are for 2020 for each of the 4 retrofit scenarios examined. For each scenario the first line of values represents to outcome if the lower limit of expected retrofit were to be achieved and the second line of values the upper limit. All reported values include a discount of 25% for expected rebound.

Table 24 : Estimated Annual Fuel Cost Savings in 2020 – Insulation to HIP Standard* ($ Million)

Scenario	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1.BAU-HIP (Lower)	37	53	15	12	20	8	0	3	**149**
1.BAU-HIP (Upper)	44	89	17	20	26	11	1	7	**215**
2.BAU+HIP (Lower)	167	189	49	23	34	11	1	6	**480**
2.BAU+HIP (Upper)	173	249	51	30	40	14	1	10	**566**
3.HIP + 50% (Lower)	218	189	65	26	41	12	2	7	**559**
3.HIP + 50% (Upper)	247	273	72	36	50	15	3	11	**707**
4.HIP + 100% (Lower)	269	189	83	31	55	15	4	8	**653**
4.HIP + 100% (Upper)	320	308	96	49	70	21	5	17	**886**

By comparing a NPV calculation of the financial benefits noted in Table 22, to the cost of insulation as detailed in Appendix 2 : Modelling Methodology – Financial, the payback periods for retrofitting ceiling insulation were determined, and are shown in Table 25 for results at a 5% discount rate and in Table 26 for a 7% discount rate.

In these tables payback periods are provided for each jurisdiction as well as a weighted national average. The top half of each table provides estimates based on insulation levels in accordance with the HIP (i.e. ranging from R3 to R4 depending upon the particular climate zone). The lower half of the table provides estimates based on a common insulation level of R5.

When insulating to the HIP standard at a 5% discount rate the payback period on the investment in ceiling insulation was found to be 5 years or less in all jurisdictions except WA and NT (7 – 8 years) and Qld (13 – 15 years) depending on the assumed fuel price. The weighted national average payback period was 6 – 7 years at 5% discount rate and 7 – 8 years at a 7% discount rate. The payback periods for insulating with R5 are typically 1 to 2 years longer than for insulation to the HIP standard, except in Queensland where significantly longer payback periods are associated with R5 insulation.

Table 25 : Payback Period - Various State Specific Fuel Price Scenarios at 5% Discount Rate (Years)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Retrofitted to HIP Standard (R3.0 to R4.0)									
No Carbon	5	2	15	4	7	4	8	2	**7**
Low Carbon	5	2	13	4	7	4	7	2	**6**
Med. Carbon	5	2	13	4	7	4	7	2	**6**
Retrofitted with R5 insulation									
No Carbon	7	3	23	6	9	5	11	2	**10**
Low Carbon	7	3	20	5	8	4	10	2	**9**
Med. Carbon	6	3	19	5	8	4	10	2	**9**

Table 26 : Payback Period - Various State Specific Fuel Price Scenarios at 7% Discount Rate (Years)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Retrofitted to HIP Standard (R3.0 to R4.0)									
No Carbon	6	3	18	4	7	4	9	2	**8**
Low Carbon	5	2	16	4	7	4	8	2	**7**
Med. Carbon	5	2	15	4	7	4	7	2	**7**
Retrofitted with R5 insulation									
No Carbon	8	3	40	6	9	5	13	2	**15**
Low Carbon	7	3	29	6	9	5	11	2	**12**
Med. Carbon	7	3	26	6	9	5	11	2	**11**

Using an assumed service life of 30 years, estimates were made of the benefit to cost ratio for the retrofitting of ceiling insulation. The results for this analysis are shown in Table 27 (5% discount rate) and Table 28 (7% discount rate).

In these tables benefit cost ratios are provided for each jurisdiction as well as a weighted national average. The top half of each table provides estimates based on insulation levels in accordance with the HIP (i.e. ranging from R3 to R4 depending upon the particular climate zone). The lower half of the table provides estimates based on a common insulation level of R5.

When insulating to the HIP standard at either a 5% or a 7% discount rate all jurisdictions show a positive benefit to cost ratio (B/C >1) for each of the fuel cost scenarios. The national average benefit to cost ratio ranges from 3.9 (7% discount and no price on carbon) to 5.6 (5% discount and medium price on carbon). For R5 the national average benefit to cost ratio ranges from 3.0 (7% discount and no price on carbon) to 4.4 (5% discount and medium price on carbon).

Table 27 : 30 Year Benefit / Cost Ratio - Various Fuel Price Scenarios at 5% Discount Rate (Years)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Retrofitted to HIP Standard (R3.0 to R4.0)									
No Carbon	4.0	10.5	1.6	5.4	3.4	5.5	2.6	13.7	**4.9**
Low Carbon	4.3	11.6	1.8	5.8	3.6	5.9	3.0	15.1	**5.4**
Med. Carbon	4.5	12.2	1.8	6.1	3.6	6.1	3.2	15.9	**5.6**
Retrofitted with R5 insulation									
No Carbon	3.1	8.2	1.2	4.0	2.7	4.5	1.9	10.7	**3.8**
Low Carbon	3.4	9.1	1.3	4.3	2.8	4.8	2.2	11.8	**4.2**
Med. Carbon	3.5	9.5	1.3	4.4	2.9	5.0	2.3	12.4	**4.4**

Table 28 : 30 Year Benefit / Cost Ratio - Various Fuel Price Scenarios at 7% Discount Rate (Years)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Retrofitted to HIP Standard (R3.0 to R4.0)									
No Carbon	3.2	8.3	1.3	4.3	2.7	4.4	2.1	10.9	**3.9**
Low Carbon	3.4	9.2	1.4	4.6	2.8	4.7	2.4	12.0	**4.3**
Med. Carbon	3.6	9.6	1.5	4.8	2.9	4.9	2.5	12.5	**4.4**
Retrofitted with R5 insulation									
No Carbon	2.5	6.5	0.9	3.1	2.1	3.6	1.5	8.5	**3.0**
Low Carbon	2.7	7.2	1.0	3.4	2.3	3.8	1.8	9.4	**3.3**
Med. Carbon	2.8	7.5	1.1	3.5	2.3	4.0	1.8	9.8	**3.4**

4.4 Greenhouse Gas Abatement Benefits

By applying greenhouse gas intensity data (see Appendix 3 : Modelling Methodology – Greenhouse) to the estimates of energy savings (see Table 20) the per household greenhouse gas emissions savings attributable to the retrofit of ceiling insulation were determined and are shown in Table 29, where average per household greenhouse gas savings estimates are provided for each jurisdiction as well as a weighted national average. The top half of the table provides estimates based on insulation levels in accordance with the HIP (i.e. ranging from R3 to R4 depending upon the particular climate zone). The lower half of the table provides estimates based on a common insulation level of R5.

It should be noted that the estimates shown in Table 29 allow for a discount of 25% due to factors such as the “Rebound effect” that are assumed to constrain benefits – refer Appendix 5 : Review of Factors Likely to Constrain Benefits for further details.

Retrofit of ceiling insulation is expected on average to reduce annual greenhouse gas emissions per household by approximately one tonne a year. For jurisdictions with more extreme climates and relatively greenhouse gas intense electricity generation (e.g. Victoria and the ACT) the savings are in the order of 2 tonnes per annum. Note the decline over time as the carbon intensity of electricity supply declines.

Table 29 : Estimated Average Greenhouse Gas Abatement Per Dwelling (Tonnes CO2-e / annum)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Retrofitted to HIP Standard (R3.0 to R4.0)									
2009	0.86	1.98	0.37	0.99	0.60	0.35	0.63	2.35	**0.97**
2010	0.84	1.97	0.36	0.98	0.59	0.35	0.62	2.34	**0.96**
2011	0.82	1.97	0.36	0.96	0.59	0.35	0.61	2.32	**0.95**
2012	0.80	1.94	0.35	0.94	0.59	0.36	0.60	2.30	**0.93**
2013	0.79	1.91	0.34	0.93	0.58	0.36	0.58	2.28	**0.91**
2014	0.77	1.88	0.34	0.91	0.58	0.37	0.57	2.26	**0.89**
2015	0.75	1.85	0.33	0.90	0.57	0.37	0.56	2.24	**0.87**
2016	0.73	1.81	0.32	0.89	0.57	0.38	0.55	2.23	**0.86**
2017	0.73	1.80	0.32	0.89	0.57	0.38	0.55	2.22	**0.85**
2018	0.72	1.79	0.32	0.88	0.56	0.39	0.55	2.22	**0.84**
2019	0.71	1.78	0.32	0.88	0.56	0.39	0.54	2.22	**0.83**
2020	0.71	1.76	0.31	0.91	0.57	0.40	0.54	2.22	**0.83**
Retrofitted with R5 insulation									
2009	0.88	2.02	0.38	1.01	0.61	0.36	0.66	2.41	**1.00**
2010	0.86	2.02	0.37	1.00	0.61	0.36	0.64	2.40	**0.99**
2011	0.84	2.02	0.37	0.98	0.60	0.36	0.63	2.38	**0.98**
2012	0.82	1.99	0.36	0.97	0.60	0.36	0.62	2.36	**0.96**
2013	0.80	1.96	0.35	0.95	0.60	0.37	0.61	2.34	**0.94**
2014	0.79	1.93	0.35	0.94	0.59	0.37	0.59	2.32	**0.92**
2015	0.77	1.89	0.34	0.92	0.59	0.38	0.58	2.30	**0.90**
2016	0.75	1.86	0.33	0.91	0.58	0.39	0.57	2.28	**0.88**
2017	0.74	1.85	0.33	0.91	0.58	0.39	0.57	2.28	**0.87**
2018	0.74	1.83	0.33	0.90	0.57	0.39	0.57	2.28	**0.86**
2019	0.73	1.82	0.33	0.90	0.57	0.40	0.56	2.28	**0.85**
2020	0.72	1.81	0.32	0.93	0.58	0.40	0.56	2.28	**0.85**

Using the modelled data from Table 29 and applying the estimated number of ceiling retrofits with and without the HIP (ie Scenarios 1 and 2 respectively) it is possible to estimate the impact of the HIP by year for each jurisdiction, this is shown in Table 30.

Note that in this table the impact (following completion of the HIP in 2010) declines over time as the carbon intensity of electricity declines. The values in this table are based on a comparison of the upper estimates of number of retrofits for each scenario, if the lower estimates were used the abatement is approximately 6% less on average (although this does vary by jurisdiction).

Table 30 : Estimated Total Greenhouse Gas Abatement Due to the HIP (Mt CO2-e / annum)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
2009	0.20	0.25	0.05	0.02	0.02	0.00	0.00	0.00	0.54
2010	0.39	0.51	0.11	0.03	0.03	0.00	0.00	0.01	1.08
2011	0.38	0.49	0.10	0.03	0.03	0.00	0.00	0.01	1.04
2012	0.36	0.47	0.10	0.03	0.03	0.00	0.00	0.01	1.00
2013	0.35	0.45	0.10	0.03	0.03	0.00	0.00	0.01	0.96
2014	0.34	0.43	0.09	0.02	0.03	0.00	0.00	0.01	0.93
2015	0.33	0.41	0.09	0.02	0.03	0.00	0.00	0.01	0.89
2016	0.32	0.39	0.09	0.02	0.02	0.00	0.00	0.01	0.85
2017	0.31	0.38	0.09	0.02	0.02	0.00	0.00	0.01	0.83
2018	0.30	0.37	0.08	0.02	0.02	0.00	0.00	0.01	0.81
2019	0.30	0.36	0.08	0.02	0.02	0.00	0.00	0.01	0.78
2020	0.29	0.34	0.08	0.02	0.02	0.00	0.00	0.01	0.76
Cumulative Total	**3.86**	**4.86**	**1.07**	**0.27**	**0.29**	**0.03**	**0.01**	**0.08**	**10.5**

Table 31 provides state and national level estimates of projected greenhouse gas abatement to be realised in the year 2020 for each of the four scenarios for retrofit examined in this study (see section 1.3.2). Due to uncertainties regarding exact numbers of dwellings that would be retrofitted, an upper and a lower estimate of savings is provided for each scenario.

Nationally, by 2020 the 2009-10 HIP program (BAU + HIP) is projected to be saving 0.7 – 0.8 MT CO_2-e of greenhouse gas emissions more than if that program had never been undertaken (BAU – HIP). If the HIP + 50% scenario were to be adopted then a further 0.2-0.3 MT CO_2-e of greenhouse gas emissions could be avoided or if the HIP + 100% scenario were adopted a further 0.4-0.7 MT CO_2-e of greenhouse gas emissions could be avoided. Figure 15 provides a graphical illustration of these savings.

Table 31 : Estimated Greenhouse Gas Abatement in 2020 from Ceiling Insulation (Mt CO2-e)

Scenario	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1. BAU-HIP (Lower)	0.08	0.11	0.03	0.02	0.03	0.01	0.00	0.01	**0.30**
1. BAU-HIP (Upper)	0.10	0.19	0.04	0.04	0.04	0.01	0.00	0.02	**0.44**
2. BAU+HIP (Lower)	0.38	0.41	0.12	0.04	0.05	0.01	0.00	0.02	**1.02**
2. BAU+HIP (Upper)	0.39	0.53	0.12	0.06	0.06	0.01	0.00	0.02	**1.20**
3. HIP + 50% (Lower)	0.49	0.41	0.16	0.05	0.06	0.01	0.01	0.02	**1.20**
3. HIP + 50% (Upper)	0.56	0.59	0.17	0.07	0.08	0.01	0.01	0.03	**1.51**
4. HIP + 100% (Lower)	0.61	0.41	0.20	0.06	0.09	0.01	0.01	0.02	**1.40**
4. HIP + 100% (Upper)	0.72	0.66	0.23	0.09	0.11	0.02	0.01	0.04	**1.89**

Figure 15 : National G Gas Savings from Ceiling Insulation Retrofit in 2020 (By Scenario)

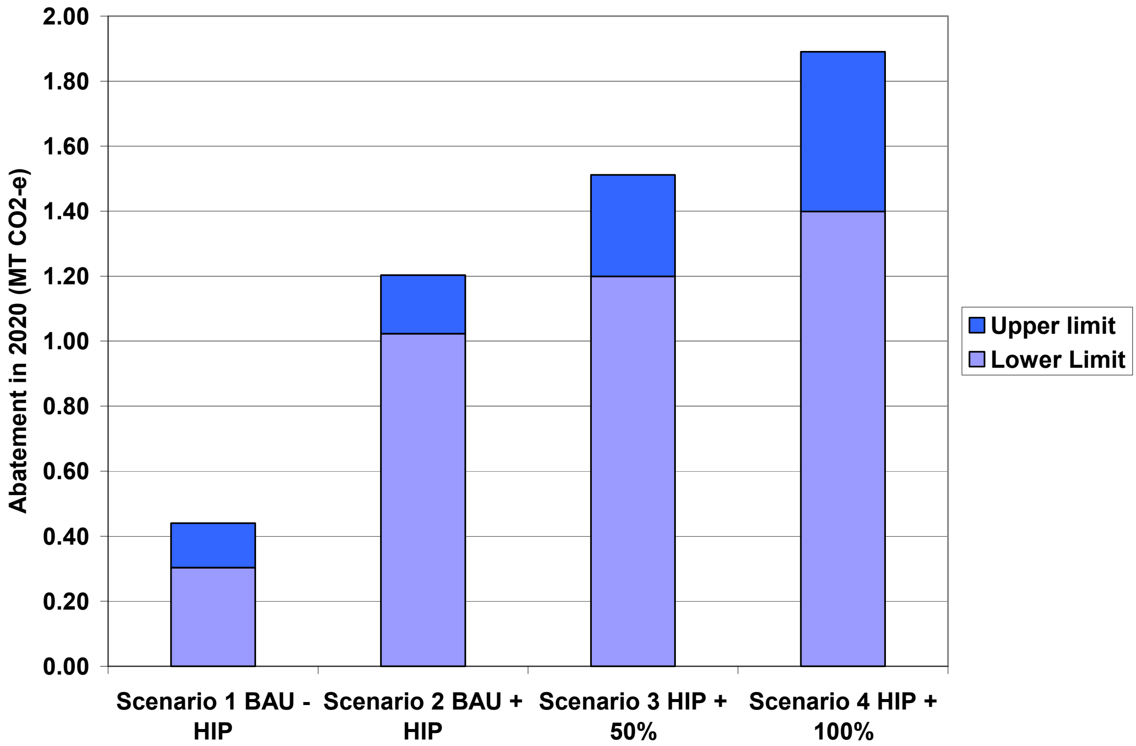


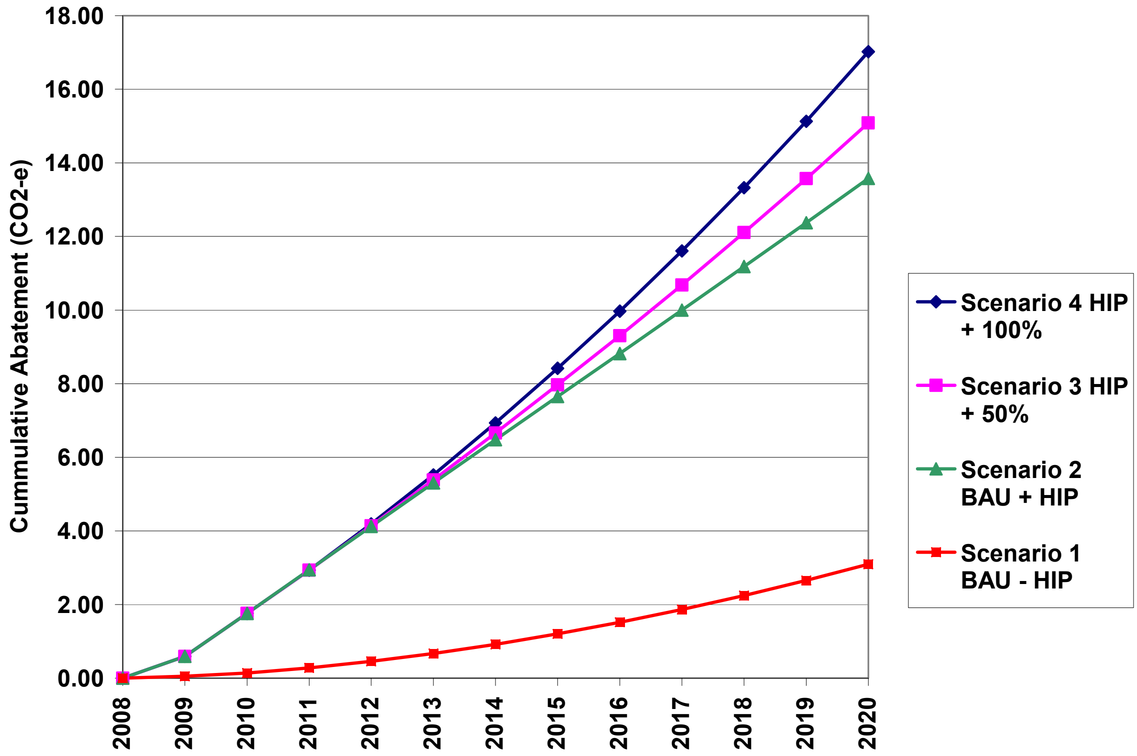
Table 32 provides state and national level estimates of projected cumulative greenhouse gas abatement to be realised between 2008 (i.e. immediately before the HIP) and 2020 for each of the four scenarios for ceiling insulation retrofit examined in this study (see section 1.3.2). Due to uncertainties regarding exact numbers of dwellings that would be retrofitted an upper and a lower estimate of savings is provided for each scenario.

Nationally, by 2020 the 2009-10 HIP program (BAU + HIP) is projected to have saved a total of approximately 10 MT CO_2-e of greenhouse gas emissions more than if that program had never been undertaken (BAU – HIP). If the HIP + 50% scenario were to be adopted (starting 2012) then a further 0.9 – 1.5 MT CO_2-e of greenhouse gas emissions could be avoided or if the HIP + 100% scenario were adopted (starting 2012) a further 1.9 – 3.4 MT CO_2-e of greenhouse gas emissions could be avoided. Figure 16 provides a graphical illustration of these savings.

Table 32 : Cumulative Greenhouse Gas Abatement by 2020 from Ceiling Insulation (MT CO2-e)

Scenario	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1. BAU-HIP (Lower)	0.58	0.81	0.24	0.17	0.22	0.04	0.01	0.06	**2.13**
1. BAU-HIP (Upper)	0.69	1.36	0.28	0.27	0.29	0.06	0.01	0.14	**3.09**
2. BAU+HIP (Lower)	4.47	4.98	1.32	0.47	0.53	0.08	0.02	0.17	**12.05**
2. BAU+HIP (Upper)	4.55	6.21	1.35	0.54	0.58	0.09	0.03	0.22	**13.58**
3. HIP + 50% (Lower)	5.07	4.98	1.52	0.48	0.58	0.08	0.04	0.17	**12.93**
3. HIP + 50% (Upper)	5.41	6.46	1.61	0.58	0.65	0.09	0.05	0.24	**15.09**
4. HIP + 100% (Lower)	5.66	4.98	1.74	0.54	0.68	0.09	0.06	0.19	**13.95**
4. HIP + 100% (Upper)	6.26	6.85	1.90	0.71	0.80	0.11	0.08	0.30	**17.02**

Figure 16 : Cumulative National G Gas Savings from Ceiling Insulation Retrofit (Upper)



4.5 Peak Load Reduction Benefits

By applying the peak load assessment methodology (see Appendix 4 : Modelling Methodology – Peak Load) to the maximum space conditioning demand data extracted from the AccuRate simulations, the average per household peak summer electrical savings attributable to the retrofit of ceiling insulation were determined. These reductions represent the predicted savings in required generating capacity during a summer maximum electrical demand event.

The individual household estimates for the summer peak load saving were then applied to the various scenarios for retrofit (see sections 1.3.2 and 3.4 for details of these scenarios) to estimate state and national electrical peak load savings. National savings are based on a simplifying assumption that the individual peak loads occurred simultaneously in each jurisdiction. These savings (as at 2020) are detailed in Table 33. Due to uncertainties regarding exact numbers of dwellings that would be retrofitted an upper and a lower estimate of savings is provided for each scenario.

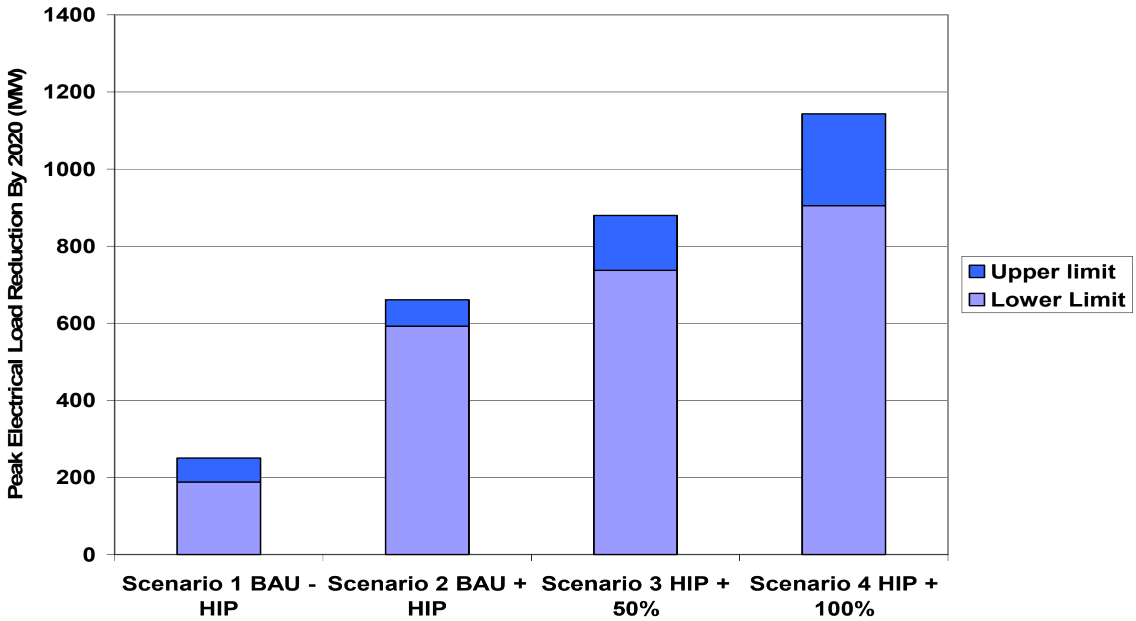
The peak load results are also shown graphically (at a national level) in Figure 17.

Table 33 : Estimated Peak load savings by 2020 – Insulation to HIP Standard* (MW)

Scenario	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1. BAU-HIP (Lower)	51	27	46	17	38	5	1	1	**188**
1. BAU-HIP (Upper)	61	46	54	28	50	7	2	3	**250**
2. BAU+HIP (Lower)	232	97	153	32	65	7	3	3	**592**
2. BAU+HIP (Upper)	241	128	160	41	75	9	3	4	**661**
3. HIP + 50% (Lower)	304	97	205	35	78	8	7	3	**737**
3. HIP + 50% (Upper)	344	141	228	49	94	10	10	5	**880**
4. HIP + 100% (Lower)	375	97	261	43	103	9	12	3	**905**
4. HIP + 100% (Upper)	446	159	302	67	132	13	16	7	**1143**

*Note : Insulation to R5 standard provides on average a 3% increase in peak load reduction

Figure 17 National Electrical Peak load reduction by 2020 – Insulation to HIP standard* (MW)



*Note : Insulation to R5 standard provides on average a 3% increase in peak load reduction

Nationally, by 2020 the 2009-10 HIP program (BAU + HIP) is projected to have saved a total of approximately 400 MW in required peak load capacity compared to the case where that program had never been undertaken (BAU – HIP). If the HIP + 50% scenario were to be adopted then a further 145 – 220 MW in required peak load capacity could be saved or if the HIP + 100% scenario were adopted a further 310 – 480 MW in required peak load capacity could be avoided.

In the study undertaken by the Institute of Sustainable Futures and Energetics for DCCEE (UTS 2010) figures for the value of avoidable generation transmission and distribution by jurisdiction were determined (see table 35 of that study). By applying those figures to the values in Table 33 the estimated monetary value of savings in peak load capacity attributable to the retrofit of ceiling insulation can be determined, see Table 34 (values in 2011$). The values of peak load capacity avoided by jurisdiction from the ISF/Energetics study are shown in Table 34, along with the estimated $ savings in peak load capacity attributable to the retrofit of ceiling insulation. Due to uncertainties regarding exact numbers of dwellings that would be retrofitted an upper and a lower estimate of savings is provided for each scenario. Table 36 shows the estimated cumulative $ savings in peak load capacity attributable to the retrofit of ceiling insulation.

By comparing the values in Table 34 : Estimated Annual Peak load savings by 2020 – Insulation to HIP Standard* ($ Million) with the values in Table 24 : Estimated Annual Fuel Cost Savings in 2020 – Insulation to HIP Standard* ($ Million), it can be seen that the annual savings in electrical system capacity costs add a benefit of approximately 40% more to the savings from fuel costs alone.

Table 34 : Estimated Annual Peak load savings by 2020 – Insulation to HIP Standard* ($ Million)

Scenario	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Summer Peak Cost Saving ($m/MW/year)	**0.39**	**0.23**	**0.27**	**0.53**	**0.22**	**0.14**	**0.22 ****	**0.39**	
1.BAU-HIP (Lower)	20	6	12	9	8	1	0	1	**58**
1.BAU-HIP (Upper)	24	11	14	15	11	1	0	1	**77**
2.BAU+HIP (Lower)	91	22	41	17	14	1	1	1	**188**
2.BAU+HIP (Upper)	94	30	43	22	16	1	1	2	**208**
3.HIP + 50% (Lower)	118	22	55	19	17	1	2	1	**236**
3.HIP + 50% (Upper)	134	32	61	26	21	1	2	2	**280**
4.HIP + 100% (Lower)	146	22	71	23	23	1	3	1	**290**
4.HIP + 100% (Upper)	174	37	81	36	29	2	3	3	**365**

*Note : Insulation to R5 standard provides on average a 3% increase in peak load savings

** No NT value is available, and cost has been assumed to be the same as WA

Table 35 : Estimated Cumulative Peak load savings by 2020 – Insulation to HIP Standard* ($ Million)

Scenario	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1.BAU-HIP (Lower)	132	42	83	64	56	5	2	4	**389**
1.BAU-HIP (Upper)	158	71	97	104	73	7	3	9	**522**
2.BAU+HIP (Lower)	994	255	442	179	134	9	6	11	**2030**
2.BAU+HIP (Upper)	1013	319	452	208	146	11	6	14	**2168**
3.HIP + 50% (Lower)	1132	255	511	186	145	9	11	11	**2261**
3.HIP + 50% (Upper)	1212	332	542	224	163	11	13	15	**2513**
4.HIP + 100% (Lower)	1271	255	586	207	173	11	16	12	**2531**
4.HIP + 100% (Upper)	1412	354	641	273	204	13	20	19	**2937**

*Note : Insulation to R5 standard provides on average a 3% increase in peak load savings

** No NT value is available, and cost has been assumed to be the same as WA

Nationally, between 2010 and 2020 the 2009-10 HIP program (BAU + HIP) is projected to have saved a total of approximately $1.7 billion in required peak load capacity compared to the case where that program had never been undertaken (BAU – HIP). If the HIP + 50% scenario were to be adopted then a further $230 – 345 million in required peak load capacity could be saved or if the HIP + 100% scenario were adopted a further $500 – 770 million in required peak load capacity could be avoided.

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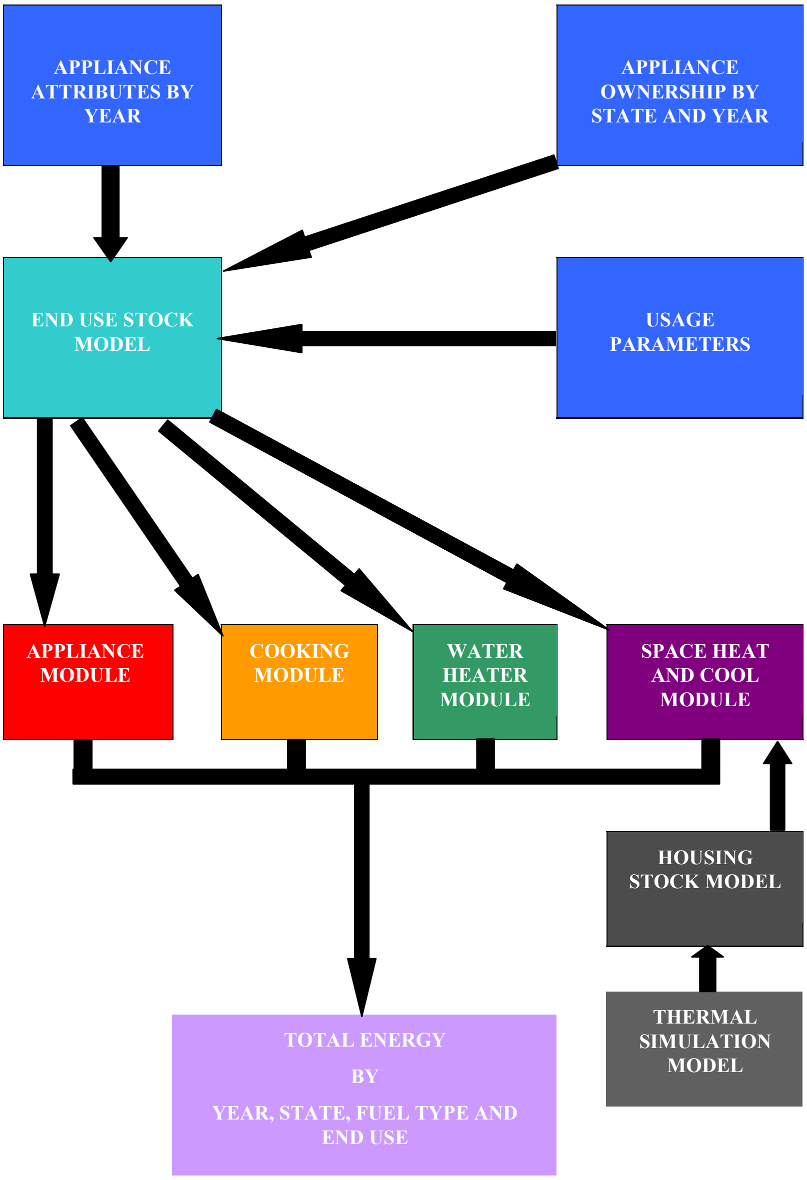
Appendix 1: Modelling Methodology – Energy

Overview

In this study the method for modelling household energy use (with and without ceiling insulation applied) is based on that used in the study *Energy Use in the Australian Residential Sector 1986-2020* (EES 2008). A schematic of the model is shown in Figure 18. This is believed to be the most comprehensive “bottom up” model of residential energy use available and has been verified against top down (ABARE) data.

Figure 18 : Schematic of EES End Use Model



The modelling consisted of taking a representative sample of dwellings in terms of type, construction and features and modelling those dwellings using thermal performance simulation software (AccuRate). Modelling was conducted firstly in “Rating Mode” to determine impacts on star ratings. For the purposes of making estimates of energy impacts the default assumptions within the AccuRate software (i.e. in rating mode) relating to occupancy of the dwelling and the operation of thermostats within the dwelling were then varied to more closely match reality (this process is detailed later in this Appendix).

The dwellings were modelled as three different cases; a base case without ceiling insulation, an improved case with insulation in accordance with the Commonwealth Home Insulation Program (HIP) and an improved case assuming R5 insulation is installed in all jurisdictions.

Modelling was undertaken in 13 representative climates zones and the results fed into the housing stock model used in the study *Energy Use in the Australian Residential Sector 1986-2020* (EES 2008). Further details regarding the methodology can be found in the full report.

Stock Model of Dwellings

Overview

In order that estimates of space conditioning load potential can be made, thermal performance simulation modelling is required to be undertaken on a representative sample of the residential building stock. It is therefore necessary to define the stock in terms of the key parameters that form the inputs into the thermal performance modelling tool used in this study ie AccuRate.

The major stock related inputs required for AccuRate that affect performance are as follows:

- Spatial details - floor plan data, ceiling heights, floor areas etc.
- Orientation.
- Basic construction types - floor, wall and roof construction combinations.
- Insulation.
- Glazing - area, type, shading.
- Level of infiltration (air leakage).

Clearly there would be, within the existing stock, an almost infinite number of variations and combinations of the above factors. It was therefore necessary to select a sample of combinations and variations that could adequately represent the actual range of combinations and variations known to be in existence. In carrying out this process particular regard was given to those factors that were likely to significantly affect thermal performance.

Stock Numbers and Characteristics

The housing stock model used in this study is based upon that developed by EES for their study entitled Energy Use in the Australian Residential Sector 1986-2020 (EES 2008). This model draws upon available data to establish a profile of housing in each Australian state and territory over a period of 20 years with projections into the future. The available data allowed dissagregation of the stock as follows:

- By Housing type (Detached, Semi Detached, Low rise flats, High rise flats).
- By Wall construction (Lightweight, Brick Veneer and Heavyweight).
- By floor type (suspended timber or concrete).
- By insulation (none, ceiling only and both ceiling and wall).

The housing stock model was constructed in 3 steps. Firstly a “base year” data set was established based on ABS survey data. This base year 1986, coincided with the last major survey of housing characteristics undertaken by the ABS. From the base year (end of financial year 1985-86) to end of financial year 2004-05 annual ABS data on new building activity was used in conjunction with many secondary data sources to establish stock levels in each of the intervening years. Finally, projections of housing stock numbers and profile were compiled until 2020 based on a “business as usual” case.

The housing stock model used is summarised in Figure 19. The actual housing stock model is relatively complex. For full details of the structure of the model refer to the study, *Energy Use in the Australian Residential Sector 1986-2020* – section 7 (EES 2008).

The proportions of each dwelling type and construction format on a State-by-State basis were derived from the data files developed in the study *Energy Use in the Australian Residential Sector 1986-2020* (EES 2008), – see Table 36. These dwellings types are a subset of the full stock model and exclude class 2 dwellings as previously noted and all “performance based” dwellings (generally post 2005 dwellings that are expected to already be fitted with ceiling insulation). Also excluded are dwellings already fitted with ceiling insulation. Generally the proportions for building type and construction type for dwellings without ceiling insulation are similar to those with insulation. An exception however is found in the case of the ACT where the previous analysis suggested that the proportion of uninsulated semi detached dwellings was significantly higher that that for uninsulated detached dwellings. This analysis was however based on old (1994) and very limited sample sizes in the smaller jurisdictions (such as the ACT and the NT) and are therefore subject to large error margins. Whilst the assumed proportion of uninsulated semi detached dwellings in the ACT is significantly higher than would otherwise be expected, in terms of the analysis in this study this simply leads to a more conservative estimate of potential energy savings stemming form ceiling insulation retrofitting in that jurisdiction.

The proportions from the original study have been scaled up to account for the excluded dwelling types as noted above (i.e. such that the total for each jurisdiction in Table 36 represents 100% of the stock in that jurisdiction).

In line with the method used in the study, *Energy Use in the Australian Residential Sector 1986-2020* – section 7 (EES 2008), all dwellings modelled were modelled facing each of the four ordinal orientations and results were then averaged across those orientations.

Figure 19 : Schematic of Housing Stock Model

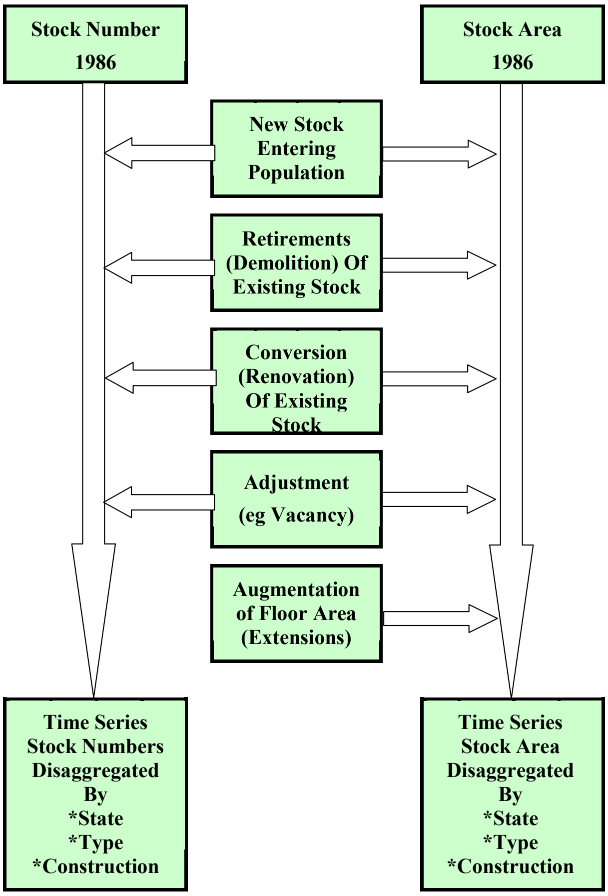


Table 36 : Penetration of Dwelling Types Without Ceiling insulation by State/Territory (2010)

Type	Construction Walls / Floor	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Detached – single storey	Light weight/Timber	26.6%	27.7%	38.0%	0.9%	13.2%	43.0%	18.5%	0.4%	28.6%
Detached – single storey	Lightweight/Concrete	2.4%	2.8%	3.3%	1.0%	3.1%	3.5%	6.5%	0.5%	2.8%
Detached – single storey	Brick Veneer/Timber	12.2%	9.2%	13.1%	0.2%	3.8%	12.9%	4.3%	6.6%	10.7%
Detached – single storey	Brick Veneer/Concrete	12.9%	10.9%	14.8%	9.4%	1.4%	4.7%	0.7%	29.6%	11.9%
Detached – single storey	Heavy Weight/Timber	14.5%	12.6%	3.5%	0.1%	23.6%	9.3%	17.6%	2.5%	10.1%
Detached – single storey	Heavy Weight/Concrete	2.8%	1.3%	1.8%	0.7%	23.7%	1.1%	13.3%	0.8%	4.4%
Detached – two storey	Light weight/Timber	3.4%	3.5%	4.7%	0.3%	1.6%	5.1%	3.4%	0.1%	3.6%
Detached – two storey	Lightweight/Concrete	0.4%	0.5%	0.7%	0.2%	0.7%	0.6%	2.2%	0.2%	0.6%
Detached – two storey	Brick Veneer/Timber	1.9%	2.0%	2.0%	0.1%	0.4%	1.9%	0.6%	2.0%	1.7%
Detached – two storey	Brick Veneer/Concrete	4.4%	3.7%	5.1%	3.4%	0.4%	1.5%	0.2%	9.6%	4.0%
Detached – two storey	Heavy Weight/Timber	1.7%	1.4%	0.5%	0.0%	2.8%	1.1%	4.3%	0.3%	1.2%
Detached – two storey	Heavy Weight/Concrete	0.7%	0.3%	0.6%	0.3%	7.9%	0.3%	4.6%	0.2%	1.4%
Detached – SA specific	Heavy Weight/Timber	0.0%	0.0%	0.0%	38.5%	0.0%	0.0%	0.0%	0.0%	1.9%
Detached – SA specific	Heavy Weight/Timber	0.0%	0.0%	0.0%	11.3%	0.0%	0.0%	0.0%	0.0%	0.6%
Detached – SA specific	Heavy Weight/Timber	0.0%	0.0%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.1%
Detached – SA specific	Heavy Weight/Concrete	0.0%	0.0%	0.0%	4.9%	0.0%	0.0%	0.0%	0.0%	0.2%
Detached – SA specific	Light weight/Timber	0.0%	0.0%	0.0%	6.1%	0.0%	0.0%	0.0%	0.0%	0.3%
Semi Detached	Brick Veneer/Timber	3.8%	9.9%	1.8%	1.0%	0.9%	5.7%	2.7%	21.5%	3.2%
Semi Detached	Brick Veneer/Concrete	4.0%	2.2%	4.0%	2.7%	0.5%	1.1%	1.0%	21.2%	3.4%
Semi Detached	Light weight/Timber	3.8%	7.5%	3.9%	2.3%	2.5%	6.0%	5.1%	0.5%	4.0%
Semi Detached	Lightweight/Concrete	0.4%	0.6%	0.5%	0.4%	0.5%	0.4%	0.5%	0.0%	0.5%
Semi Detached	Heavy Weight/Timber	2.7%	3.3%	0.6%	12.8%	5.7%	1.7%	10.3%	3.3%	2.8%
Semi Detached	Heavy Weight/Concrete	1.5%	0.4%	1.0%	1.8%	7.3%	0.2%	4.2%	0.6%	1.8%

Climates Modelled

Climate zones selected for modelling were based on those used in the study Energy Use in the Australian Residential Sector 1986-2020 (EES 2008) - see chapter 7.7. Noting however that for this study three additional climate zones (or “grouped zones”) were added, namely Perth (climate zone 13), Hobart (climate zone 26) and Richmond (climate zone 28). The inclusion of these three zones ensures that all capital cities are represented in the modelled climates.

In summary, the climate zone selection was based on the following considerations.

AccuRate, the modelling tool used in this study, distinguishes 69 different climatic zones throughout Australia. To determine the penetration of households in each of these climate zones the AccuRate concordance files for climate zone and postcode were cross matched against the Australia Post statistics file of private and business postal addresses. The AccuRate concordance files capture 99.2% of all postcodes identified by Australia Post.

For some postcodes, AccuRate notes that up to 3 climate zones can be applicable. That is, the geographic boundaries of the post code span several AccuRate climate zones. Across Australia eighty eight percent of dwellings had postcodes that lay within a single climate zone, 11% had postcodes that spanned 2 climate zones and 1% had postcodes that spanned 3 climate zones.

In cases where a postcode spanned more than one climate zone the number of postal address attributed by Australia post to that postcode was split evenly between the climate zones nominated in AccuRate for that postcode. Whilst this assumption may result in the over or under representation of households in a particular climate zone within those postcodes that span multiple climate zones, the error in terms of heating and cooling load estimates is likely to be small. This is because generally, multiple climate zones within a single postcode are unlikely to differ significantly from one another due to their geographic proximity.

For the study, Energy Use in the Australian Residential Sector 1986-2020 (EES 2008) the 69 zones were divided into several “grouped zones”, each group sharing similar climatic characteristics (in terms of modelling outcomes). Each of these grouped zones could then be represented by just one strategically selected AccuRate climate zone within that grouping. This representative zone was then used for modelling runs.

In formulating the set of grouped zones for modelling it was important that the range of those grouped climate zones was representative of the range of climate zones throughout Australia, in particular they were selected to be representative of:

- major centres of population;
- the full range of climate types from heating dominated to cooling dominated, tropical, subtropical, temperate and sub temperate; and
- each of the 8 states and territories that are to be modelled separately in this study.

In total, 13 representative climate zones were selected with slight variations in apportionment of stock numbers depending upon whether heating or cooling loads were being evaluated. The assumed proportions of housing stock by climate group are shown in Table 38 (heating) and Table 39 (cooling).

Table 37 : Assumed Penetration of Housing Stock by Climate Type (group) – Heating (%)

Heating	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
1-Darwin	0	0	0.5	0	0.3	0	75.2	0
5-Townsville	0	0	23.3	0	2.4	0	8.5	0
10-Brisbane	3.3	0	68.2	0.2	3.2	0	0.4	0
13 - Perth	0	0	0	0	83.6	0	0	0
16-Adelaide	0	2.7	0	87.2	6.3	0	0	0
21-Melbourne RO	4.5	9.6	0	0	4.2	0	0	0
24-Canberra	3.2	13.4	0	0	0	0	0	99.7
26- Hobart	0	0	0	0	0	60.5	0	0
28 - Richmond	37.8	0	0	0	0	0	0	0
56-Mascot	46.2	0	7.9	1.6	0	0	16	0
60-Tullamarine	1.5	29.6	0.1	4.9	0	0	0	0
62-Moorabbin	0	44.1	0	0	0	17.5	0	0
65-Orange	3.6	0.7	0	6.1	0	22	0	0.3

Table 38 : Assumed Penetration of Housing Stock by Climate Type (group) – Cooling (%)

Cooling	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
1-Darwin	0	0	0.3	0	0.8	0	82.2	0
5-Townsville	0	0	21.5	0.2	2.6	0	17.8	0
10-Brisbane	19.7	0.3	51.5	1.8	10.6	0	0	0
13 - Perth	0	0	0	0	66.3	0	0	0
16-Adelaide	0	2.7	26.6	87	0	0	0	0
21-Melbourne RO	16.2	9.3	0	0	0.9	0	0	0
24-Canberra	3.2	0.3	0	0	0	0	0	99.7
26- Hobart	0	0	0	0	0	100	0	0
28 - Richmond	22.6	0	0	0	0	0	0	0
56-Mascot	33.3	0	0	0	0	0	0	0
60-Tullamarine	1.5	40.2	0.1	0	15.1	0	0	0
62-Moorabbin	0	43.8	0	0	0.4	0	0	0
65-Orange	3.6	3.4	0	11	3.3	0	0	0.3

Modelling Software

Overview

The AccuRate building assessment software used in this study was developed by the CSIRO and is the successor to the first generation Nationwide House Energy Rating (NatHERS) software on which several key building thermal performance assessment tools in Australia were based.

AccuRate is an enhanced version of the NatHERS software. It is a rating tool that assigns a star rating to a residential building (a detached or semi-detached house, unit, townhouse, or apartment) based on its calculated annual heating and cooling energy requirements (not energy consumption, i.e. the efficiency of heating and cooling equipment is not taken into account).

Several assumptions in the form of AccuRate program settings also had to be made for the purposes of undertaking thermal simulation modelling. These included such things as ceiling heights, glazing systems, window coverings, overshadowing, natural and mechanical ventilation, levels of building sealing and so on. The settings for these parameters in this study are the same as those adopted in the study *Energy Use in the Australian Residential Sector 1986-2020* (EES 2008) - see chapter 8.8.

To make estimates of actual energy use (as distinct from determining a star rating in rating mode), the default assumptions within the AccuRate software (i.e. in rating mode) relating to occupancy of the dwelling and the operation of thermostats within the dwelling were varied to more closely match reality. Settings as adopted in AccuRate in rating mode whilst adequate for comparative rating purposes were not considered adequate for the purposes of estimating actual space heating and cooling loads expected to prevail in an average household. These adjustments in relation to user behaviour were undertaken on the basis of research undertaken in the study, Energy Use in the Australian Residential Sector 1986-2020 (EES 2008) and primarily affect occupancy and thermostat settings and are detailed below in the following two subsections

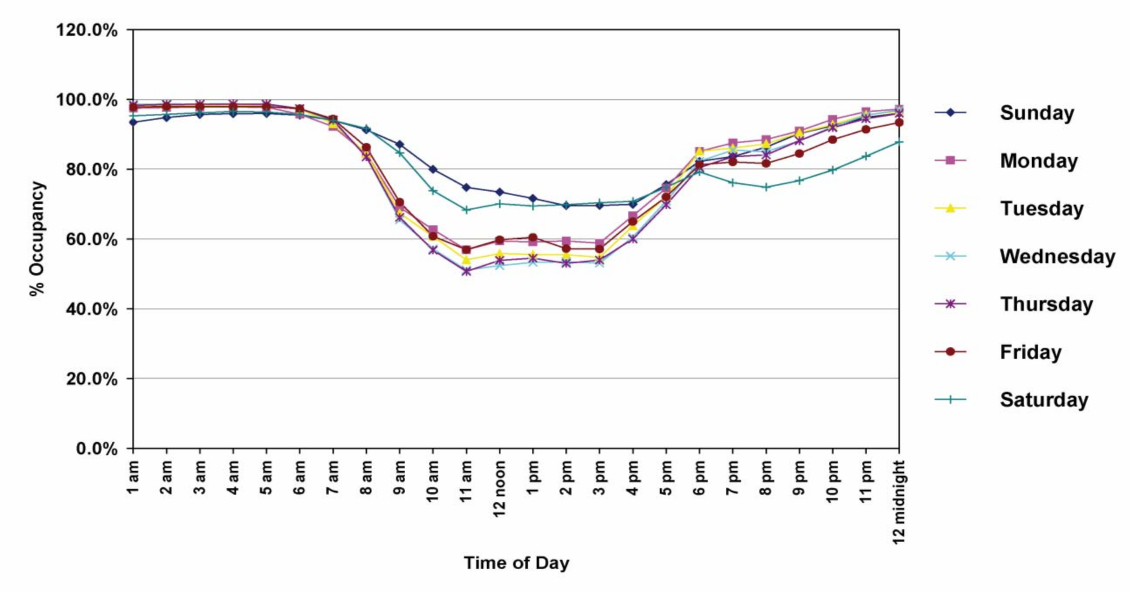
Adjustments for Occupancy

The default settings for occupancy (ie hours of occupation) used in AccuRate assume that the dwelling is to be occupied 24 hours a day (although not all zones within the dwelling are assumed to be continuously occupied e.g. Living spaces 7am until Midnight, bedroom spaces 4pm until 9am). These default settings are reflected in the stringency levels for the star bands ie the target load for a particular star rating assumes that this 24 hour occupancy profile will prevail.

In the study Energy Use in the Australian Residential Sector 1986-2020 (EES 2008) – see Figure 20 it was found that householders will occupy their dwellings somewhat less than the hours of occupancy assumed in the default settings embodied in AccuRate. The impact of this lower occupancy will be to reduce the expected space conditioning load and thereby any savings that may be derived from the application of an improvement measure.

More realistic occupancy settings were achieved by manipulating the scratch files in AccuRate to reflect the profile as described in Figure 20. Full details of the methodology can be found in section 8.4 of the study *Energy Use in the Australian Residential Sector 1986-2020* (EES 2008).

Figure 20 : Residential Occupancy Profile – Australia 1992 and 1997 (averaged) (EES 2008)



Adjustments for Thermostat Operation

The default settings for thermostat operation (i.e. at what temperature is it assumed that an occupant shall initiate and at what temperature shall they maintain their heating or cooling) used in AccuRate are detailed in the AccuRate user guide (AccuRate V1.1.4.1). These default settings are reflected in the stringency levels for the star bands i.e. the target load for a particular star rating assumes that householders will behave in accordance with those assumptions. For this study it has been assumed that the thermostat settings for heating operation are realistic and therefore valid. However, in terms of cooling operation it has been postulated on the basis of some survey evidence that householders, following initiation of cooling, will on average expect a higher level of comfort than that adopted as the default in AccuRate. This is particularly apparent in the warmer climates. The impact of this higher comfort standard in cooling mode will be to increase the expected space cooling load and thereby increase the abatement stemming from the application of an improvement measure such as ceiling insulation.

For this study an alternative cooling thermostat operation in line with that as detailed in section 8.6 of the study *Energy Use in the Australian Residential Sector 1986-2020* (EES 2008) was used.

Scope of space conditioning Equipment examined

Overview

An assessment of the benefits that accrue from ceiling insulation retrofit is dependent to a significant degree upon the ownership and attributes of the stock of space conditioning equipment used by householders to meet their thermal comfort requirements. The space conditioning model used in this study is based on that used in the study *Energy Use in the Australian Residential Sector 1986-2020* (EES 2008) – see section 6.

Output from the AccuRate thermal performance model is in terms of potential heating and cooling loads. To determine actual estimated energy demand experienced by the householder, the potential space conditioning load was processed through a stock model of space conditioning equipment. That model covers both ownership and attributes of the stock of space conditioning equipment. This process is detailed graphically in Figure 18 and in more detail in section 6 of the study Energy Use in the Australian Residential Sector 1986-2020 (EES 2008)[12]. The effect of the space conditioning stock model is to constrain the space conditioning load predicted by AccuRate to more realistic levels.

For this study the following range of space conditioning equipment types were included in the analysis:

1. Resistive electric heating
2. Room Reverse Cycle heating
3. Ducted Reverse Cycle heating
4. Room Gas heating
5. Ducted Gas heating
6. LPG Gas heating
7. Wood Closed Combustion heating
8. Wood Open Combustion heating
9. Room Reverse Cycle cooling
10. Room Cooling Only cooling
11. Ducted cooling
12. Evaporative cooling.

[12] Noting that the original 2008 model has been updated with the latest ABS appliance survey data and the performance characteristics of air-conditioners have been updated to account for the latest (2011) MEPS requirements.

Zoning Constraint

Zoning is the tendency of some householders to limit space conditioning to selected areas of their dwellings. This strategy limits the amount of energy required by the household for space conditioning compared to householders who choose to space condition their entire dwelling. In some cases, zoning occurs because the output of the relevant heating or cooling equipment is of insufficient capacity to heat or cool the whole dwelling. But many householders consciously limit active space conditioning to living areas (which is more typical in Australia than in more severe climates in North America or Europe, for example) with only limited heating or cooling in bedroom areas.

The default settings in AccuRate limit space conditioning from 7am until midnight in living spaces and 4pm until 9am in bedroom spaces. This means that effectively these spaces are partially zoned by virtue of the fact that they are assumed to be unoccupied and therefore unconditioned for certain portions of the day (although in reality some householders may choose to condition unoccupied spaces). The issue of how occupancy limits space conditioning use is dealt with earlier in this section. This section deals with limitations on the areas of the dwelling that can be heated and or cooled if desired by the householder.

In reality there is a very wide range of voluntary or imposed zoning regimes adopted by different householders, ranging from whole house heating and cooling to no heating or cooling at all. Primarily, zoning strategies are understood to be driven by the particular space conditioning technology installed by the householder. A householder with only a single room heater in their living room cannot choose to heat the entire house or for that matter cool any of their dwelling whereas a householder with a ducted reverse cycle air-conditioner can choose to heat or cool their entire dwelling (if the system is of sufficient capacity).

For the purposes of this study it was assumed that each of the various space conditioning technologies known to be installed in Australian households (as noted above) will impose on average a specific “zoning factor” that will constrain the actual space heating and cooling energy consumption estimated by AccuRate under the standard zoning assumptions. The zoning factors as determined in the study *Energy Use in the Australian Residential Sector 1986-2020* (EES 2008) were adopted for this study (see Table 39).

Table 39 : Zoning Factors by Space Conditioning Technologies and State (EES 2008)

Equipment	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Resistive Heating	0.25	0.25	0.2	0.2	0.2	0.2	0.2	0.35
Reverse Cycle Room - Heating	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.35
Ducted heaters Reverse Cycle	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Room Gas Heaters*	0.25	0.6	0.25	0.35	0.3	0.5	0.25	0.3
Ducted Gas Heaters*	0.6	0.8	0.6	0.7	0.65	0.7	0.6	0.65
LPG Gas Room Heaters	0.3	0.5	0.3	0.3	0.3	0.5	0.3	0.5
Wood Heaters Closed	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Wood Heaters Open	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Room Reverse Cycle – Cooling	0.3	0.3	0.3	0.3	0.3	0.3	0.25	0.3
Room Cooling Only	0.3	0.3	0.3	0.3	0.3	0.3	0.25	0.3
Central Ducted Cooling	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Evaporative	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9

*Note: Room gas is projected to rise to 0.4 in SA and 0.35 in WA by 2020 and Ducted Gas is projected to rise to 0.8 in SA and 0.7 in WA by 2020

Appendix 2 : Modelling Methodology – Financial

Overview

The financial analysis undertaken in this study included several aspects that relied on a range of assumptions. Apart from the assumptions relating to discount rates and payback periods (see section 1.3.6), the key aspects of the financial analysis included:

- The assumed cost of the investment in ceiling insulation
- The assumed cost of the fuels used for space conditioning which together with the estimated energy savings, form the basis for valuing the return on the investment in insulation to the householder in the form of reduced energy bills.
- The value of avoided generating and network capacity due to reductions in summer maximum electrical demand through the retrofit of ceiling insulation.

The assumptions used for each of these aspects of the financial analysis are detailed in the following sections.

It should be noted that unlike the estimates for energy or greenhouse gas savings the estimates of financial savings to the householder do not include a discount for any rebound effect that may occur. No discount is applied because for the householder, rebound or “comfort creep” (if it occurs) is not an issue. If such discretionary behaviour 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.

Cost of the Investment - Insulation costs

Estimates for the cost of the required investment in ceiling insulation were determined by ICANZ for each jurisdiction via a survey of its key members. The results of that survey are shown in Table 40.

Table 40 : Average Cost of Retrofitting Ceiling Insulation (ICANZ 2011)

Type	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
R3 Batt	$8.70	$8.70	$8.70	$9.50	$11.70	$10.25	$9.55	$8.70
R3.5 Batt	$9.60	$9.60	$9.60	$10.31	$12.56	$11.00	$10.15	$9.60
R4 Batt	$10.40	$10.40	$10.40	$11.38	$13.44	$12.20	$10.75	$10.40
R5 Batt	$12.60	$12.60	$12.60	$14.50	$16.00	$15.00	$13.55	$12.60

Fuel Costs

As noted in section 1.3.6, for this study three fuel pricing scenarios were examined, these were:

- BAU
- BAU + Low carbon price
- BAU + Medium carbon price

Electricity Price Estimates

Prices for electricity have been constructed as the sum of major cost components, comprising wholesale costs, network (transmission and distribution) cost, retail operating costs, and retail margin. The starting point for estimating residential prices in all cities except Melbourne is the energy component of published maximum or default tariffs, as at June 2010, i.e. prior to price increases effective 1 July in a number of States, as set by the relevant regulatory agency or process in each State and Territory. In Melbourne, the initial price is the approximate average of AGL's published standing offer prices in each network region within the Melbourne metropolitan area. The fixed or standing charge component of total annual residential supply costs is ignored, meaning that the prices used are slightly lower than full average costs per kWh (though more representative of marginal costs). However, since the fixed component accounts for only a small proportion of total annual costs, this is not a great distortion. Moreover, the use of published default or standing offer prices is likely to over-state prices paid by consumers who take advantage of individual contract prices which are available in cities with significant levels of retail competition.

Price component shares for Sydney, Brisbane, Adelaide, Hobart and Canberra are from AER (2010), plus a variety of individual AER network price determination reports, as are the trends in the network cost component out to 2014 or 2015 for these cities plus Melbourne. Over the longer term, real network costs are assumed to increase by 1% per year to 2035, and remain constant thereafter. Retail operating costs, derived from the cost component data, are assumed to remain constant in real terms throughout the projection period. The retail margin is calculated as a percentage of wholesale plus retail operating costs and the percentage itself is similarly assumed to be constant, though the percentage itself varies between cities.

Trends in the wholesale cost component were taken from data provided by the Emissions Projections Team of the Department of Climate Change and Energy Efficiency; and separate costs series were provided for each State electricity market. The Department also provided a time series for the pass-through cost of the Large Renewable Energy Target scheme (LRET) and the Small-scale Renewable Energy Scheme (SRES).

The modelling from which the wholesale market costs were derived was for a 'without carbon price' case. A carbon price was therefore added on a cost pass-through basis. Three alternative cases were assumed. Scenario 1 has no carbon price; the Scenario 2, lower carbon price case starts at $23 per t CO_2-e (2011 prices) in 2012-13 and increases at 4% per year for the whole projection period; the Scenario 3, medium carbon price case also starts at $23, but increases by $4 per tonne each year throughout the projection period.

Gas Price Estimates

The approach used to construct projected natural gas prices was similar to that used for electricity. The major cost components for natural gas prices are wholesale costs (including carbon price costs if applicable), network (transmission and distribution) cost, retail operating costs, and retail margin. Only two jurisdictions, NSW and SA, regulate maximum residential gas prices; these regulated prices, as at June 2010, were used as the starting point for estimating residential prices in Sydney and Adelaide. For Melbourne and Brisbane the initial price is the approximate average of AGL's published standing offer prices in a representative sample of locations in each city, covering each network region within the respective metropolitan areas. In Perth, Canberra and Hobart, published default prices of the sole or dominant gas retailer in each city are used. There is no general reticulated supply of natural gas.

Price component shares for Sydney and Adelaide are from AER (2010). For other cities the various components were directly estimated, applying professional judgement to data gathered from a variety of sources. Various individual AER network price determination reports provided guidance on the size and trend in network costs over the next few years in Sydney, Brisbane, Adelaide and Canberra. Thereafter, network costs are assumed to increase by 1% per year until 2030 and then remain constant. Estimates of wholesale costs draw on various AER documents and other sources. It should be noted that these vary considerably between cities, but it is assumed that there will be a general convergence towards export parity netback levels, as the gas markets of eastern Australia become increasingly strongly inter-connected and LNG export projects come on stream in Queensland. Over the longer term, rapidly growing demand for natural gas for electricity generation is expected to place steady upward pressure on wholesale costs for gas. Retail operating costs and retail margin were estimated in similar way to that used for the corresponding components of electricity costs.

The overall outcome is that natural gas prices are projected to increase steadily throughout the projection period, but more slowly than electricity prices.

Other Fuels Price Estimates

Prices for the lesser fuels, LPG and firewood, were based on estimates made by Allen Consulting Group for the Residential Mandatory Disclosure project. The cost (2011 prices) of LPG ranged from 4.4 to 5.2 cents /MJ depending upon the jurisdiction and the cost (2011 prices) of firewood ranged from 0.5 to 1.0 cents /MJ ($80 to $160 per tonne) depending upon the jurisdiction

Value of the Avoided Generating and Network capacity

Estimates of avoided increases in summertime electrical maximum demand due to the installation of ceiling insulation were made in this study (see Table 33).

Using these estimates, factors relating to the annual value of a MW of peaking capacity avoided were then applied to determine the annual savings due to ceiling insulation retrofit through summertime peak load reduction (as reported in Table 34).

The cost factors used were derived from a recent report by ISF/Energetics for DCCEEE (*BUILDING OUR SAVINGS: Reduced Infrastructure Costs from Improving Building Energy Efficiency*), and are shown in Table 41. (UTS 2010)

Table 41 : Value of Avoided Summertime Peak Electrical Load Capacity ($M/MW/annum)

NSW	VIC	QLD	SA	WA	TAS	NT	ACT
0.39	0.23	0.27	0.53	0.22	0.14	-	0.39

Appendix 3 : Modelling Methodology – Greenhouse

Method

Each space conditioning appliance type uses a particular form of fuel. For this study 4 different fuel types were tracked as follows:

- Electricity
- Gas
- LPG
- Firewood

Estimated space conditioning energy use was aggregated into each of these 4 fuel types, noting that firewood is separately tracked according to the equipment type it is burnt in, either closed combustion or open combustion, this is important because the type of combustion significantly affects the greenhouse gas intensity of this fuel type.

Finally greenhouse gas coefficients were applied to each fuel type to determine estimated total greenhouse gas emissions per household by state and territory. By comparing the estimated greenhouse gas emissions before and after the application of insulation an estimate of the abatement potential could be made.

Greenhouse Gas Coefficients

Greenhouse gas coefficients represent the expected emissions of greenhouse gases per unit of energy delivered for a particular fuel type. These coefficients are expressed in terms of the equivalent mass (g) of carbon dioxide (CO2-e) per unit of energy (J).

Estimates of the greenhouse gas intensities of fuels have been made by the Commonwealth Department of Climate Change (and its predecessors) over the past few years. Generally these estimates have remained fairly steady over time for all fuel types except electricity.

For this study Greenhouse gas coefficients were primarily derived from those developed by George Wilkenfeld and Associates for the Department of Environment Water Heritage and the Arts. These forward estimates are routinely used by the Commonwealth Government when preparing regulatory impact assessments relating to matters of energy policy. These estimates are however subject to a considerable degree of uncertainty as government policy in respect of greenhouse gas abatement continues to develop at a rapid pace. In particular, the impacts of the recently announced but yet to be finalised, carbon price is likely to have an impact on the estimates for electricity.

The greenhouse gas coefficients used in this study are presented in Table 42 (Electricity) and Table 43 (all other fuels).

Table 42 : Greenhouse Gas Intensity of Electricity[1] by Jurisdiction and Year (kg CO2-e / GJ)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
2008	275	355	282	275	234	22	224	275	275
2009	270	348	280	270	232	24	223	270	270
2010	266	341	277	266	231	26	222	266	266
2011	262	319	273	261	230	29	220	262	262
2012	257	297	269	256	230	32	217	257	257
2013	253	275	264	251	229	35	214	253	253
2014	249	253	260	247	228	38	211	249	249
2015	244	231	256	242	228	42	208	244	244
2016	244	222	254	241	227	44	208	244	244
2017	243	214	253	239	226	47	207	243	243
2018	243	206	252	238	224	50	207	243	243
2019	242	197	251	237	223	53	206	242	242
2020	242	189	250	236	222	56	206	242	242

Table 43 : Greenhouse Gas Intensity by Fuel type and State 2010 (kg CO2-e / GJ)

Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Natural Gas [2]	66.1	57.3	57.3	70.7	58.9	60	57.1	66.1
LPG [3]	65.2	65.2	65.2	65.2	65.2	65.2	65.2	65.2
Wood Open Combustion [4]	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
Wood Closed Combustion [4]	57.7	57.7	57.7	57.7	57.7	57.7	57.7	57.7

Data Sources:

1. Source: National Greenhouse Accounts Factors 2010
2. Source: Guide to Preparing Regulatory Impact Statements for the National Appliance and Equipment Energy Efficiency Program (GWA 2010 Unpublished)
3. Source: Guide to Preparing Regulatory Impact Statements for the National Appliance and Equipment Energy Efficiency Program (GWA 2008)
4. Source: Victoria's Greenhouse Gas Emissions 1990, 1995, 2000 and 2005: End-Use Allocation Of Emissions for the DSE Victoria (George Wilkenfeld and Associates 2008)

Appendix 4 : Modelling Methodology – Peak Load

Background

This study has included an estimate of the likely peak load reduction benefits that can be expected to accrue as a result of the retrofitting of ceiling insulation. Traditionally, supply side solutions have been used to deal with peak load issues. However, these have proven very costly and place a drain on limited resources that some argue would be better directed towards demand side solutions such as ceiling insulation retrofitting.

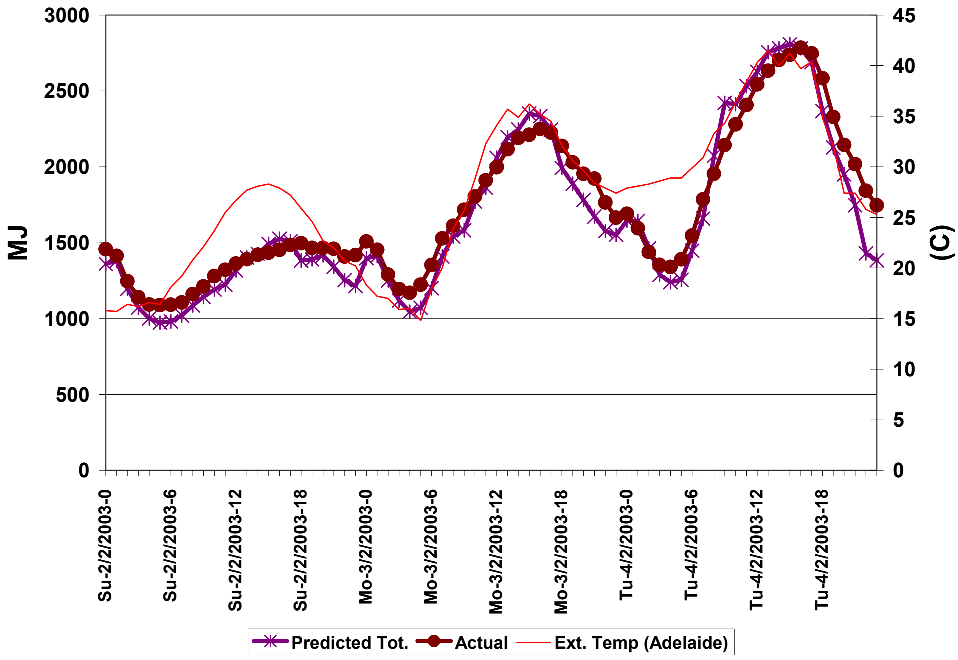
In 2004 Energy Efficient Strategies developed a model of Victoria's electrical peak load for VENCORP (The Victorian Energy Networks Corporation) and for the Australian Greenhouse Office (now The Department of Climate change and Energy Efficiency). The study that accompanied the model was entitled *Electrical Peak Load Analysis – Victoria 1999-2003* (EES 2004). In that study it was established that provided appropriate and representative input data is used, AccuRate thermal simulation software can be used to infer summer electrical peak loads associated with the space cooling of dwellings to an accuracy of +/- 3%.

The input data requirements, as used in this study, are:

- A model of each states residential building stock
- A model of the state space cooling equipment stock
- A model of the performance of the states space conditioning stock
- Representative user behaviour settings
- Representative zoning constraint

The 2004 study used actual weather data to test and prove the model's accuracy against actual state electrical load. A similar study was repeated by EES for Energy SA and DEWHA with some refinements to the AccuRate software which improved the curve fit of the modelled load. A sample of the most recent peak load modelling outputs from the model developed for South Australia can be seen in Figure 21.

Figure 21 : Comparison of modelled and Actual Electrical loads – South Australian Example



In this sample taken over 3 days in February 2003 the maximum daily temperature rose from approximately 28°C on the first day to over 40°C on the third day. The modelled load (purple line) tracks closely to the actual measured load (brown line) particularly at the hour of the day when maximum demand occurred – which is the critical point in terms of planning for infrastructure to meet the expected maximum demand.

Estimating Reductions in Peak Loads

For this study the same method was used as in the VENCORP and South Australian studies to estimate each states electrical peak load impacts that would be expected as a result of the retrofit of ceiling insulation.

AccuRate hourly cooling load results for each of the sample dwellings in each of the 13 climatic regions were interrogated using the Accubatch facility. Outputs were obtained for all the insulation options examined in this study as well as the business as usual case (uninsulated). To determine the expected summer cooling peak electrical load for the cohort of dwellings examined in each of the four scenarios, the results from the AccuRate hourly load modelling were weighted in accordance with:

- The prevalence of each climate region within each jurisdiction
- The prevalence of the various housing types and constructions
- The ownership of space conditioning equipment (and saturation)

- The conversion efficiency of the installed space conditioning equipment.
- Zoning constraints associated with each form of space cooling technology

The analysis assumes that the reduced peak loads associated with improved building shell performance will result in a simple reduction in demand by householders equivalent to the modelled reduction. In reality, improved building shell performance will result in fewer summer days during which the internal environmental conditions will be outside acceptable comfort limits. At some point in the scale of improvement some householders are likely to decide that the installation of an air-conditioner is not warranted. For these householders the savings in operational and plant costs would be greater than otherwise predicted by the model. This study did not assume that there would be any reduction in space conditioning plant ownership as a result of retrofitting insulation to the ceiling.

CLF Factors

An alternative method for estimating the likely savings in peak load due to the application of an energy saving measure is what is known as the Conservation Load Factor (CLF), developed in the United States.

The Conservation Load Factor (CLF) (Koomey 1990) concept was introduced in order to provide a simple basis for estimating the peak load savings and consequential financial benefit from a reduction in peak load. The CLF is defined as the average annual load savings divided by the peak load savings, where both are based on measured data or the output of an hourly simulation model.

CLF = [Annual Energy Savings (kWh)/8760]/Peak Load Savings (kW)

The concept is analogous to a demand side capacity factor, or measure of the peakiness of end use. For end uses like refrigeration with a relatively flat based load throughout the year, values of 0.7 are typical. For end uses such as residential air conditioning (A/C) with a relatively peaky performance throughout the year, the CLF value is much lower, typically between 0.01 and 0.1. High A/C demand is weather related so that A/C use is peak coincident with large peak demand savings relative to total annual energy used.

In the US CFL factors have been determined for a number of locations as detailed in Table 44. As expected for air conditioning, the smallest CFL occurs for the mildest climate where A/C use is rarer, while the largest value occurs for the Florida climate where A/C is a more regular feature of summer living.

This approach has also been taken up by recent work in Australia (UTS 2010) to use this concept to link peak load reduction with avoided capital, O&M and transmission/distribution costs in the electricity network. The UTS modelling provides estimates of annual energy and peak load savings by State. The EES peak load modelling studies however provide a strong basis for asserting a real basis for linking annual energy and peak load reductions through the CFL. Based on the EES methodology CLF factors as noted in Table 45 were determined for each jurisdiction in Australia (noting that the EES model has only been rigorously tested in Victoria and South Australia).

Table 44: US Data on Residential Air Conditioning CLF Values from Case Studies (LBNL 2002)

Data Source	CFL	Location
SoCal Ed 1991	0.0834	Southern California Edison
PG & E 1992 Zone R	0.0726	Desert/Mountains – very hot
PG & E 1992 Zone S	0.0695	Valley - hot
PG & E 1992 Zone	0.0332	Hills – moderate climate
Florida Solar Energy Center	0.127	Homestead, Florida
Koomey (1990)	0.15	US National Average

Table 45: Estimated CLF factors for Summer Electrical Peak based on EES Simulation Modelling

Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
kW reduction / house	0.436	0.42	0.42	0.65	0.69	0.34	0.61	0.36
kWh reduction / house	206	60.6	231	225	250	8.5	669	76.7
Calculated CLF	**0.05**	**0.02**	**0.06**	**0.04**	**0.04**	**0.003**	**0.12**	**0.02**

From Table 45 we note that the modelled values derived in this study for the Australian jurisdictions align with expectations based on the corresponding US climate case studies (Table 44) as follows:

- Southern California (LA) equates approximately to Adelaide or Perth in terms of the Köppen–Geiger climate classification (Temperate Mesothermal – Dry Summer , sub tropical)
- Florida equates with Cairns in terms of the Köppen–Geiger climate classification (Tropical Megathermal – Monsonal) , this is considered to be the closest match to Darwin
- Melbourne, Canberra and Hobart ((Temperate Mesothermal climates) have low factors because they experience relatively short summers (ie low annual cooling demand) but with very high temperatures (sometimes in excess of 40^{o}C) confined to a few days during the summer. Their low CLF factors roughly align with the factors determined in the US for the "Hills – moderate climate" which is understood to be based around the San Francisco region.

It should be noted that both the values for kW and kWh reduction in Table 45 take comfort creep into account, and are thus 75% of the actual modelled values.

The CLF approach also provides a simple methodology to use the annual equivalent cost for new generating plant to value energy savings. (Koomey 1990)

Appendix 5 : Review of Factors Likely to Constrain Benefits

Introduction

Several factors are likely to impact on the expected benefits arising from the retrofit of ceiling insulation. The main factors considered in this study were:

- Limitations on the longevity of the improvement measure
- Rebound or comfort creep (space conditioned area changes, thermostat changes)
- Sub-optimal installation practices

Each of these factors are discussed in the following subsections.

Longevity of the improvement measure

The longevity of a particular improvement measure will impact on its lifetime contribution to greenhouse gas abatement - the longer the service life, the greater the potential abatement. Service life will vary according to the type of improvement measure, in particular its durability.

Materials such as insulation should last the life of the dwelling. Dwellings will persist on average for about 70 to 100 years but the stock is biased towards newer stock i.e. about half the existing stock would probably have been built in the past 30 years. This means that the expected longevity of some of the more durable improvement measures may be conservative.

In the submissions to the NSW government "Summary of Energy Savings Scheme (ESS) Ideas and Comments– February 2009 Submissions" CSR argued that the lifespan for insulating materials should be set at 40 years. Enact Energy also argued for a 40 year lifespan for these product types. It is understood that the Victorian VEET scheme used a value of 25 years for insulation materials. For this study an assumed lifespan for ceiling insulation of 30 years was adopted. Whilst not as high as that argued by companies such as CSR, this value takes into account the fact that some of the dwellings to be insulated may be demolished in fewer than 30 years

Rebound effect or comfort creep

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.

For the householder, "comfort creep" (if it occurs) is not an issue, for this 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. For government however it is less straight forward. From a government perspective a key outcome of the scheme is a reduction in greenhouse gas emissions for those dwellings that participate in the scheme.

Where comfort creep does occur the energy savings predicted for the energy efficiency measures will not be realised in full. .

Unfortunately there is little Australian data in the form of post occupancy surveys that support an estimate of the likely impact of this phenomenon. What has been found is the following:

Gas and Fuel Corporation Gas Demand Management Project - Victoria

The Gas and Fuel Corporation undertook a number of significant studies of residential energy use in the 1980's and early 1990's. The Gas Demand Management Discussion Paper No. 9 released in December 1991 analyses the saving in gas heating due to the installation of ceiling insulation. This was a longitudinal survey of 300 houses households. It analysed the winter energy consumption of these households before and after they had installed ceiling installation. The project also surveyed these households to determine the type of heating, the extent of use in terms of rooms heated and times of operation and whether the occupants had changed the way they heat their houses after the installation of insulation. The study found that ceiling insulation did result in statistically significant energy savings

The Gas and Fuel also asked a number of questions to determine whether people had changed the way they used their heaters after the installation of insulation. Table 46 below presents these results.

Table 46 Changes in Use of Heaters after the Installation of Insulation (Gas and Fuel 1991)

User Behaviour Affected	% of Centrally Heated Homes			% of Space Heated Homes		
	Increase	No Change	Decrease	Increase	No Change	Decrease
Hours of Use	11	45	44	5	60	35
Heating Thermostat	7	60	33	5	50	45
Area Heated	17	76	7	21	71	8

The table above demonstrates that after installing insulation the majority of the sample did not change the way they used heating. For those households which did change most of them:

- reduced their thermostat setting: the better heat distribution afforded by insulation meant that the house could be heated to a lower temperature and still remain comfortable,
- reduced the hours of use: the ceiling insulation meant that the house did not cool down as quickly and so maintained comfortable conditions without heating for longer, and
- around 1 in 5 households increased the area heated.

The first two factors listed should act to reduce energy use while the increase in area heated will increase energy use. Taken together these changes to user behaviour suggested that there was little or no rebound effect that could be associated with the installation of insulation.

UK Energy Research Centre Study

In a UK study entitled “The Rebound Effect: an assessment of the evidence for economy-wide energy savings from improved energy efficiency (Sorrell 2007) prepared for the UK Energy Research Centre in London it was concluded following the review of a number of studies that the level of shortfall is typically in the order of 10 to 30% for heating in developed countries following thermal performance upgrades.

Study of Public Housing in Tasmania

In this project, a sample of around 140 houses was fitted with meters which measured the energy use of individual appliances: off peak heating, auxiliary heating, hot water, lighting, cooking and general power for a period of 21 months. Meters were read on the same day for each house at monthly intervals. Householders were interviewed about the extent of their energy use and their understanding of and attitudes toward energy use. The sample was selected to include only a handful of house design types and only two types off peak heaters were used. This limited the variability of the sample in terms of heater type, area of house, design features and construction materials. Further the use of public housing tenants reduced the socio-demographic variability of the sample.

This study found that houses with wall and ceiling insulation used 12% less energy than houses with ceiling insulation only. This is close to the full theoretical value which again indicated that there is little rebound effect.

Evaluation of the Home Energy Advisory Service in Victoria

The Home Energy Advisory Service was established in Victoria to provide energy saving advice and retrofitting for Commonwealth Health Card holders. To ensure the program was effective the energy use before and after receiving the service was analysed for 3000 clients. Having a large sample allowed the researchers to ensure that the comparison of energy use eliminated other extraneous variables while still providing samples of sufficient size to ensure statistical significance.

The phase 2 report (DITR, 1985) showed that households who received ceiling insulation had 9.2% lower gas usage and 7.6% lower electricity usage indicating that supplementary heating using fans heaters etc. was also reduced. The full theoretical saving for a space heated home (not centrally heated) will be in the order of 12%, this represents a rebound of approximately 25% This is a particularly important finding for if any sample is likely to be under-heating - and would therefore show potential for rebound - it would be those with lower incomes such as the clients of this service.

Impact of Retrofit Wall Insulation in the ACT

The ACT Government offers a rebate to those who install Cavity Wall Insulation. This product is a loose fill insulation which can be blown into existing walls. The ACT government engaged consultants to examine the impacts of the retrofit wall insulation on the energy use of a sample of households (Beckman, 2003). Over the 72 houses in the sample a total energy saving including gas and electricity was 15%. While this is less than the ACT Greenhouse plan forecast, it is in line with the theoretical savings that simple heat flow calculations would indicate.

Study for Energy Efficiency Conservation Authority – NZ

The New Zealand study entitled "Home Energy Rating Scheme : Cost benefit analysis "(Energy Consult April 2009), included a component that covered the retrofit of insulation to existing dwellings. For that component the authors estimated the potential rebound effect at 25%. The basis of this estimate is unknown.

Conclusion

Determination of an appropriate rebound factors for application in the various jurisdictions within Australia are hampered by a lack of available data. Studies from Victoria and the ACT as well as further a field tend to place the rebound effect somewhere in the range of 0 – 30% noting that this is likely to vary depending on factors such as the socio-economic status of the household and the severity of the local climate. Considering the results of these various studies it was decided that an assumed rebound effect of 25% would be appropriate for this study. That is, it is assumed that following the application of improvement measures only 75% of the theoretical space conditioning energy savings are likely to be realised.

Whilst the assumed value of 25% is toward the high end of available estimates (i.e. conservative) this is considered reasonable on the grounds that actual realised savings in energy consumption are also likely in some cases to be marginally constrained by sub optimal installation practices.