INSULATION COUNCIL OF AUSTRALIA AND NEW ZEALAND

Department of Manufacturing, Innovation, Trade,
Resources and Energy (DMITRE,
Energy Markets and Programs Division,
GPO Box 1264,
Adelaide SA 5001

12 August 2013

Dear Administrator,

REES Review – Directions Paper

The Insulation Council of Australia and New Zealand (ICANZ) welcomes the opportunity to offer its comments on the content REES Review Directions Paper and congratulates the South Australian Government for the successes REES has achieved to date.

The insulation industry in Australia currently employs approximately 4,000 people in the manufacture, marketing, distribution and installation of insulation in residential, commercial and industrial applications. ICANZ represents the largest manufacturers and suppliers of insulation in Australia and New Zealand and its members supply over 70% of market requirements.

Saving energy and reducing emissions

Much research has now been done on how best to reduce energy use and as a consequence mitigate carbon emissions. Almost unanimously all findings support improving energy efficiency as the most potent, cost effective and available avenue to pursue in the first instance. Improving the energy efficiency of new buildings is addressed through increasing the energy efficiency requirements in the National Construction Code. Improving energy efficiency in existing buildings has also been identified as a source of major greenhouse gas abatement, significant and permanent cost saving measures and as a high priority target for abatement programs. In many instances retrofitting insulation – particularly ceiling insulation – is the most cost-effective first step - and once fitted helps maximise the benefit of other energy efficiency improvements.

Barriers to the uptake of energy efficiency measures are not simply an Australian phenomenon – they are global. Despite the short financial paybacks attributed to many available energy efficiency options, virtually all advanced economies have found it necessary to introduce a package of regulatory and assistance measures to assist with the uptake of energy efficiency measures. Providing education and compelling information down to a household or small business level still remains a major barrier.

Electricity prices have increased at a much higher rate than inflation in recent years. From June 2007 to June 2012 Australia's electricity prices rose by 72 per cent.[1] With less disposable income available, some households will require further guidance and incentives to take advantage of energy efficiency measures.

[1] Australian Bureau of Statistics, 4102.0 - Australian Social Trends, Sep 2012 – Household energy use and costs, (2012), ABS, < http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4102.0Main+Features10Sep+2012>

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Consumers need leadership

Consumers have indicated that they are willing to use less energy in their homes and have called on governments to lead the way. In 2011, the Clean Energy Council conducted a survey of 1,000 Australians to determine their attitudes towards energy efficiency. The findings shows that:

- 95% of respondents were concerned or very concerned about rising energy costs;
- 89% willing to take action to use less energy;
- 80% believe governments should take leadership on issues of energy efficiency
- 73% wanted more information on how they could save energy
- Approximately 40% of those surveyed at the time were aware of at least one government program to assist households save energy.

Status of Federal Government policies effecting energy efficiency

The current Federal Carbon Tax targets major industrial users and does not provide any direct link to residential energy behaviour or benefits of energy efficiency. Similarly, the Federal Government's Low Income Energy Efficiency Programme (LIEEP) and Community Energy Efficiency Programme (CEEP) are specifically project driven and many address improving information and education only. Both the Federal Government's proposed ETS and the Coalition's Direct Action policy assume there will be a strong, complimentary and supporting broad based energy efficiency program. However although a national white certificate scheme has been evaluated by the Federal Government its current status is uncertain. Residential mandatory disclosure for residential premises sold or leased has been approved by COAG for several years but its introduction is now not a priority and likely to be some years away. Establishing a National Energy Efficiency Target also does not seem imminent.

State energy efficiency programs

In the interim to any agreed national program being established, South Australia, Victoria, New South Wales - and now the ACT- have established successfully operating state based programs that are effectively reaching households and small businesses. This gives suppliers more confidence to continue to invest, employ and compete in this relatively new market.

Whereas each state program has its own unique features, states should collaborate and evaluate opportunities to harmonize activities and administration that could potentially encourage stronger competition from suppliers and result in reducing the operating costs of state programs. More commonality in state programs also provides economies to suppliers.

Obtaining states' agreement would be a precondition to the introduction of any national energy savings scheme. The more states' schemes have in common in products, services and administration, the more feasible and the earlier it becomes possible to consider a national program.

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Future direction of REES

ICANZ strongly encourages the South Australian Government to continue REES activities for the foreseeable future.

ICANZ congratulates the South Australian Government on its impressive success rate to date in reaching over 165,000 households, surpassing its targets, achieving a 3.5:1 benefits to cost ration and for delivering successful administration and effective auditing processes. ICANZ applauds the South Australian Government for being the only Australian government to support the installation of ceiling insulation in its energy efficiency agenda,

These successes to date are a good start and there are still many opportunities for further savings. South Australian householders on average are the fourth largest energy consumers in Australia. Approved products and audit services currently offered through REES have undoubtedly helped many South Australian households to decide to invest in better energy efficiency and as a result lower their personal household energy consumption. This has contributed to savings for themselves and cumulative savings for South Australia as a whole.

In ICANZ view - and as raised in the Directions Paper – REES should include prescribed targets for low income and 'working poor' households as well as measures to encourage and incentivize stronger regional participation. These groups should not be disadvantaged by any future changes in REES.

South Australia should also be open to expanding the current program in future to extend beyond the residential market. Energy use in Commercial activities is increasing and opportunities to improve the energy efficiency - particularly for SMEs – is almost untapped. Focus to date has either been on improving energy efficiency in residential buildings or on larger scale Commercial refurbishments. ICANZ encourages South Australia examine the progress made in the Commercial market segment by Victoria and New South Wales and assess the potential benefits similar approaches could offer South Australian SMEs.

ICANZ also agrees with the suggestion of the Independent Evaluation to express targets in terms of energy metrics as from 2014. This measure is more meaningful to consumers and SMEs.

Other complementary programs worth consideration.

A complementary and standalone program is the introduction of mandatory disclosure of energy performance for any residence sold or leased. As mentioned earlier this has been on COAG's agenda for several years but has fallen out of favour in recent times.

ICANZ can see great value in supporting residential mandatory disclosure because it is low-cost; shares responsibility between Government, industry and householders and it educates entitled parties by providing recent energy performance of the proposed property. This is particularly relevant to disadvantaged groups with limited disposable income.

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Similarly ICANZ also supports the establishment and commitment to a progressive range of energy efficiency targets for each sector of the economy. Without the existence of targets it is not possible to commit to longer term objectives. Once targets have been defined, quantified and agreed, steps and priorities to achieve these can more easily be introduced and put into place.

Yours sincerely,

Dennis D'Arcy
ICANZ CEO

Attachment: For your interest and future reference I attach a soft copy of a study (*'The Value of Insulation Based Residential Energy Savings Measures In Australia'*) commissioned by ICANZ and completed by Energy Efficient Strategies in September 2012.

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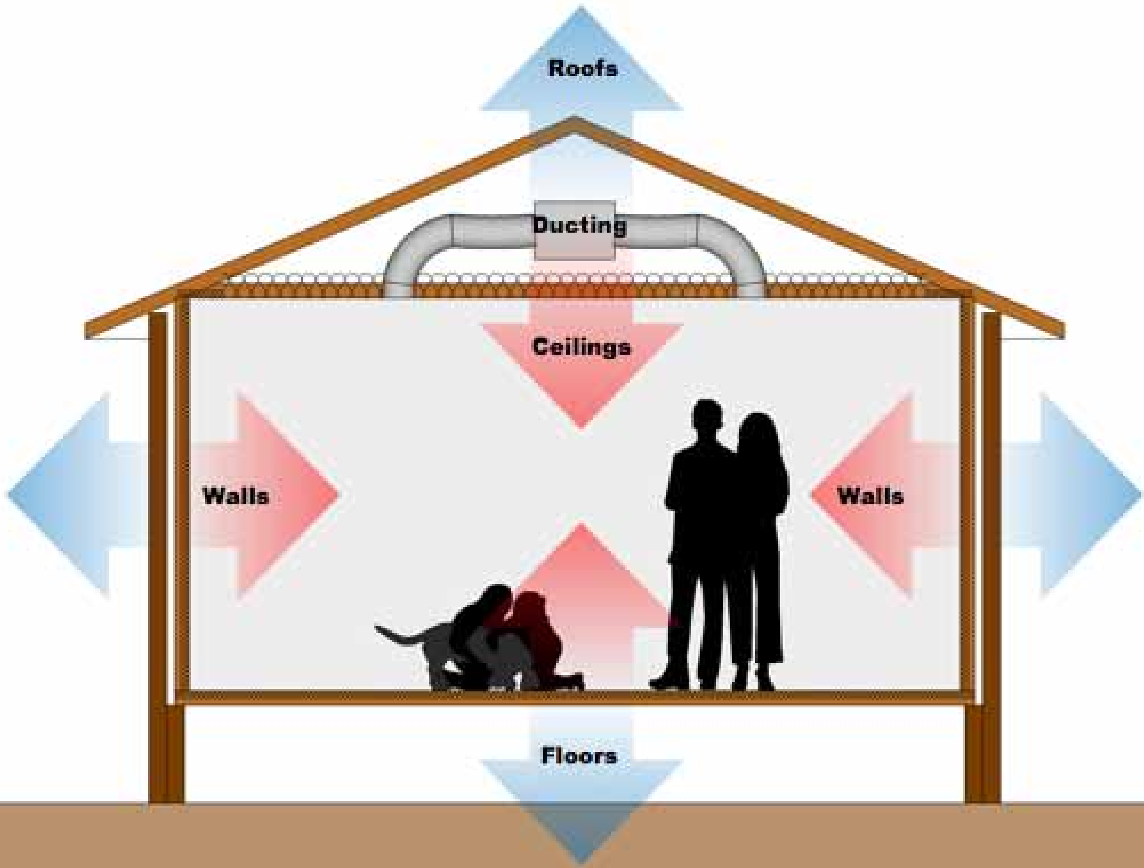
Report prepared for

ICANZ

THE RIGHT INSULATION MATTERS

V10, September 2012

The Value of Insulation Based Residential Energy Savings Measures In Australia



Prepared by Energy Efficient Strategies

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ABBREVIATIONS

General Abbreviations

BREE	Bureau of Resource and Energy Economics (formerly ABARE)
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
RMD	Residential Mandatory Disclosure (of energy performance)
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 state the case for a range of cost effective insulation based residential energy savings measures appropriate to a significant proportion of householders throughout Australia.

There are 5 areas of **viable cost effective** insulation based energy savings measures for residential dwellings that are evaluated in this study, these are:

1. Retrofit of ceiling insulation to previously uninsulated ceilings. (estimated scope for retrofit in 2012, 1.3 million households)
2. Retrofit of top up ceiling insulation to less than optimally insulated ceilings (estimated scope for retrofit in 2012, 2.1 million households)
3. Retrofit of wall insulation to previously uninsulated external walls. (estimated scope for retrofit in 2012, 3.5 million households)
4. Retrofit of floor insulation to previously un-insulated suspended timber floors (estimated scope for retrofit in 2012, 0.7 million households)
5. Replacement of older space conditioning ducting with better insulated and better sealed ducting (estimated scope for retrofit in 2012, 0.5 million households)

In addition, this study also presents the findings from an earlier study[1] regarding the retrofit of ceiling insulation (this earlier study included the impacts associated with the Commonwealth Home Insulation Program (HIP), however this study focuses only on the remaining potential for such retrofit).

Historically, both nationally and internationally a number of barriers have meant that the market has failed to significantly increase the proportion of effectively insulated existing housing stock, despite considerable investment in marketing programs. ICANZ believes that governments of all persuasions should, where indicated in this study, include ceiling, wall and floor insulation, top up ceiling insulation and insulated duct replacement (upgrade) as part of their residential energy saving programs.

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 insulation in all its forms will continue to be identified by those programs. Despite the particular delivery issues that arose during the HIP, this study argues that retrofit of most forms of insulation and the

[1] The Value of Ceiling Insulation - Impacts Of Retrofitting Ceiling Insulation To Residential Dwellings In Australia (EES 2011)

upgrading of insulated ductwork using a properly designed and paced program will deliver significant benefits at little risk to both householders and the community.

WHY INSULATE?

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

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

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

WHAT OPTIONS WERE EXAMINED IN THIS STUDY?

For each of the energy saving measures, apart form the business as usual case, two notional implementation options were examined:

- Option 1 (50% Scenario): This scenario assumes that the retrofit options to existing residential dwellings from 2012 onwards will be such that by 2020, 50% of the un-retrofitted stock shall be retrofitted.
- Option 2 (100% Scenario): This scenario assumes that the retrofit options to existing residential dwellings from 2012 onwards will be such that by 2020, 100% of the “eligible” un-retrofitted stock shall be retrofitted. The estimates of “eligible” stock numbers is in fact 10% less than actual stock numbers without the particular energy savings measure. This discounting is in consideration of the fact that in some dwellings retrofit would be impractical or excessively expensive (eg negligible underfloor space requiring the removal of the flooring to effect sub-floor insulation).

KEY STUDY FINDINGS

Benefits to the Householder

Each of the energy savings measures examined in this study were found to offer a range of benefits to the householder. On average, nationally in 2012:

- Ceiling Insulation increased star ratings by 2.2 stars, reduced energy costs by $299, and reduced greenhouse gas emissions by 0.93 Tonnes $CO_{2\text{-}e}$
- Ceiling top up Insulation increased star ratings by 0.5 stars, reduced energy costs by $49, and reduced greenhouse gas emissions by 0.15 Tonnes $CO_{2\text{-}e}$
- Wall Insulation increased star ratings by 1.0 stars, reduced energy costs by $91, and reduced greenhouse gas emissions by 0.29 Tonnes $CO_{2\text{-}e}$
- Floor Insulation (R2.5) increased star ratings by 0.2 stars, reduced energy costs by $39, and reduced greenhouse gas emissions by 0.11 Tonnes $CO_{2\text{-}e}$
- Duct replacement reduced energy costs by $133, and reduced greenhouse gas emissions by 0.47 Tonnes $CO_{2\text{-}e}$

In the ACT, where mandatory disclosure of residential building energy performance (RMD) has been required since 1999 and potentially in all other jurisdictions (when they too adopt RMD), an improvement in energy star rating would be expected to also add significantly to a property's value at time of sale.

Improvements varied significantly from jurisdiction to jurisdiction with benefits significantly higher than the averages noted above in jurisdictions with more severe climates. Jurisdictional results are provided below in Table 1 (star rating improvements), Table 2 (operational energy cost improvements), Table 3 (greenhouse gas emission reductions) and Table 4 (energy reductions).

Table 1 : Benefits to the Householder – Star Rating Improvement (2012)

Benefit	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Ceiling Insulation	+2.2	+1.9	+2.3	+2.3	+2.7	+1.9	+2.1	+1.9	**+2.2**
Top up to Ceiling	+0.5	+0.4	+0.4	+0.6	+0.8	+0.4	+0.4	+0.5	**+0.5**
Wall Insulation	+1	+1	+1	+1.2	+0.8	+1	+0.8	+1.2	**+1**
Floor Insulation[1]	+0.2	+0.4	+0.1	+0.1	+0.1	+0.5	+0.1	+0.4	**+0.2**

Note 1: Assumes R2.5 floor insulation fitted

Table 2 : Benefits to the Householder – Annual Operational Cost Savings ($) 2012

Benefit	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Ceiling Insulation	$254	$586	$105	$359	$279	$462	$187	$668	**$299**
Top up to Ceiling	$42	$99	$15	$63	$46	$81	$27	$115	**$49**
Wall Insulation	$74	$192	$35	$99	$50	$155	$64	$227	**$91**
Floor Insulation[1]	$31	$98	$4	$17	$15	$88	$17	$85	**$39**
Duct replacement[2]	$124	$200	$186	$136	$125	$109	$659	$223	**$133**

Note 1: Assumes R2.5 floor insulation fitted

Note 2: Weighted average for ducted gas, ducted R/C and ducted cooling only systems (R1.5 ducting)

Table 3 : Benefits to the Householder – Annual Greenhouse Gas Emission Savings (t CO2-e) 2012

Benefit	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Ceiling Insulation	0.80	1.94	0.35	0.94	0.59	0.36	0.60	2.30	**0.93**
Top up to Ceiling	0.13	0.33	0.05	0.17	0.10	0.06	0.09	0.39	**0.15**
Wall Insulation	0.23	0.64	0.12	0.26	0.11	0.12	0.21	0.78	**0.29**
Floor Insulation[1]	0.09	0.31	0.01	0.04	0.02	0.07	0.05	0.26	**0.11**
Duct replacement[2]	0.54	0.74	0.72	0.45	0.35	0.05	2.38	0.72	**0.47**

Note 1: Assumes R2.5 floor insulation fitted

Note 2: Weighted average for ducted gas, ducted R/C and ducted cooling only systems (R1.5 ducting)

Table 4 : Benefits to the Householder – Energy Savings (MJ/annum) 2012

Benefit	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Ceiling Insulation	8461	31096	2285	10848	9306	23326	2734	24095	**11958**
Top up to Ceiling	1398	5223	332	1895	1512	4069	391	4134	**2830**
Wall Insulation	2453	10182	696	2860	1612	7819	913	8200	**8625**
Floor Insulation[1]	1136	5351	144	729	688	4487	251	3140	**2156**
Duct replacement[2]	2707	11067	2587	2192	2124	1481	9197	8436	**7732**

Note 1: Assumes R2.5 floor insulation fitted

Note 2: Weighted average for ducted gas, ducted R/C and ducted cooling only systems (R1.5 ducting)

Cost Effectiveness

An analysis of the cost effectiveness of each of the insulation based energy savings measures reveals that each measure was found to be cost effective in some if not all jurisdictions. In summary:

- Both ceiling insulation and reverse cycle air conditioner duct replacement was found to be cost effective in all jurisdictions.
- Duct replacement in gas heaters was cost effective in all jurisdictions except Qld and NT (were such systems are extremely uncommon in any case).
- Top up ceiling insulation was cost effective in all jurisdictions except Qld, WA and NT.
- Floor insulation was cost effective in Victoria and the ACT and potentially Tasmania (assuming a modest increase in energy prices).
- Duct replacement in cooling only type ducted air-conditioners was cost effective in Qld and NT.
- Wall insulation was cost effective in Victoria, Tasmania and the ACT at current installation costs and cost effective in NSW, SA and potentially NT at expected reduced costs[2] associated with economies of scale.

[2] The peak industry body (ICANZ) estimates that savings in the order of one third are achievable with economies of scale for this form of retrofit which is at present considered to be a "boutique" industry

Detailed jurisdictional results are provided below in Table 5. In that table, whilst a range of threshold discount rates (3%, 5% and 7%) are used to establish cost effectiveness it is argued that for long term investments such as those represented in this study (that provide effectively tax free returns to the investor), a discount rate of 3% is justifiable[3].

Table 5 : Cost Effectiveness of energy saving measure (ie is Benefit/Cost > 1[4]) 2012

Benefit	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Ceiling Insulation	Yes(7)	Yes(7)	Yes(7)	Yes(7)	Yes(7)	Yes(7)	Yes(7)	Yes(7)	Yes(7)
Top up to Ceiling	Yes(3)	Yes(7)	No	Yes(7)	No	Yes(7)	No	Yes(7)	Yes(5)
Wall Insulation	Yes(3*)	Yes(7)	No	Yes(7*)	No	Yes(7)	Yes(3+*)	Yes(7)	Yes(7*)
Floor Insulation	No	Yes(5)	No	No	No	Yes(3+)	No	Yes(5)	No
Duct (Gas)	Yes(5)	Yes(7)	No	Yes(5)	Yes(3)	Yes(7)	No	Yes(7)	Yes(5)
Duct (Rev. Cycle)	Yes(5)	Yes(7)	Yes(7)	Yes(7)	Yes(5)	Yes(7)	Yes(7)	Yes(5)	Yes(5)
Duct (Cooling)	No	No	Yes(5)	No	No	No	Yes(7)	No	No

Legend

Yes(7)	Indicates the measure is cost effective with a 7% discount rate and current energy pricing trends
Yes(5)	Indicates the measure is cost effective with a less than 7% discount rate (discount rate indicated in brackets)
Yes(3+)	Indicates the measure is cost effective only at 3% discount rate and assuming a higher trend in energy prices
No	Indicates the measure is not cost effective under any of the economic scenarios examined in this study

* Indicates that cost effectiveness relies on reduced improvement capital costs (wall insulation only – see Appendix 2)

The Potential for Retrofit

An analysis of the current stock of residential buildings in Australia indicates that there remains huge potential for retrofitting of insulation based energy savings measures. Of the approximate 12 million potential opportunities identified in this study approximately 8 million were found to be cost effective. A breakdown of the opportunities found to be cost effective by jurisdiction is given in Table 6 below.

Table 6 : Potential Scope for Cost Effective Retrofit of Energy Savings Measures (000's of households)

Benefit	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Ceiling Insulation	529	98	399	64	125	24	23	13	**1,275**
Top up to Ceiling	729	922		338		93		65	**2,146**
Wall Insulation	1,640	1,195		400		124	47	58	**3,464**
Floor Insulation		601				70		27	**698**
Duct (Gas)	27	288		6	8	0		12	**342**
Duct (Rev. Cycle)	45	10	6	16	6	1	<1	2	**86**
Duct (Cooling)			8				2		**10**

Note: Greyed fields indicate that as this measure was found to be not cost effective under present circumstances, no potential for retrofit has been assumed.

[3] In the study The Garnaut Climate Change Review it is argued that discount rates of between 1.35 per cent and 2.65 per cent are justified for long term investment in climate change mitigation

[4] Benefit to Cost ratios used as the basis for this table rounded to nearest one decimal place

Estimated Potential Benefits at the State/Territory and National Level by 2020

Energy

In terms of energy savings, if the 100% scenario were to be adopted (ie by 2020 all dwellings that are practical to retrofit would be retrofitted[5]), it is estimated that national energy savings in 2020 would be 8.2PJ (ceiling insulation program), 6.8 PJ (ceiling insulation top up program), 19.2PJ (wall insulation program), 4.1 PJ (floor insulation program) and 3.1 PJ (duct replacement program). National energy savings are shown graphically in Figure 1 and state level savings for the 100% scenario are shown in Table 7. All these energy estimates include a discount of 25% for expected rebound.

Figure 1 : Estimated Potential National Energy Savings in 2020 (By Scenario)

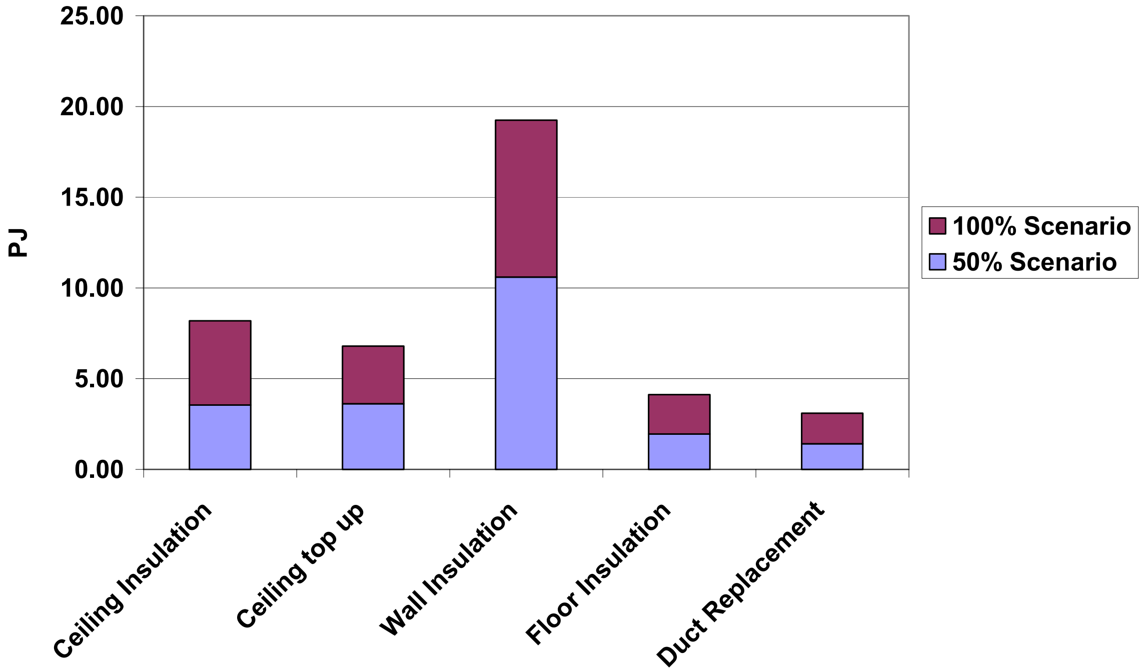


Table 7: Estimated Potential National Energy Savings in 2020 - 100% Scenario (PJ)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Ceiling Insulation	3.74	2.13	0.69	0.43	0.71	0.24	0.05	0.19	**8.19**
Top up to Ceiling	0.91	4.32	0.07	0.59	0.35	0.30	0.01	0.24	**6.79**
Wall Insulation	3.74	11.36	0.74	1.09	1.02	0.79	0.04	0.45	**19.24**
Floor Insulation	0.63	2.87	0.04	0.13	0.11	0.25	0.00	0.08	**4.12**
Duct replacement[1]	0.22	2.62	0.03	0.07	0.05	0.00	0.02	0.10	**3.10**

Note 1: Weighted average for ducted gas, ducted R/C and ducted cooling only systems (R1.5 ducting)

Note 2: The energy savings from the separate measures have not been totalled as improvements to wall insulation would reduce to some extent the savings from floor insulation and duct replacement. Conservatively the total savings for all measures would be at least 38PJ or 8% of residential energy use.

[5] The 100% scenario is used to illustrate the potential for savings. In reality for some of the improvement measures it may not be practical to complete 100% retrofit by 2020.

Greenhouse Gas

In terms of greenhouse gas abatement, if the 100% scenario were to be adopted (ie by 2020 all dwellings that are practical to retrofit would be retrofitted), it is estimated that national greenhouse gas emission savings in that year would be 0.69 Mt CO_{2-e} (ceiling insulation program), 0.46 Mt CO_{2-e} (ceiling insulation top up program), 1.4 Mt CO_{2-e} (wall insulation program), 0.24 Mt CO_{2-e} (floor insulation program) and 0.25 Mt CO_{2-e} (duct replacement program).

Projected cumulative savings in greenhouse gas emissions by 2020 (100% scenario) for each jurisdiction are shown in Table 8 and graphically by year in Figure 2. All these abatement estimates include a discount of 25% for expected rebound.

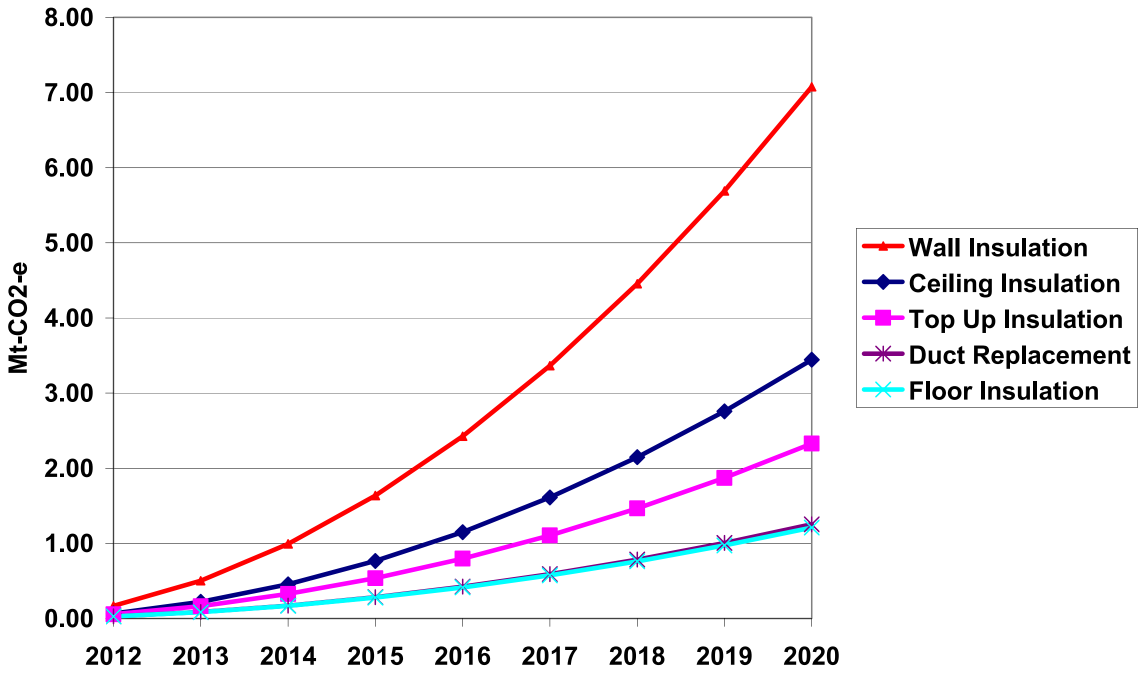
Table 8: Potential Cumulative Greenhouse Gas Abatement by 2020 – 100% Scenario (Mt CO_{2-e})

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Ceiling Insulation	1.71	0.63	0.54	0.17	0.22	0.02	0.06	0.08	**3.44**
Top up to Ceiling	0.41	1.33	0.06	0.25	0.12	0.03	0.01	0.12	**2.33**
Wall Insulation	1.72	3.50	0.66	0.49	0.36	0.08	0.04	0.22	**7.08**
Floor Insulation	0.25	0.83	0.02	0.04	0.02	0.02	0.00	0.03	**1.21**
Duct replacement[1]	0.21	0.85	0.04	0.06	0.03	0.00	0.02	0.04	**1.25**

Note 1: Weighted average for ducted gas, ducted R/C and ducted cooling only systems (R1.5 ducting)

Note 2: The greenhouse gas savings from the separate measures have not been totalled as improvements to wall insulation would reduce to some extent the savings from floor insulation and duct replacement. Conservatively the total savings for all measures would be at least 14 Mt CO_{2-e}

Figure 2 : Potential Projected Cumulative National Greenhouse Gas Savings (100% Scenario)



Peak Load

In terms of electrical peak load reduction, if the 100% scenario were to be adopted (ie by 2020 all dwellings that are practical to retrofit would be retrofitted), it is estimated that national electrical peak load reductions in that year would be 482 MW (ceiling insulation program), 216 MW (ceiling insulation top up program), 910 MW (wall insulation program), 76 MW (reverse cycle duct replacement program) and 110 MW (cooling only duct replacement program) -see Table 9 (includes values by jurisdiction).

Projected cumulative infrastructure investment savings stemming from the projected reductions in peak electrical load between now and 2020 (100% scenario) for each jurisdiction are shown in Table 10 and graphically at a national level in Figure 3. All these peak load reduction estimates include a discount of 25% for expected rebound.

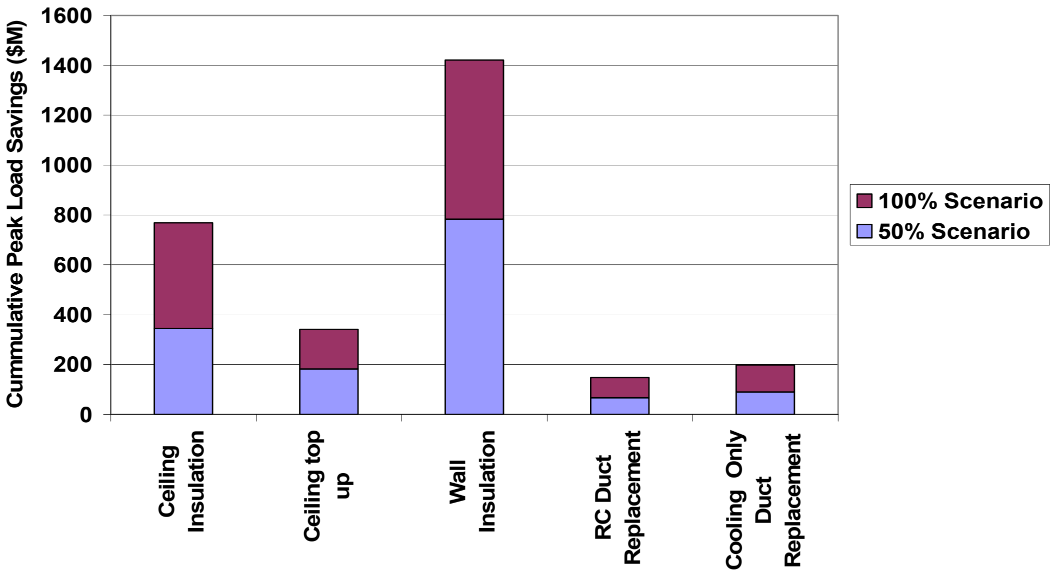
Table 9 : Estimated Potential Peak Load Savings by 2020 – 100% Scenario (MW)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Ceiling Insulation	205.5	30.8	141.9	26.6	57.7	4.1	12.7	3.0	**482.2**
Top up to Ceiling	49.4	68.6	20.7	33.9	30.7	6.6	1.2	4.6	**215.6**
Wall Insulation	268.9	197.8	224.9	82.3	106.8	17.2	5.6	6.5	**910.0**
R. Cycle Duct	37.6	9.3	5.6	16.1	5.2	0.5	0.3	1.5	**76.1**
Cooling Only Duct	39.6	23.8	7.8	21.6	14.2	0.5	1.6	1.3	**110.5**

Table 10 : Estimated Potential Cumulative Peak Load Savings by 2020 – 100% Scenario ($ Million)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Ceiling Insulation	399.2	34.1	189.6	65.7	58.3	2.4	14.0	5.4	**768.5**
Top up to Ceiling	96.2	78.8	27.9	90.6	33.0	4.5	1.3	9.1	**341.4**
Wall Insulation	523.7	227.0	303.3	220.5	115.1	11.8	6.2	12.8	**1420**
R. Cycle Duct	75.6	10.9	7.8	43.9	5.8	0.3	0.4	3.1	**147.7**
Cooling Only Duct	79.6	27.9	10.8	59.0	16.0	0.4	1.8	2.6	**198.0**

Figure 3: Estimated Potential Cumulative Peak load savings by 2020 – by Scenario ($ Million)



Summary of Findings

This report, commissioned by ICANZ, demonstrates the value and cost effectiveness of the various insulation based energy saving measures (ESMs) examined. By responsibly pacing a retrofit program between now and 2020 the benefits associated with the various ESMs could be extended to large sections of the Australian residential building stock.

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

- Significant energy savings which equate to a reduction in energy costs that in some cases amount to several hundred dollars in savings per annum.
- A payback in investment costs within the life of the retrofitted product in most cases and in selected cases a payback within just a few years.
- Reduction in household greenhouse gas emissions that range from a few hundred kilograms to more than a two tonnes per annum depending upon the ESM adopted and the jurisdiction.
- An increase in the average NatHERS star rating ranging from 0.2 to 2.2 stars depending upon the ESM adopted and the jurisdiction.
- 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 these measures can deliver

- National savings in space heating and cooling energy costs ranging from $100 million to $600 million annually ($2012) depending upon the ESM adopted.
- Cumulative national savings in greenhouse gas emissions ranging from 1.2 to 7.1 million tonnes of CO2-e abatement depending upon the ESM adopted.
- A reduction in peak electrical load by 2020 of between 100 MW and 900 MW depending upon the ESM adopted.
- A national cumulative saving in capital investment in infrastructure required to meet that peak load demand of between $0.15 billion and $1.4 billion depending upon the ESM adopted.

The retrofit of the various insulation based energy saving measures examined in this study represent some 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 some if not all of these key insulation based residential energy saving measures.

1. Project Overview

1.1 Background

The thermal insulation of various building elements 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 and walls and to a lesser degree timber floors (depending on climate zone) of all new dwellings in Australia has effectively been mandatory since 2005. Such practice is common throughout the developed world.

Whilst ceiling and wall insulation is now standard for all new housing in Australia, there remains a significant number of existing dwellings with little or no wall, floor or ceiling insulation and many dwellings with poorly performing space conditioning ductwork.

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 some of 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 all forms of insulation post the 2009–10 House Insulation Program. ICANZ believes that governments of all persuasions should include wall and floor insulation, top up ceiling insulation and insulated duct replacement (upgrade) as key residential energy saving measures. 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 insulation in all its forms will continue to be identified by those programs. Despite the particular delivery issues that arose during the HIP, this study argues that retrofit of most forms of insulation and the upgrading of insulated ductwork should be promoted as one of the best and most cost effective energy saving measures that should be supported at all levels of government.

This study builds upon work undertaken in a 2011 study for ICANZ entitled "The Value of Ceiling Insulation - Impacts of Retrofitting Ceiling Insulation to Residential Dwellings in Australia (EES 2011)" and relies on the methodology developed for that earlier study.

1.2 Aim of this study

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

- Demonstrate the benefits associated with various forms of insulation retrofit programs in terms of energy savings and greenhouse gas abatement.
- Estimate the potential for retrofitting of various forms of insulation and ductwork replacement to Australian residential dwellings.
- Quantify the energy, greenhouse gas and peak load reduction potential of insulation retrofits and ductwork replacement to residential buildings.
- Undertake a cost benefit analysis of the energy saving measures 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 a range of insulation based energy saving measures 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 a range of insulation based energy savings measures 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 the range of insulation based energy savings measures to the existing residential building stock at a jurisdictional level (section 4).

There are 5 areas of insulation based energy savings measures for residential dwellings that are examined in this study. These are:

1. Retrofit of ceiling insulation to previously uninsulated ceilings. (refer section 3 for details of the scope for potential retrofit of this option)
2. Retrofit of top up ceiling insulation to less than optimally insulated ceilings (refer section 3 for details of the scope for potential retrofit of this option)
3. Retrofit of wall insulation to previously uninsulated external walls. (refer section 3 for details of the scope for potential retrofit of this option)
4. Retrofit of floor insulation to previously un-insulated suspended timber floors (refer section 3 for details of the scope for potential retrofit of this option)
5. Replacement of older space conditioning ducting with better insulated and better sealed ducting (refer section 3 for details of the scope for potential retrofit of this option)

1.3.2 Scenarios Modelled

This study included the examination of 3 different scenarios as a means of illustrating the potential benefits that could be realised from wall, floor, ceiling top up insulation programs as well as a program of space conditioning duct replacement.

BAU Case

This is the business as usual case that assumes that the retrofit of the various insulation and duct replacement options simply follows the current trend.

Option 1 (50% Scenario) – An intervention to retrofit half of the eligible stock by 2020

This scenario assumes that the retrofit options undertaken on existing residential dwellings from 2012 onwards will be such that by 2020, 50% of the un-retrofitted stock (as at 2011) shall be retrofitted.

Option 2 (100% Scenario) - An intervention to retrofit all of the eligible stock by 2020

This scenario assumes that the retrofit options undertaken on existing residential dwellings from 2012 onwards will be such that by 2020, 100% of the "eligible" un-retrofitted stock (as at 2011) shall be retrofitted. The estimates of "eligible" stock numbers is in fact typically 10% less[6] than actual stock numbers without the particular energy savings measure. This discounting is in consideration of the fact that in some dwellings retrofit would be impractical or excessively expensive (eg negligible underfloor space requiring the removal of the flooring to effect sub-floor insulation).Note that the estimates for the number of eligible housing stock vary according to the intervention. For details of the estimates of eligible stock numbers see section 3.

[6] More in the case of floor insulation retrofit – see section 3

1.3.3 Dwelling Types Examined

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

- Class 1a (i) - detached houses;
- Class 1a (ii) - attached dwellings (including "town houses", "terrace houses" and "villas");

Class 2 dwellings (flats) were excluded – the majority of ceilings in these dwellings are bounded above by another occupancy and as such there is no value in applying ceiling insulation or top up ceiling insulation. Similarly the majority of floors in these dwellings are bounded below by another occupancy and as such there is no value in applying floor insulation. Wall insulation is a possibility, however typically a significant number of a class 2 dwellings boundary walls are bounded by another occupancy and the few walls which are external to the building typically have a high proportion of glazing. Finally, residential type flexible ducting as used in detached dwellings is not as commonly used within class 2 dwellings and in any case such ducting is usually located between floors where duct losses are less critical.

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 11). 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 assigned to each state and territory.

Table 11 : 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 Base case assumption

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

Retrofit of ceiling insulation to previously uninsulated ceilings.

It was assumed that the subject dwellings would have no wall insulation. Generally, for existing dwellings, ceiling insulation would have been applied preferentially to wall insulation both during construction and as a retrofit option. This means that for the subject dwellings, given that they had no ceiling insulation the likelihood of them having wall insulation is very low.

No floor insulation was assumed either as less than 1% of existing dwellings in 2005 (when performance requirements were introduced into the BCA that effectively require both ceiling and wall insulation) were recorded as having floor insulation fitted – ABS 4602:2005.

Retrofit of top up ceiling insulation to less than optimally insulated ceilings

It is assumed that the dwelling subject to this energy savings measure has less than optimal ceiling insulation installed. It is assumed that the dwelling was constructed prior to the mid 1990s when the first regulations regarding ceiling insulation were introduced in selected states such as Victoria. Prior to the introduction of regulations the voluntary installation of ceiling insulation typically included for 50mm thick fibreglass insulation batts (or equivalent) with an R value of approximately R1.0

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

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

Retrofit of wall insulation to previously uninsulated external walls.

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

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

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

Retrofit of floor insulation to previously un-insulated suspended timber floors

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

Since performance regulations were introduced in the mid 2000s an increasing number of new dwellings now have floor insulation fitted. This means that the cohort of dwellings considered eligible for retrofit for this energy savings measure will have been constructed pre 2005[7] and as such are assumed to have:

[7] In reality, many dwellings constructed post 2005 will not have floor insulation fitted. However, these dwellings will have been built to a reasonably high thermal performance standard (5 stars typically) and as such have been excluded form consideration in this study for retrofitting of floor insulation

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

Replacement of older space conditioning ducting with better insulated and better sealed ducting

It is assumed that the dwelling subject to this energy savings measure has less than optimal ducting installed. Based on a study entitled "Field study on gas ducted heating systems in Victoria (Palmer 2008) it was determined that installations made prior to the mid 1990s would on average have a duct loss of 30% or more[8]. Systems of this age (>15 years old) are also more likely to be replaced. Naturally the dwellings in which these systems are housed would also need to have been built at or before the mid 1990's. As such the cohort of dwellings considered eligible for retrofit for this energy savings measure were constructed prior to the mid 1990's they are assumed to have:

- An average of R1.5 insulation fitted in the ceiling (as adopted as a stock average in the study *Energy Use in the Australian Residential Sector 1986-2020* (EES 2008))
- No wall insulation (less than 20% of all Australian dwellings in 1994 were recorded as having wall insulation fitted – ABS 4602:2005)
- No floor insulation (only 0.3% of dwellings in 1994 were recorded as having floor insulation fitted – ABS 4602:1994)

1.3.6 Retrofit Options Examined

Sample dwellings were modelled as per the base case noted in section 1.3.5 then remodelled with the particular energy saving measure applied. The details of the measures applied are as follows:

Retrofit of ceiling insulation to previously uninsulated ceilings.

The improvements were in the form of added ceiling insulation. The level of insulation applied was set in accordance with the values specified in the HIP program as shown in Figure 12, ie:

- 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

[8] It is expected that ducting associated with other forms of space conditioning equipment would have a similar profile in terms of performances versus age of ductwork.

Table 12 : 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[a]	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.

Retrofit of top up ceiling insulation to less than optimally insulated ceilings

Final insulated levels were set in line with the values specified in the HIP program (based on BCA requirements) as shown in Table 12 above. As the ceilings were already assumed to be insulated with R1.0 insulation this meant that the applied insulation was R1.0 less than that specified in Table 12 ie

- R3 ceiling insulation as mandated for BCA climate zones 1 – 3 was achieved by adding R2.0 insulation on top of the pre-existing R1.0 insulation.
- R3.5 ceiling insulation as mandated for BCA climate zones 4 – 6 was achieved by adding R2.5 insulation on top of the pre-existing R1.0 insulation.
- R4 ceiling insulation as mandated for BCA climate zones 7 & 8 was achieved by adding R3.0 insulation on top of the pre-existing R1.0 insulation.

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

Retrofit of wall insulation to previously uninsulated external walls.

Differing levels of insulation were assumed to be applied according to the wall type as follows:

- Lightweight walls – assumed to be between 90 and 100mm thick. At this thickness a value of R2.5 might be expected if rock wool were used.

- Brick Veneer – The insulation value achieved will vary according to the particular site conditions and the way the insulation is applied as follows:
    - Where no sarking is affixed to the outside of the frame then both the space between the wall studs and the cavity can be filled with rock wool giving a thickness of approximately 130mm or an R value of R3.0 (conservative estimate).
    - Where sarking is affixed to the outside of the frame and only the space between the studs can be filled (from the inside) then a value of R2.5 might be expected if rock wool were used.
    - Where sarking is affixed to the outside of the frame and insulation is pumped in via the roof to both the cavity and to the top half of the framed wall (ie above the nogging), the top half can be filled with rock wool giving a thickness of approximately 130mm or an R value of R3.0 and the lower half can be filled with rock wool in the cavity only assumed to be 40 to 50 mm thick or an R value of R1.0. This would give an average R value of R1.5

  In reality the installations to brick veneer walls are likely to be a combination of the above options, consequently an average R value of R2.5 has been assumed.
- Heavyweight (Cavity Brick Walls) – assumed to be between 40 and 50mm thick giving an R value of R 1.0 for rock wool

Retrofit of floor insulation to previously un-insulated suspended timber floors

For this study three levels of floor insulation retrofit were examined as follows:

- R1.5
- R2.0
- R2.5

Replacement of older space conditioning ducting with better insulated and better sealed ducting

Three different levels of duct performance were examined in this study:

- R1.0
- R1.5
- R2.0

Generally it was found that R1.5 produced the most economically optimal results.

1.3.7 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. For this study three different levels of discount rate were examined:

- 7% representing the level commonly mandated by governments when assessing the viability of a proposed market intervention
- 3% representing what is considered a reasonable return on a long term investment, particularly considering that the returns are tax free.
- 5% representing a mid point between the 2 values noted above

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

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 other words the Benefit to Cost ratio is equal to one.

Based on the known longevity of the various energy savings measures the maximum acceptable payback periods were set as follows:

Table 13 : Assumed Longevity of Energy Saving Measures (Max. Acceptable Payback)

Energy Saving Measure	Longevity (Max. Payback)
Retrofit of wall insulation	30 years
Retrofit of floor insulation	30 years
Retrofit of top up insulation to ceilings	30 years
Replacement of space conditioner ducting	20 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 two scenarios for fuel costs were modelled:

- BAU (includes the current carbon tax)
- BAU + (Increased 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. In the BAU 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 (as well as generation, transmission and distribution costs) 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 + Increased 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 BAU and BAU+ 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 16. This is believed to be the most comprehensive "bottom up" model of residential energy use available and has been verified against top down (BREE) 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 from 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 (ie the energy savings measure) 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 the energy savings measure(i.e. based on the analysis outlined in section 1.4)
- Assumed payback period (see section 1.3.7)
- Applied Discount rate (see section 1.3.7)
- Projected fuel costs (see section 1.3.7 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[9])

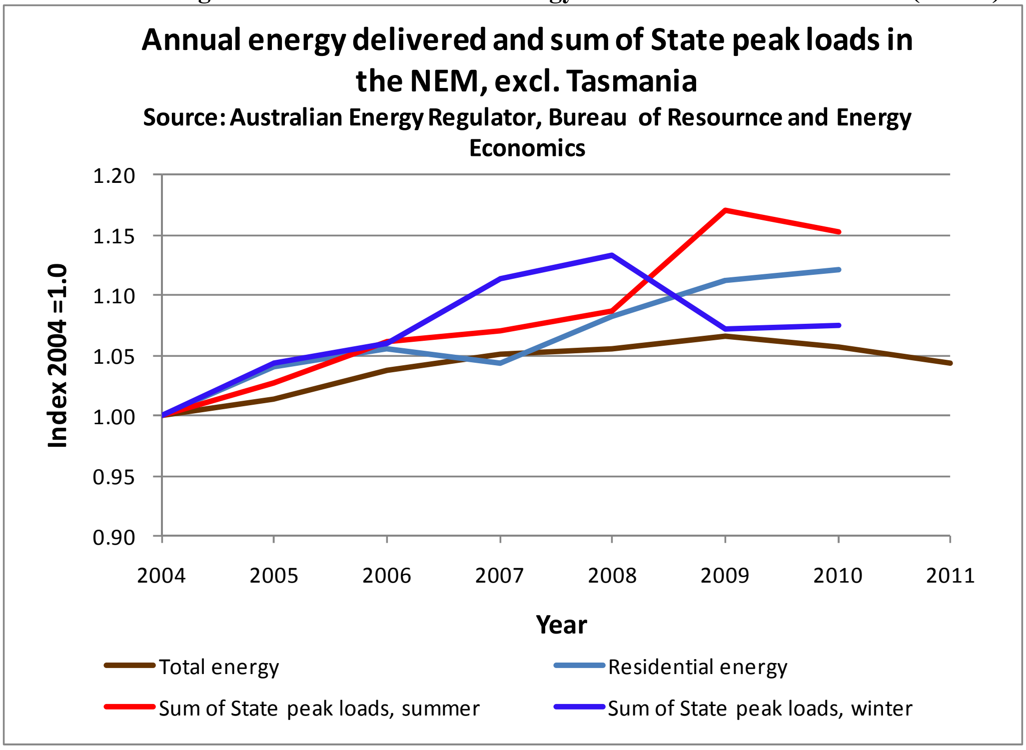
[9] Firewood is separately tracked according to the equipment type it is burnt in, either closed combustion or open combustion, this is important because the type of combustion significantly affects the greenhouse gas intensity of this fuel type.

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 the various energy saving measures to the sample dwellings an estimate of the abatement potential was 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 (BREE)



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 the energy savings measures examined in this study 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 Insulate?

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 (>50^0C), ceiling insulation is also effective in limiting heat flow from the roof space down into the dwelling.

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 does however typically offer 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.

Similarly, well insulated flexible ducting offers an effective barrier to heat loss (during heating) or heat gain (during cooling) from or to the conditioned air within the ductwork. In older, poorly insulated and sealed ductwork up to half the heating or cooling energy can be lost in its transmission from the central heater/cooler to the interior of the home.

2.2 Co Benefits - Health

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

Until recently, houses in Australia have been constructed to quite poor energy efficiency standards. Such houses experience greater extremes of internal temperatures. A study of Victorian houses undertaken to explore the impact of the

1990 Victorian regulation to install ceiling insulation in new houses showed an average performance of 0.9 stars in 1991 and 2.2 stars in 1999 (EES 2000).

It is generally acknowledged that at temperatures below 16^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.

2.3 Co Benefits – Improved Property Value

To evaluate the impact of improved thermal performance and therefore star rating of a house really requires the underpinning of a mandatory disclosure system as exists in the ACT. 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 for instance adds about 2 stars to the dwelling energy rating. While there can be no guarantee that the ACT results would be replicated in all States, particularly those with milder climates and lower conditioning energy requirements, the recent rises in energy costs could be expected to improve market responses to energy ratings. In the ACT, the cost of a 2 star improvement through the retrofit of ceiling insulation is of the order of just 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 various energy savings measures to residential buildings is naturally dependent upon the actual number of dwellings remaining without those energy saving measures fitted. This study attempts to make estimates of the current potential for the retrofitting of a range of energy saving measures via reference to various data sources, primarily the ABS.

The ABS has undertaken several surveys in the ABS4602 series that has examined floor, wall and ceiling insulation of dwellings as well as the ownership of various forms of heating and cooling equipment, including those forms that are associated with ducting. This data is analysed in Section 3.2.

3.2 ABS Data and current estimates

Estimates for ceiling wall and floor insulation rates were based on estimates published in ABS4602. Estimates for the ownership of ducted space conditioners were based on data derived from the study Energy Use in the Australian Residential Sector 1986-2020 (EES 2008)

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, 2008 and the last survey reported was undertaken in 2011.

The percentage of dwellings reported to be insulated is shown in Table 14. This includes all locations for insulation including ceilings, walls and floors.

The following subsections detail the estimates for the potential for the retrofitting of each of the energy savings measures examined in this study.

Table 14 : Percentage of dwellings reported to be insulated by year (ABS)

Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Reported as being Insulated									
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
2011	63.4	76.5	61.7	78.0	73.7	78.9	43.8	80.5	69.0
Reported as not being insulated									
1994	39.4	17	53.6	15.7	36.7	28.8	28.4	9.7	33.1
1999	31.6	12.4	48.6	12.5	29	22.3	31.6	9.4	27.6
2002	28	12.1	44.8	12.8	22.9	21.2	27.4	7.9	25
2005	24.8	9.2	35.5	8.7	20.4	12.2	16.4	3.6	20.6
2008	25.7	8.5	30	8.6	16.2	10.9	21.2	4.6	19.2
2011	18.2	7.8	20.3	8.1	12.8	10.1	24.2	4.3	14.3
Reported as unknown									
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
2011	18.4	15.6	18.0	13.9	13.5	11.0	32.0	15.1	16.7

3.2.1 *Retrofit of Ceiling Insulation*

The potential for ceiling insulation retrofit is based upon analysis undertaken in the earlier (partner) study to this study entitled *The Value of Ceiling Insulation: Impacts Of Retrofitting Ceiling Insulation To Residential Dwellings In Australia EES* (2011). The analysis pre and post HIP is reproduced from that study in Table 15 below.

Table 15 : 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

For this study the upper estimates for remaining potential were used as this more closely aligns with the latest (2011) ABS data[10]. Under this scenario there is projected to be approximately 1.275 million households that could potentially be retrofitted with ceiling insulation by 2020. This figure includes an allowance (discount) of 10% for dwellings that are likely to be impractical to retrofit.

3.2.2 Retrofit of Top up ceiling insulation

According to ABS 4602, the proportion of insulated dwellings that have insulation fitted to their ceilings is as per Table 16 . By multiplying the number of dwellings reported as insulated (Table 14) by the percentage of those dwellings reported as being insulated with ceiling insulation, a value for the number of dwellings with ceiling wall or floor insulation can be derived for each year that a survey was conducted. Typically however, as can be seen from Table 14 a significant percentage of respondents (typically 15-20%) noted that they did not know if their dwelling was insulated or not. In these circumstances it has been assumed that the rate of insulation amongst the respondents that “don’t know” is the same as those that do know. It would normally be expected that the rate of insulation in the unknown category would match that in the known category, so the approach taken is considered to make for a conservative estimate of the remaining number of un-insulated dwellings - see Table 17 (ceiling insulation).

Table 16 : 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
2011	97.8	97.2	97.9	98.7	99.3	97.3	95.3	97.3	97.8

Table 17 : Estimated percentage of dwellings with ceiling insulation by year

Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1994	51.2	79.2	31.9	79.9	58.1	66.4	59.5	86.5	59.4
1999	58.5	84.1	37.7	83.6	65.9	72.1	57.6	87.9	64.9
2002	63.2	84.4	42.2	84.9	73.2	74.5	58.9	90.1	68.4
2005	66.7	87.6	51.8	89.1	76.1	84.3	73.7	94.9	73.0
2008	65.6	88.5	58.5	89.4	80.5	85.3	68.6	92.4	74.7
2011	76.0	88.2	73.7	89.4	84.6	86.3	61.4	92.4	81.0

[10] The latest ABS data suggests that there are approximately 1.5 million households in 2011 without ceiling insulation

As noted in section 1.3.5 it is assumed that the cohort of dwellings suitable for this energy saving measure are those dwellings constructed prior to the mid 1990s. Accordingly the percentages noted in Table 17 for 1994 for dwellings with ceiling insulation (assumed to be R1 on average) can be converted into estimated numbers of households with R1.0 insulation by multiplying these values by the total number of households as reported by the ABS in ABS3236-2010 for that year.

These values are then discounted for the following factors:

- so as to exclude class II dwellings which are not considered in this study. The proportion of dwellings in each jurisdiction and year that are categorised as class II dwellings were derived from the study Energy Use in the Australian Residential Sector 1986-2020 (EES 2008).
- By 10% to account for dwellings with inaccessible roof spaces ie flat roofs and cathedral ceilings.
- By a further 9% (approximately 0.5% per annum) to account for those households that are assumed to have had top up or replacement insulation undertaken since early 1990s (ie in past 20 years). This figure of 9% is considered to be very conservative (high) given that this represents approximately half of all ceiling retrofits undertaken over that period and those with some ceiling insulation fitted are expected to be less inclined to retrofit ceiling insulation compared to those that have no ceiling insulation fitted.

The results of this analysis showing the estimated number of dwellings by jurisdiction considered suitable for retrofit of top up ceiling insulation are shown in Table 18.

Table 18 : Estimated Number of Suitable Dwellings for Ceiling Insulation Top up (000's)

NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
729	922	259	338	270	93	18	65	2,694

The BAU case beyond 2011 assumes the rate of retrofit to be 0.5% (based on trend analysis from 1994-2011), this is considered to be a high (conservative estimate).

3.2.3 Retrofit of Wall insulation

According to ABS 4602, the proportion of insulated dwellings that have insulation fitted to their walls is as per Table 19. By multiplying the number of dwellings reported as insulated (Table 14) by the percentage of those dwellings reported as being insulated with wall insulation, a value for the number of dwellings with wall insulation can be derived for each year that a survey was conducted. Typically however, as can be seen from Table 14 a significant percentage of respondents (typically 15-20%) noted that they did not know if their dwelling was insulated or not. In these circumstances it has been assumed that the rate of insulation amongst the respondents that "don't know" is the same as those that do know. It would normally be expected that the rate of insulation in the unknown category would match that in the known category, so the approach taken is considered to make for a conservative estimate of the remaining number of un-insulated dwellings - see Table 20 (wall insulation).

Table 19 : Percentage of Insulated dwellings reported to have wall insulation by year (ABS)

Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1994	26.1	27.5	25.8	24.5	6.4	26.5	23.9	31.3	24.6
1999	24.0	31.5	26.1	27.3	7.7	26.6	16.1	39.8	25.7
2002	26.8	35.0	26.9	35.0	6.8	31.2	26.7	40.1	28.4
2005	32.6	40.3	24.9	34.4	9.8	33.4	14.7	43.9	31.7
2008	33.4	38.8	23.4	32.4	8.0	32.0	19.2	43.7	30.7
2011	24.1	34.4	16.6	33.8	8.2	35.8	15.8	46.3	25.4

Table 20 : Estimated percentage of dwellings with wall insulation by year

Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1994	13.8	22.1	9.0	20.1	3.8	18.2	14.5	27.9	15.0
1999	14.4	26.8	10.6	23.2	5.1	19.7	9.4	35.4	17.1
2002	17.2	30.0	12.0	29.9	5.0	23.8	16.2	36.5	19.8
2005	22.4	35.8	13.7	31.0	7.5	28.7	11.0	42.0	23.6
2008	22.5	34.8	14.3	29.1	6.5	27.9	13.4	41.2	23.4
2011	18.7	31.2	12.5	30.6	7.0	31.7	10.2	44.0	21.0

The percentages noted in Table 20 for households with wall insulation can be converted into estimated numbers of households without wall insulation by multiplying these values (subtracted from 100% to give numbers without wall insulation) by the total number of households as reported by the ABS in ABS3236-2010 for the given year. These values are then discounted for the following factors:

- so as to exclude class II dwellings which are not considered in this study. The proportion of dwellings in each jurisdiction and year that are categorised as class II dwellings were derived from the study Energy Use in the Australian Residential Sector 1986-2020 (EES 2008).
- so as to exclude dwellings with walls that might be considered impractical or overly costly to retrofit. For the purposes of this study this has been estimated to be 10% of all dwellings currently without wall insulation.

The results of this analysis showing the estimated number of dwellings by jurisdiction to have no wall insulation by year are shown in Table 21.

The BAU case beyond 2011 assumed that there is a 0.1% rate of retrofit. In reality there is very little data on this aspect but considering the very small number of contractors that engage in this type of work, the BAU estimate of approximately 6,000 retrofits per annum is considered to be a high (conservative estimate).

Table 21 : Number of Dwellings Estimated To Have No Wall Insulation by Year (000's)

Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1994	1,457	1,063	889	392	518	131	34	62	4,545
1999	1,552	1,069	983	395	567	133	40	60	4,798
2002	1,543	1,072	1,016	370	598	128	38	61	4,826
2005	1,464	1,016	1,033	370	608	121	41	57	4,709
2008	1,504	1,078	1,086	392	655	126	43	59	4,944
2011	**1,640**	**1,195**	**1,187**	**400**	**701**	**124**	**47**	**58**	**5,352**

3.2.4 Retrofit of Floor insulation

According to ABS 4602, the proportion of insulated dwellings that have insulation fitted to their floors is as per Table 22. By multiplying the number of dwellings reported as insulated (Table 14) by the percentage of those dwellings reported as being insulated with floor insulation, a value for the number of dwellings with floor insulation can be derived for each year that a survey was conducted. Typically however, as can be seen from Table 14 a significant percentage of respondents (typically 15-20%) noted that they did not know if their dwelling was insulated or not. In these circumstances it has been assumed that the rate of insulation amongst the respondents that "don't know" is the same as those that do know. It would normally be expected that the rate of insulation in the unknown category would match that in the known category, so the approach taken is considered to make for a conservative estimate of the remaining number of un-insulated dwellings - see Table 23 (Floor insulation).

Table 22 : Percentage of Insulated Dwellings Reported To Have Floor Insulation by Year (ABS)

Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1994	0.7	0.8	0.7	0.3	0.0	1.0	1.9	1.3	0.6
1999	0.6	0.4	1.0	0.2	0.2	1.7	0.9	1.2	0.6
2002	0.8	0.7	0.7	0.3	0.2	1.4	0.0	3.0	0.7
2005	1.1	0.9	0.7	0.7	0.4	3.4	0.0	3.3	1.0
2008	1.5	1.3	0.4	0.0	0.0	4.9	0.0	4.3	1.1
2011	1.7	1.4	0.7	0.9	0.6	5.2	1.4	4.5	1.1

Table 23 : Estimated Percentage Of All Dwellings With Floor Insulation By Year

Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1994	0.4	0.6	0.2	0.2	0.0	0.7	1.2	1.2	0.4
1999	0.4	0.3	0.4	0.2	0.1	1.3	0.5	1.1	0.4
2002	0.5	0.6	0.3	0.3	0.1	1.1	0.0	2.7	0.5
2005	0.8	0.8	0.4	0.6	0.3	2.9	0.0	3.2	0.7
2008	1.0	1.2	0.2	0.0	0.0	4.3	0.0	4.1	0.8
2011	1.3	1.3	0.5	0.8	0.5	4.6	0.9	4.3	0.9

The percentages noted in Table 23 for dwellings with floor insulation can be converted into estimated numbers of households without floor insulation by multiplying these values (subtracted from 100% to give numbers without floor insulation) by the total number of households as reported by the ABS in ABS3236-2010 for the given year.

These values were then discounted for the following factors:

- so as to exclude class II dwellings which are not considered in this study. The proportion of dwellings in each jurisdiction and year that are categorised as class II dwellings were derived from the study Energy Use in the Australian Residential Sector 1986-2020 (EES 2008).
- so as to exclude dwellings with other than suspended timber floors which would not be suitable for insulation retrofit. The proportion of dwellings in each jurisdiction and year that have other than suspended timber floors (typically these have concrete slab on ground floors) were derived from the study Energy Use in the Australian Residential Sector 1986-2020 (EES 2008).
- so as to exclude dwellings with suspended timber floors that have limited or no access which are considered not suitable for insulation retrofit. For the purposes of this study this has been conservatively estimated at 50% of the stock of housing with suspended timber floors (noting that most dwellings built post WWII should have adequate crawl space under floors and these dwellings represent significantly more than 50% of the total stock in Australia).

The results of this analysis showing the estimated number of dwellings by jurisdiction having no floor insulation and that are considered suitable for retrofit are shown in Table 24.

Table 24 : Number of Suitable Dwellings Estimated To Have No Floor Insulation by Year (000's)

Year	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1994	680	610	389	206	201	74	16	33	2,208
1999	683	627	395	207	202	75	16	33	2,238
2002	674	628	396	206	202	75	17	32	2,229
2005	652	618	381	200	196	72	16	30	2,166
2008	641	608	376	201	196	71	16	28	2,136
2011	**628**	**601**	**369**	**197**	**192**	**70**	**16**	**27**	**2,100**

The BAU case beyond 2011 assumed there to be 0.6% rate of retrofit (based on trend analysis from 2008-2011). This equates to approximately 12,000 retrofits per annum which is considered to be a high (conservative estimate)

3.2.5 Replacement of Space Conditioner ductwork

As noted in section 1.3.5 it is assumed that the cohort of dwellings suitable for this energy saving measure are those dwellings constructed prior to the mid 1990s. Data derived from the study *Energy Use in the Australian Residential Sector 1986-2020* (EES 2008) was used to determine the percentage of households in 1995 that included space conditioning equipment that utilized ductwork (see Table 25).

Table 25 : Percentage of Dwellings By Space Conditioner Type 1995 (EES 2008)

Space-conditioner Type	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Ducted RC	3.3	1.0	0.7	4.1	1.3	0.5	1.2	3.0
Ducted gas	2.0	26.6	0.2	1.6	1.8	0.0	0.0	18.1
Ducted AC	3.5	2.4	1.0	5.6	3.7	0.5	5.5	2.5
Evaporative	5.3	7.4	3.9	15.5	13.0	0.7	15.3	5.9
Total	14.1	37.3	5.8	26.8	19.9	1.8	22.0	29.6

The percentages noted in Table 25 can be converted into estimated numbers of households considered eligible for ductwork replacement by multiplying these values by the total number of households as reported by the ABS in ABS3236-2010 for the year 1995.

These values were then discounted for the following factors:

- So as to exclude class II dwellings which are not considered in this study. The proportion of dwellings in each jurisdiction and year that are categorised as class II dwellings were derived from the study Energy Use in the Australian Residential Sector 1986-2020 (EES 2008).
- By 25% to account for dwellings already retrofitted with high performance ductwork and also for those dwellings where it would be impractical to replace the ductwork (eg where the ductwork is located sub-floor and there is poor access).

The results of this analysis showing the estimated number of dwellings by jurisdiction considered suitable for ductwork replacement are shown in Table 26 .

Table 26 : Estimated Number of Suitable Dwellings For Ductwork Replacement (000's)

Space-conditioner Type	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Ducted RC	45	10	6	16	6	1	0	2	86
Ducted gas	27	288	2	6	8	0	0	12	343
Ducted AC	47	27	8	22	16	1	2	2	124
Evaporative	75	85	32	64	60	1	5	4	328
Total	202	430	49	111	92	2	7	22	916
Total Excluding Evaporative	127	345	17	47	32	1	2	17	553

The BAU case beyond 2011 assumed there to be 2% rate of retrofit. This equates to approximately 11,000 retrofits per annum.

3.3 Forward projections

As noted in section 1.3.2, in this study 3 main scenarios are examined as follows:

- BAU Case
- 50% Scenario - An intervention to retrofit half of the eligible stock by 2020 (50% Retrofit)
- 100% Scenario - An intervention to retrofit all of the eligible stock by 2020 (100% Retrofit). Noting that 100% retrofit includes discounts as noted in the preceding sections

The projections for each form of energy saving measure and each scenario are shown graphically below in Figure 5 (ceiling insulation program), Figure 6 (ceiling insulation top up program), Figure 7 (wall insulation program), Figure 8 (floor insulation program) and Figure 9 (duct replacement program).

Figure 5 : Projections for number of dwellings without ceiling insulation (000's)

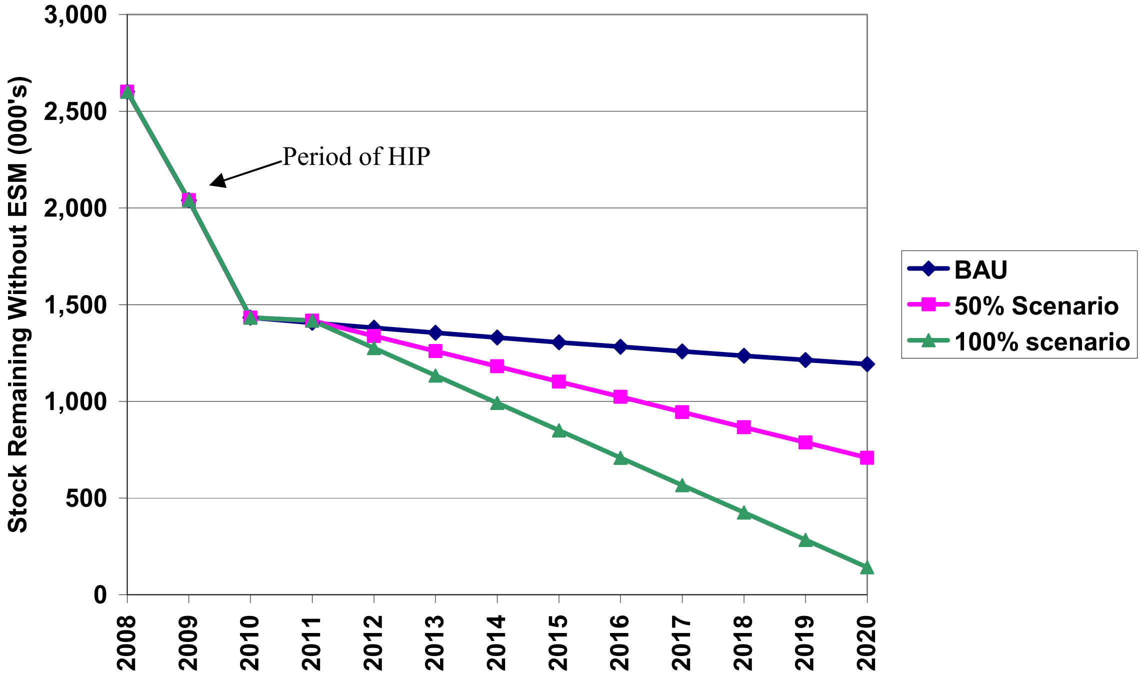


Figure 6 : Projections for number of dwellings with potential for ceiling insulation top up (000's)

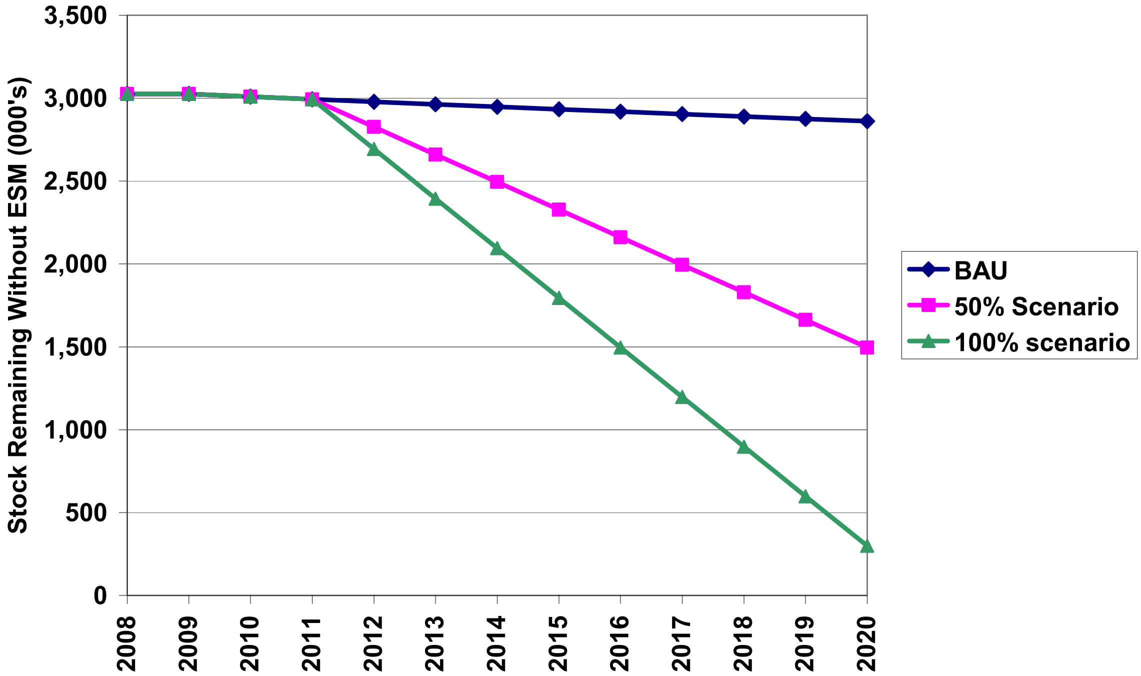


Figure 7 : Projections for number of dwellings without wall insulation (000's)

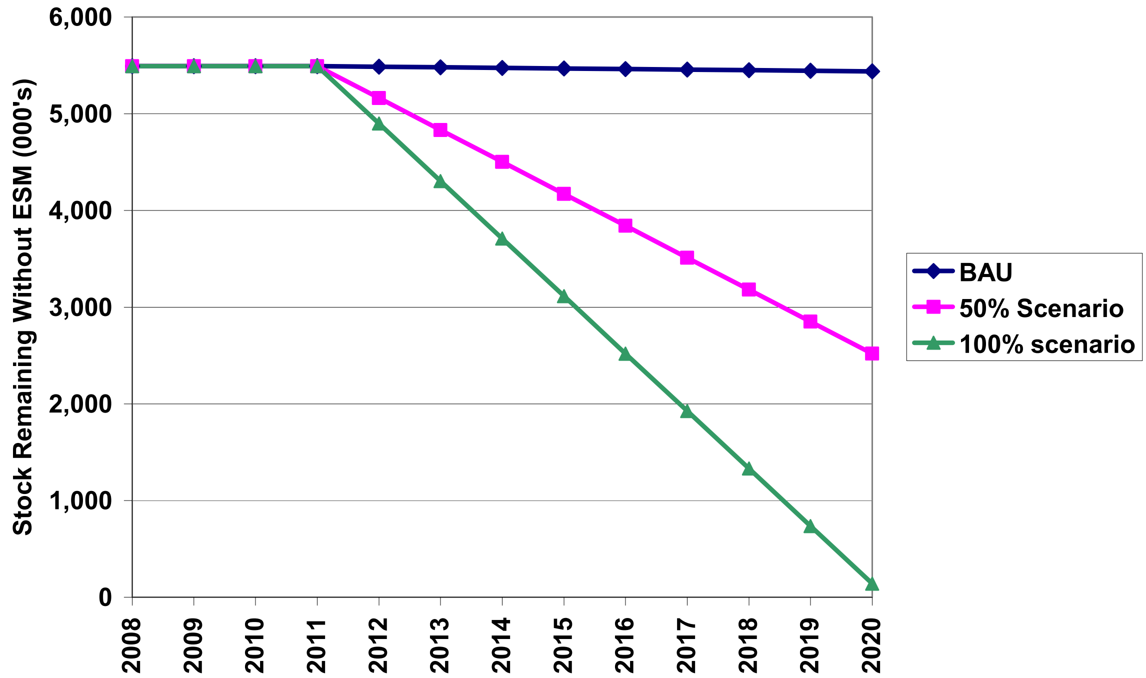


Figure 8 : Projections for number of dwellings (timber floored) without floor insulation (000's)

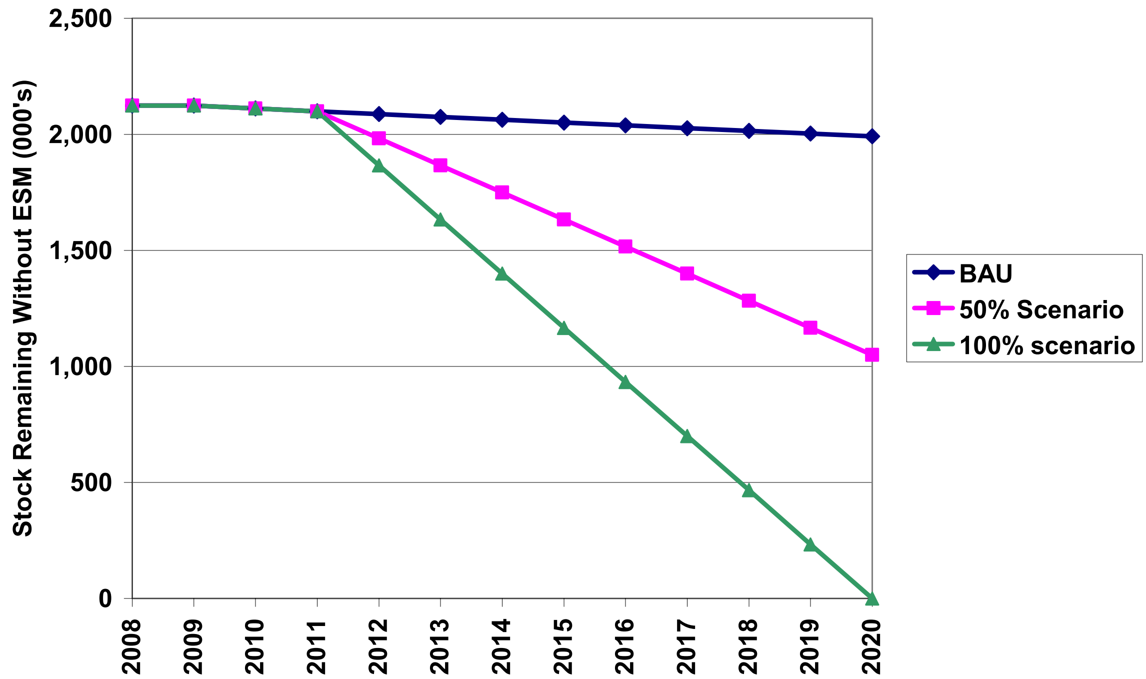
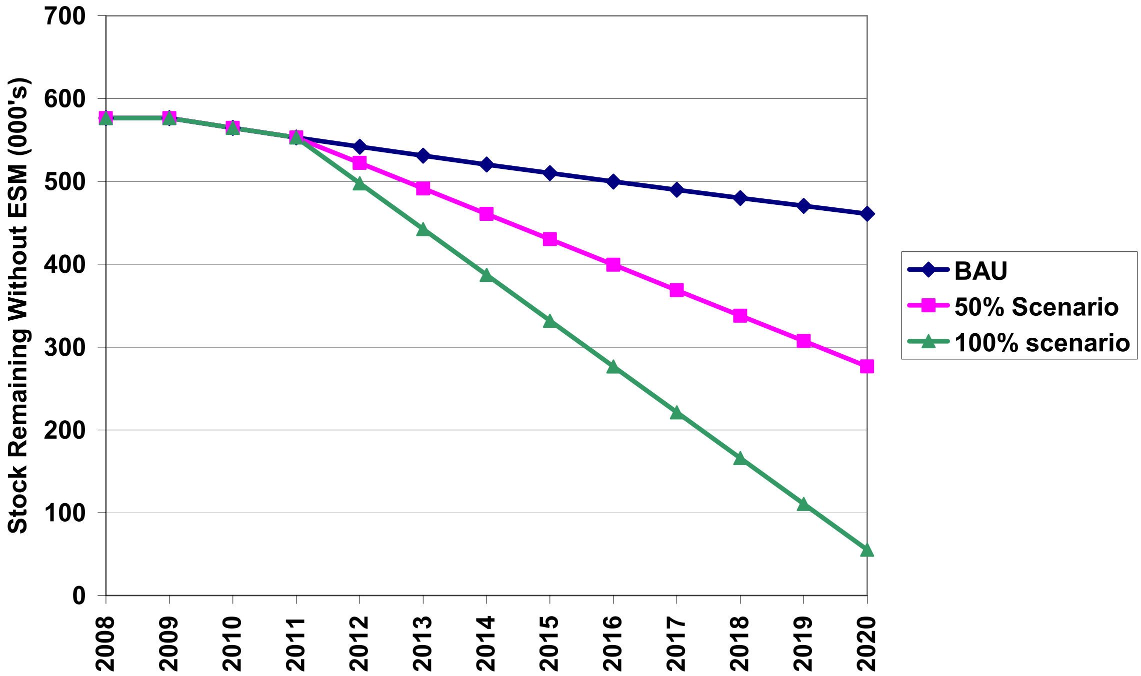


Figure 9 : Projections for number of dwellings with potential for duct replacement (000's)



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 in terms of improved star rating.
- Section 4.3 details the benefits in terms of reduced space conditioning energy consumption.
- Section 4.4 details the benefits in terms of the financial returns to the householder.
- Section 4.5 details the benefits in terms of greenhouse gas abatement.
- Section 4.6 details the benefits in terms of reductions in peak electrical loads attributable to space conditioning and associated generation and network cost savings.

4.2 Improved Star Rating Benefits

Prior to the application of the various insulation based energy savings measures each dwelling type modelled in this study exhibited a range of performances.

After applying the various energy savings measures, the sample dwellings exhibited an improved range of performances. The estimated national average improvements were:

- Ceiling Insulation : 2.2 star improvement (Base case assumes R0 to ceiling)
- Top up to under insulated ceilings : 0.5 star improvement (Base case assumes R1.0 to ceiling based on pre 90's installations – see section 3.2.2)
- Wall Insulation : 1.0 star improvement (Base case assumes R1.5 to ceiling)
- Floor Insulation : 0.2 star improvement (Base case assumes R1.5 to ceiling)

Details of the range of star ratings observed in both the unimproved and the improved cases as well as the net improvement in star rating for each jurisdiction can be found in Table 27 (ceiling insulation), Table 28 (top insulation to under insulated ceilings),Table 29 (wall insulation) and Table 30 (floor insulation).

Table 27 : 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**
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**

Table 28 : Estimated Star Rating Improvement due to Retrofit of top up Ceiling Insulation

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Star Rating Performance of Dwellings with sub standard Ceiling Insulation									
Detached	1.8-4.1	2-3.9	1.4-4	2-4	1.8-4.1	2-3.9	1.8-4.7	2-4	1.8-4
Semi Detached	2.7-4.6	3-4.2	2.6-4.3	2.8-4.4	2.5-4.9	3-4.1	2.7-3.9	3-4.2	4-2.7
Average All	**2.7**	**2.7**	**2.6**	**3.3**	**3.3**	**2.5**	**3.3**	**3.2**	**2.8**
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**
Average Star Rating Improvement due to Ceiling Insulation Top up									
Improvement	**0.5**	**0.4**	**0.4**	**0.6**	**0.8**	**0.4**	**0.4**	**0.5**	**0.5**

Table 29 : Estimated Star Rating Improvement due to Retrofit of Wall Insulation

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Star Rating Performance of Dwellings with no Wall Insulation									
Detached	2-4.4	2.2-4.1	1.5-4.2	2.2-4.2	1.9-4.5	2.1-4.1	2-4.8	2.1-4.2	1.9-4.3
Semi Detached	2.8-4.8	3.1-4.3	2.8-4.5	2.9-4.6	2.6-5.2	3.1-4.2	2.8-4.1	3.1-4.4	4.3-2.9
Average All	**2.94**	**2.90**	**2.83**	**3.51**	**3.63**	**2.66**	**3.46**	**3.38**	**2.96**
Star Rating Performance of Dwellings with Wall Insulation									
Detached	3-5.2	3.2-4.9	2.6-4.9	3.3-5.1	2.9-5.6	3.2-5.2	2.8-5.6	3.2-5	2.9-5.1
Semi Detached	4-5.7	4.3-5.3	3.7-4.9	4-5.5	3.7-6.1	4.5-5.3	3.7-4.5	4.4-5.4	5.1-4
Average All	**3.90**	**3.94**	**3.79**	**4.70**	**4.42**	**3.71**	**4.25**	**4.58**	**3.94**
Average Star Rating Improvement due to Wall Insulation Retrofit									
Improvement	**1.0**	**1.0**	**1.0**	**1.2**	**0.8**	**1.0**	**0.8**	**1.2**	**1.0**

Table 30 : Estimated Star Rating Improvement due to Retrofit of Floor Insulation

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Star Rating Performance of Dwellings with no Ceiling Insulation									
Detached	2-4.2	2.2-3.9	1.5-4.1	2.2-4.1	1.9-4.5	2.1-4	2-4.8	2.1-4.1	1.9-4.1
Semi Detached	2.8-4.3	3.1-4.1	2.8-4	2.9-4.2	2.6-4.3	3.1-4.1	2.8-3.7	3.1-4.3	4.1-2.9
Average All	**2.74**	**2.81**	**2.54**	**3.48**	**3.22**	**2.60**	**3.31**	**3.37**	**2.76**
Star Rating Performance of Dwellings with ceiling insulation to HIP standard (R3.0 – R4.0)									
Detached	2.1-4.3	2.6-4.3	1.5-4	2.4-4.4	2-4.7	2.7-4.4	2-4.9	2.6-4.4	2.1-4.3
Semi Detached	3.1-4.5	3.5-4.5	2.9-4	3.1-4.3	2.8-4.4	3.6-4.5	2.9-3.8	3.5-4.6	3.1-4.4
Average All	**2.97**	**3.23**	**2.59**	**3.62**	**3.29**	**3.11**	**3.43**	**3.75**	**2.97**
Average Star Rating Improvement due to Ceiling Insulation Retrofit									
Improvement	**0.23**	**0.42**	**0.05**	**0.14**	**0.07**	**0.52**	**0.11**	**0.38**	**0.22**

4.3 Energy Reduction Benefits

Estimates of potential savings in energy consumption resulting from the application of the various energy savings measures based on the methodology detailed in Appendix 1: Modelling Methodology – Energy are detailed in Table 31 (ceiling insulation), Table 32 (top insulation to under insulated ceilings), Table 33 (wall insulation), Table 34 (floor insulation) and Table 35 (space conditioning duct replacement).

In these tables potential 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.

It should be noted that the estimates shown in these tables 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 31 represent 75% of the modelled outcomes.

Table 31 : Estimated Average Energy Savings by Fuel Type in 2012 – Ceiling Insulation (MJ)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Elec. Heating	1576	1386	432	1792	882	3936	18	3378	1228
Gas Heating	1776	23927	50	3181	2875	617	20	17932	6158
LPG Heating	293	331	48	260	86	458	86	12	221
Wood Closed	3742	4965	804	4361	4313	16790	116	2481	3415
Wood Open	334	276	123	402	316	1498	2	8	278
Cooling	740	212	828	853	834	27	2492	283	657
Total	**8461**	**31096**	**2285**	**10848**	**9306**	**23326**	**2734**	**24095**	**11958**

Table 32 : Estimated Average Energy Savings by Fuel Type in 2012 – Ceiling Top up Insulation (MJ)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Elec. Heating	261	233	64	312	142	687	2	579	248
Gas Heating	295	4018	7	554	462	108	2	3076	1650
LPG Heating	49	56	7	45	14	80	8	2	43
Wood Closed	621	834	120	760	693	2930	11	426	741
Wood Open	55	46	18	70	51	261	0	1	56
Cooling	117	37	115	153	150	4	367	49	93
Total	**1398**	**5223**	**332**	**1895**	**1512**	**4069**	**391**	**4134**	**2830**

Table 33 : Estimated Average Energy Savings by Fuel Type in 2012 – Wall Insulation (MJ)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Elec. Heating	457	454	107	457	149	1319	3	1154	1125
Gas Heating	515	7831	12	812	486	207	3	6125	3180
LPG Heating	85	108	12	66	15	154	15	4	131
Wood Closed	1085	1625	198	1113	729	5629	20	847	3658
Wood Open	97	90	30	103	53	502	0	3	303
Cooling	215	74	336	308	181	8	871	67	227
Total	**2453**	**10182**	**696**	**2860**	**1612**	**7819**	**913**	**8200**	**8625**

Table 34 : Estimated Average Energy Savings by Fuel Type in 2012 – Floor Insulation (MJ)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Elec. Heating	227	241	45	143	77	759	2	450	194
Gas Heating	256	4166	5	254	252	119	2	2392	1301
LPG Heating	42	58	5	21	8	88	7	2	35
Wood Closed	539	864	83	348	378	3237	10	331	591
Wood Open	48	48	13	32	28	289	0	1	45
Cooling	25	-26	-6	-69	-54	-4	230	-36	-11
Total	**1136**	**5351**	**144**	**729**	**688**	**4487**	**251**	**3140**	**2156**

Table 35 : Estimated Average Energy Savings by Fuel Type in 2012 – Duct Replacement (MJ)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Ducted Gas Systems (Heating Only)									
Gas Heating	5256	12340	1744	5089	3437	13380	638	10442	11322
Reverse Cycle Ducted Air-conditioning (Heating and Cooling)									
Elec. Heating	1433	2384	472	1164	854	3072	174	2538	1425
Elec. Cooling	1257	451	2493	1233	1414	60	9166	496	1258
Cooling only Ducted Air-conditioning (Cooling only)									
Elec. Cooling	1257	451	2493	1233	1414	60	9166	496	1274
Weighted Average All									
All Fuels	2707	11067	2587	2192	2124	1481	9197	8436	7732

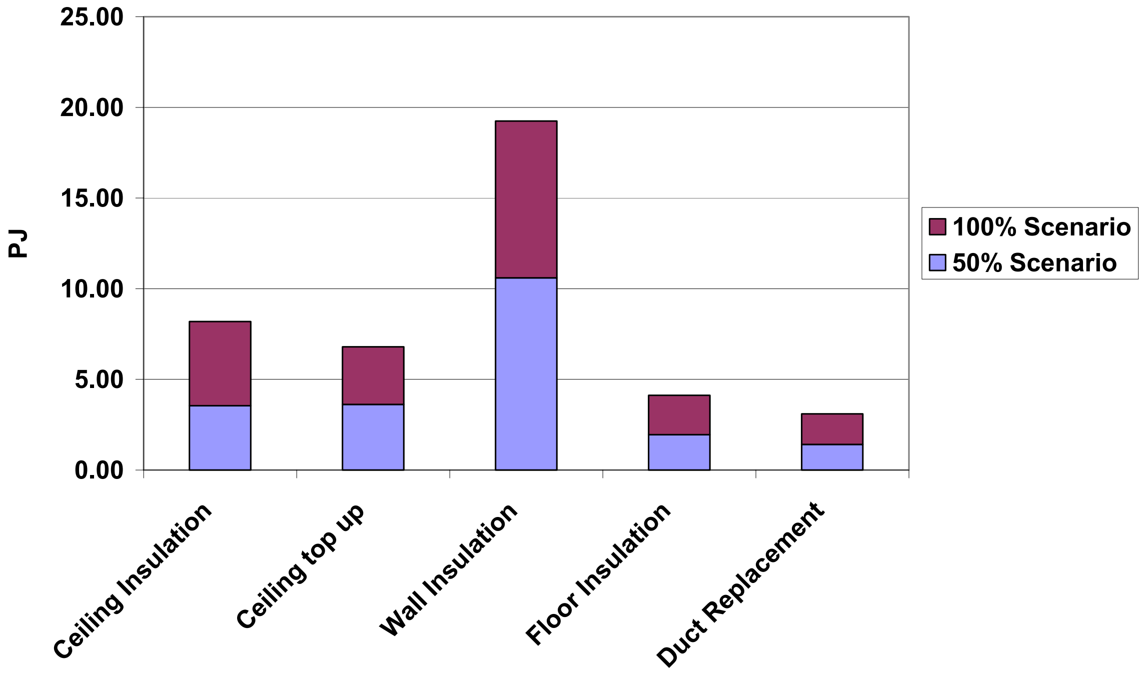
By applying the results from Table 31 to Table 35 inclusive to the various scenarios for retrofit (see sections 1.3.2 and 3.3 for details of these scenarios) an estimate of potential state and national energy savings was derived. These potential savings are detailed in Table 36. In this table the results presented are for the year 2020 for each of the 2 retrofit scenarios examined. All reported values include a discount of 25% for expected rebound. Figure 10 shows graphically the results at a national level.

Table 36 : Estimated State and National Level Energy Savings in 2020 (PJ/annum)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
With Ceiling Insulation Retrofit									
50% Scenario	1.87	0.86	0.33	0.13	0.24	0.03	0.03	0.05	3.55
100% Scenario	3.74	2.13	0.69	0.43	0.71	0.24	0.05	0.19	8.19
With Ceiling Insulation Top Up									
50% Scenario	0.48	2.30	0.04	0.31	0.19	0.16	0.00	0.13	3.62
100% Scenario	0.91	4.32	0.07	0.59	0.35	0.30	0.01	0.24	6.79
With Wall Insulation Retrofit									
50% Scenario	2.06	6.26	0.41	0.60	0.56	0.44	0.02	0.25	10.60
100% Scenario	3.74	11.36	0.74	1.09	1.02	0.79	0.04	0.45	19.24
With Floor Insulation Retrofit									
50% Scenario	0.30	1.36	0.02	0.06	0.05	0.12	0.00	0.04	1.95
100% Scenario	0.63	2.87	0.04	0.13	0.11	0.25	0.00	0.08	4.12
With Duct Replacement (Ducted Gas)									
50% Scenario	0.05	1.18	0.00	0.01	0.01	0.00	0.00	0.04	1.29
100% Scenario	0.10	2.59	0.00	0.03	0.02	0.00	0.00	0.10	2.84
With Duct Replacement (Ducted Reverse Cycle)									
50% Scenario	0.04	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.07
100% Scenario	0.08	0.02	0.01	0.03	0.01	0.00	0.00	0.00	0.15
With Duct Replacement (Ducted Cooling)									
50% Scenario	0.02	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.05
100% Scenario	0.04	0.01	0.01	0.02	0.01	0.00	0.01	0.00	0.10
With Duct Replacement (All Types)									
50% Scenario	0.10	1.20	0.01	0.03	0.02	0.00	0.01	0.05	1.41
100% Scenario	0.22	2.62	0.03	0.07	0.05	0.00	0.02	0.10	3.10

Note: The above estimated energy savings are potential savings only. In some cases it may not be cost effective to undertake a particular energy saving measure in a particular jurisdiction. Refer to section 4.4 for details of cost effectiveness of each measure in each jurisdiction

Figure 10 : Estimated Potential National Energy Savings in 2020 (By Scenario)



4.4 Financial Benefits to the Householder

Potential 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 37. In this table potential savings are based on the BAU fuel price scenario (see section 1.3.7).

Table 37 : Benefits to the Householder – Annual operational cost savings ($) 2012

Benefit	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Ceiling Insulation	$254	$586	$105	$359	$279	$462	$187	$668	$299
Top up to Ceiling	$42	$99	$15	$63	$46	$81	$27	$115	$49
Wall Insulation	$74	$192	$35	$99	$50	$155	$64	$227	$91
Floor Insulation[1]	$31	$98	$4	$17	$15	$88	$17	$85	$39
Duct replacement[2]	$124	$200	$186	$136	$125	$109	$659	$223	$133

Note 1: Assumes R2.5 floor insulation fitted

Note 2: Weighted average for ducted gas, ducted R/C and ducted cooling only systems (R1.5 ducting)

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 38 provides similar detail to Table 37 except that the impact of each of the two fuel cost scenarios is shown on the annual savings in fuel costs estimated to be realised in 2020.

Table 38 : Benefits to the Householder – Annual operational cost savings ($) by 2020

Benefit	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
BAU fuel cost scenario									
Ceiling Insulation	$303	$787	$127	$458	$356	$507	$196	$819	$375
Top up to Ceiling	$50	$132	$18	$80	$59	$88	$29	$141	$62
Wall Insulation	$88	$258	$43	$125	$65	$170	$67	$278	$114
Floor Insulation[1]	$37	$131	$5	$23	$16	$97	$18	$104	$47
Duct replacement[2]	$149	$274	$202	$157	$164	$123	$624	$270	$165
BAU + fuel cost scenario									
Ceiling Insulation	$313	$820	$132	$472	$363	$522	$206	$853	$389
Top up to Ceiling	$51	$138	$19	$83	$60	$91	$30	$146	$64
Wall Insulation	$91	$269	$45	$129	$66	$175	$71	$289	$119
Floor Insulation[1]	$38	$137	$5	$24	$16	$100	$19	$109	$49
Duct replacement[2]	$156	$286	$211	$163	$167	$128	$657	$280	$172

Note 1: Assumes R2.5 floor insulation fitted

Note 2: Weighted average for ducted gas, ducted R/C and ducted cooling only systems (R1.5 ducting)

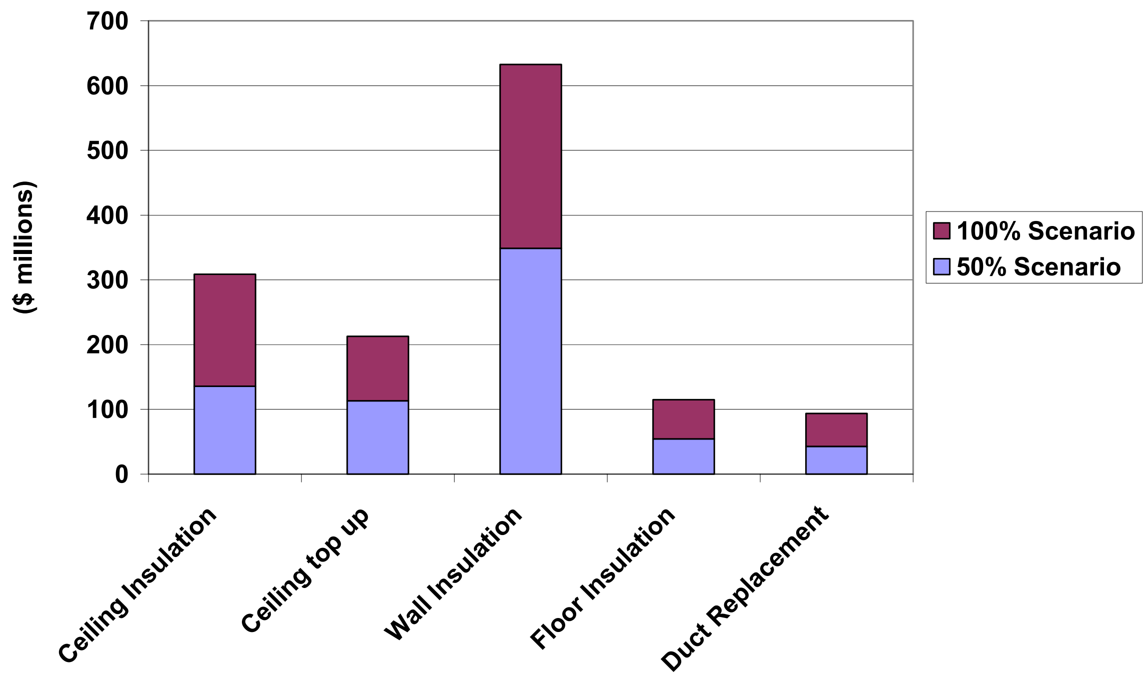
By applying the results from Table 38 to the various scenarios for retrofit (see sections 1.3.2 and 3.3 for details of these scenarios) an estimate of potential state and national fuel cost savings was derived. These savings are detailed in Table 39. In this table the results presented are for 2020 for each of the 2 retrofit scenarios examined. Figure 11 shows graphically the results at a national level.

Table 39 : Estimated State and National Level Fuel Cost Savings by 2020 ($M/annum)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
With Ceiling Insulation Retrofit									
50% Scenario	71.3	23.0	20.7	5.8	10.2	0.9	2.1	1.8	**135.8**
100% Scenario	142.4	57.3	43.2	18.8	30.0	6.2	4.0	6.8	**308.8**
With Ceiling Insulation Top Up									
50% Scenario	18.4	61.8	2.4	13.7	8.1	4.2	0.3	4.6	**113.3**
100% Scenario	34.5	116.0	4.5	25.7	15.1	7.8	0.5	8.6	**212.7**
With Wall Insulation Retrofit									
50% Scenario	78.5	168.1	28.0	27.4	24.8	11.5	1.7	8.8	**348.7**
100% Scenario	142.4	305.1	50.7	49.7	44.9	20.8	3.1	16.1	**632.8**
With Floor Insulation Retrofit									
50% Scenario	10.3	35.4	0.8	2.1	1.3	3.0	0.1	1.3	**54.3**
100% Scenario	21.8	74.8	1.7	4.4	2.9	6.4	0.3	2.7	**114.9**
With Duct Replacement (Ducted Gas)									
50% Scenario	1.4	28.5	0.0	0.3	0.4	0.0	0.0	1.3	**32.0**
100% Scenario	3.1	62.6	0.1	0.7	0.9	0.0	0.0	2.9	**70.3**
With Duct Replacement (Ducted Reverse Cycle)									
50% Scenario	3.0	0.8	0.5	1.2	0.5	0.1	0.1	0.1	**6.2**
100% Scenario	6.7	1.8	1.0	2.6	1.0	0.1	0.2	0.3	**13.7**
With Duct Replacement (Ducted Cooling)									
50% Scenario	1.5	0.3	0.5	0.8	0.8	0.0	0.4	0.0	**4.3**
100% Scenario	3.2	0.7	1.2	1.7	1.7	0.0	0.8	0.0	**9.4**
With Duct Replacement (All Types)									
50% Scenario	5.9	29.7	1.1	2.3	1.6	0.1	0.4	1.5	**42.5**
100% Scenario	13.0	65.2	2.3	5.1	3.6	0.1	1.0	3.2	**93.5**

Note: The above estimated energy savings are potential savings only. In some cases it may not be cost effective to undertake a particular energy saving measure in a particular jurisdiction. Refer to section 4.4 for details of cost effectiveness of each measure in each jurisdiction

Figure 11 : Estimated Potential National Fuel Cost Savings in 2020 (By Scenario)



By comparing a net present value (NPV) calculation of the financial benefits (see Table 37 for 2012 values and Table 38 for 2020 values), to the cost of the various insulation based energy savings measures examined in this study as detailed in Appendix 2 : Modelling Methodology – Financial, an assessment of the cost effectiveness of each energy saving measure was made.

Using an assumed service life of 30 years for all measures except duct replacement (20 year life assumed), estimates were made of the benefit to cost ratio for the retrofitting of the various energy savings measures. The results for this analysis are shown in Table 40 (3% discount rate), Table 41 (5% discount rate) and Table 42 (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 the BAU fuel cost scenario and the lower half provides estimates based on the BAU+ fuel cost scenario.

The results of the cost effectiveness analysis are summarised in Table 43. In this table, dark green shading indicates that the measure is cost effective against the full range of economic settings examined in this study (including at a 7% discount rate and the current projections for fuel costs). Light green shading indicates that the measure is cost effective at some of the economic settings examined in this study (eg 3% or 5% discount rate) but not all and the pink shading indicates that the measure is not cost effective at any of the economic settings examined in this study.

Table 40 : Benefit / Cost Ratio at 3% Discount Rate

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
BAU fuel cost scenario									
Ceiling Insulation	5.6	15.3	2.3	7.6	4.6	7.7	3.8	19.7	7.0
Top up to Ceiling	1.1	3.2	0.4	1.6	0.9	1.6	0.7	4.2	1.4
Wall Insulation	0.8	2.4	0.4	1.1	0.5	1.6	0.6	2.7	1.0
Wall Insulation (RC)	1.2	3.5	0.5	1.6	0.8	2.4	0.9	4.0	1.6
Floor Insulation	0.3	1.3	0.0	0.2	0.1	0.9	0.2	1.4	0.5
Duct (Gas)	1.3	2.4	0.5	1.3	1.1	3.7	0.3	2.8	1.4
Duct (Rev. Cycle)	1.2	1.4	1.4	1.4	1.3	1.6	4.0	1.2	1.3
Duct (Cool. Only)	0.6	0.2	1.1	0.7	0.8	0.0	3.9	0.2	0.7
BAU+ fuel cost scenario									
Ceiling Insulation	5.8	16.1	2.4	7.9	4.7	8.0	4.1	20.7	7.3
Top up to Ceiling	1.2	3.3	0.4	1.7	0.9	1.6	0.7	4.4	1.5
Wall Insulation	0.8	2.5	0.4	1.1	0.6	1.7	0.7	2.8	1.1
Wall Insulation (RC)	1.3	3.7	0.6	1.7	0.8	2.5	1.0	4.2	1.6
Floor Insulation	0.4	1.4	0.0	0.2	0.1	1.0	0.2	1.5	0.5
Duct (Gas)	1.3	2.5	0.5	1.3	1.1	3.8	0.3	2.9	1.4
Duct (Rev. Cycle)	1.3	1.5	1.4	1.4	1.3	1.7	4.2	1.3	1.4
Duct (Cool. Only)	0.6	0.2	1.2	0.7	0.8	0.0	4.1	0.2	0.7

Table 41 : Benefit / Cost Ratio at 5% Discount Rate

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
BAU fuel cost scenario									
Ceiling Insulation	4.3	11.6	1.8	5.8	3.6	5.9	3.0	15.1	5.4
Top up to Ceiling	0.9	2.4	0.3	1.2	0.7	1.2	0.5	3.2	1.1
Wall Insulation	0.6	1.8	0.3	0.8	0.4	1.2	0.5	2.1	0.8
Wall Insulation (RC)	0.9	2.7	0.4	1.2	0.6	1.8	0.7	3.1	1.2
Floor Insulation	0.3	1.0	0.0	0.2	0.1	0.7	0.1	1.1	0.4
Duct (Gas)	1.1	2.0	0.4	1.0	0.9	3.1	0.2	2.3	1.1
Duct (Rev. Cycle)	1.0	1.2	1.1	1.2	1.0	1.4	3.3	1.0	1.1
Duct (Cool. Only)	0.5	0.2	1.0	0.6	0.6	0.0	3.3	0.2	0.5
BAU+ fuel cost scenario									
Ceiling Insulation	4.5	12.2	1.8	6.1	3.6	6.1	3.2	15.9	5.6
Top up to Ceiling	0.9	2.5	0.3	1.3	0.7	1.3	0.6	3.4	1.1
Wall Insulation	0.6	1.9	0.3	0.9	0.4	1.3	0.5	2.2	0.8
Wall Insulation (RC)	1.0	2.8	0.4	1.3	0.6	1.9	0.8	3.2	1.3
Floor Insulation	0.3	1.0	0.0	0.2	0.1	0.7	0.1	1.1	0.4
Duct (Gas)	1.1	2.1	0.4	1.1	0.9	3.2	0.2	2.4	1.2
Duct (Rev. Cycle)	1.1	1.2	1.2	1.2	1.1	1.4	3.5	1.1	1.2
Duct (Cool. Only)	0.5	0.2	1.0	0.6	0.7	0.0	3.4	0.2	0.6

Table 42 : Benefit / Cost Ratio at 7% Discount Rate

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
BAU fuel cost scenario									
Ceiling Insulation	3.4	9.2	1.4	4.6	2.8	4.7	2.4	12.0	4.3
Top up to Ceiling	0.7	1.9	0.3	1.0	0.5	1.0	0.4	2.5	0.9
Wall Insulation	0.5	1.4	0.2	0.7	0.3	1.0	0.4	1.6	0.6
Wall Insulation (RC)	0.7	2.1	0.3	1.0	0.5	1.5	0.6	2.4	1.0
Floor Insulation	0.2	0.8	0.0	0.1	0.1	0.6	0.1	0.8	0.3
Duct (Gas)	0.9	1.6	0.4	0.9	0.8	2.6	0.2	1.9	0.9
Duct (Rev. Cycle)	0.9	1.0	1.0	1.0	0.9	1.1	2.8	0.9	0.9
Duct (Cool. Only)	0.4	0.2	0.8	0.5	0.5	0.0	2.8	0.1	0.5
BAU+ fuel cost scenario									
Ceiling Insulation	3.6	9.6	1.5	4.8	2.9	4.9	2.5	12.5	4.4
Top up to Ceiling	0.7	2.0	0.3	1.0	0.6	1.0	0.5	2.6	0.9
Wall Insulation	0.5	1.5	0.2	0.7	0.3	1.0	0.4	1.7	0.7
Wall Insulation (RC)	0.8	2.2	0.4	1.0	0.5	1.5	0.6	2.5	1.0
Floor Insulation	0.2	0.8	0.0	0.1	0.1	0.6	0.1	0.9	0.3
Duct (Gas)	0.9	1.7	0.4	0.9	0.8	2.6	0.2	2.0	1.0
Duct (Rev. Cycle)	0.9	1.0	1.0	1.0	0.9	1.2	2.9	0.9	1.0
Duct (Cool. Only)	0.4	0.2	0.8	0.5	0.5	0.0	2.9	0.1	0.5

Table 43 : Summary - Cost Effectiveness of Energy Saving Measure (ie is Benefit/Cost > 1) 2012

Benefit	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Ceiling Insulation	Yes(7)	Yes(7)	Yes(7)	Yes(7)	Yes(7)	Yes(7)	Yes(7)	Yes(7)	Yes(7)
Top up to Ceiling	Yes(3)	Yes(7)	No	Yes(7)	No	Yes(7)	No	Yes(7)	Yes(5)
Wall Insulation	Yes(3*)	Yes(7)	No	Yes(7*)	No	Yes(7)	Yes(3+*)	Yes(7)	Yes(7*)
Floor Insulation	No	Yes(5)	No	No	No	Yes(3+)	No	Yes(5)	No
Duct (Gas)	Yes(5)	Yes(7)	No	Yes(5)	Yes(3)	Yes(7)	No	Yes(7)	Yes(5)
Duct (Rev. Cycle)	Yes(5)	Yes(7)	Yes(7)	Yes(7)	Yes(5)	Yes(7)	Yes(7)	Yes(5)	Yes(5)
Duct (Cooling)	No	No	Yes(5)	No	No	No	Yes(7)	No	No

Legend

Yes(7)	Indicates the measure is cost effective with a 7% discount rate and current energy pricing trends
Yes(5)	Indicates the measure is cost effective with a less than 7% discount rate (discount rate indicated in brackets)
Yes(3+)	Indicates the measure is cost effective only at 3% discount rate and assuming a higher trend in energy prices
No	Indicates the measure is not cost effective under any of the economic scenarios examined in this study

* Indicates that cost effectiveness relies on reduced improvement capital costs (wall insulation only – see Appendix 2 : Modelling Methodology – Financial)

4.5 Greenhouse Gas Abatement Benefits

By applying greenhouse gas intensity data (see Appendix 3 : Modelling Methodology – Greenhouse) to the estimates of potential energy savings (see Table 31 to Table 35) the per household potential greenhouse gas emissions savings attributable to the retrofit of the various insulation based energy savings measures were determined (see Table 44). In this table, average per household greenhouse gas savings estimates are provided for each jurisdiction as well as a weighted national average.

As can be seen from this table, reduction in household greenhouse gas emissions range from a few hundred kilograms to more than a two tonnes per annum depending upon the ESM adopted and the jurisdiction.

It should be noted that the estimates shown in Table 44 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.

Table 44 : Estimated Av. Greenhouse Gas Abatement per Dwelling in 2012 (Tonnes CO2-e / annum)

Benefit	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Ceiling Insulation	0.80	1.94	0.35	0.94	0.59	0.36	0.60	2.30	**0.93**
Top up to Ceiling	0.13	0.33	0.05	0.17	0.10	0.06	0.09	0.39	**0.15**
Wall Insulation	0.23	0.64	0.12	0.26	0.11	0.12	0.21	0.78	**0.29**
Floor Insulation	0.09	0.31	0.01	0.04	0.02	0.07	0.05	0.26	**0.11**
Duct (Gas)	0.40	0.78	0.11	0.37	0.21	0.94	0.04	0.77	**0.40**
Duct (Rev. Cycle)	0.81	1.00	0.87	0.65	0.55	0.11	2.42	0.89	**0.84**
Duct (Cool. Only)	0.38	0.16	0.73	0.33	0.34	0.00	2.37	0.14	**0.42**
Duct (W. average)	0.54	0.74	0.72	0.45	0.35	0.05	2.38	0.72	**0.47**

Using the modelled data from Table 44 and applying the estimated number of potential retrofits under each scenario it is possible to estimate the potential impact of each of the insulation based energy savings measures for each jurisdiction.

Table 45 provides state and national level estimates of projected potential greenhouse gas abatement to be realised in the year 2020 for each of the two scenarios (see section 1.3.2) for retrofit examined in this study. The results are also shown graphically in Figure 12.

Table 45 : Estimated Greenhouse Gas Abatement in 2020 by Scenario (Mt CO2-e)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
With Ceiling Insulation Retrofit									
50% Scenario	0.17	0.05	0.05	0.01	0.02	0.00	0.01	0.01	**0.31**
100% Scenario	0.33	0.13	0.11	0.04	0.05	0.00	0.01	0.02	**0.69**
With Ceiling Insulation Top Up									
50% Scenario	0.04	0.14	0.01	0.03	0.01	0.00	0.00	0.01	**0.24**
100% Scenario	0.08	0.26	0.01	0.05	0.02	0.01	0.00	0.02	**0.46**
With Wall Insulation Retrofit									
50% Scenario	0.18	0.38	0.07	0.05	0.04	0.01	0.00	0.02	**0.76**
100% Scenario	0.33	0.68	0.13	0.10	0.07	0.02	0.01	0.04	**1.39**
With Floor Insulation Retrofit									
50% Scenario	0.02	0.08	0.00	0.00	0.00	0.00	0.00	0.00	**0.11**
100% Scenario	0.05	0.16	0.00	0.01	0.00	0.00	0.00	0.01	**0.24**
With Duct Replacement (Ducted Gas)									
50% Scenario	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	**0.08**
100% Scenario	0.01	0.16	0.00	0.00	0.00	0.00	0.00	0.01	**0.18**
With Duct Replacement (Ducted Reverse Cycle)									
50% Scenario	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.02**
100% Scenario	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	**0.04**
With Duct Replacement (Ducted Cooling)									
50% Scenario	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.01**
100% Scenario	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.03**
With Duct Replacement (All Types)									
50% Scenario	0.02	0.08	0.00	0.01	0.00	0.00	0.00	0.00	**0.11**
100% Scenario	0.04	0.17	0.01	0.01	0.01	0.00	0.00	0.01	**0.25**

Figure 12 : Estimated Potential National Greenhouse Gas Savings in 2020 (By Scenario)

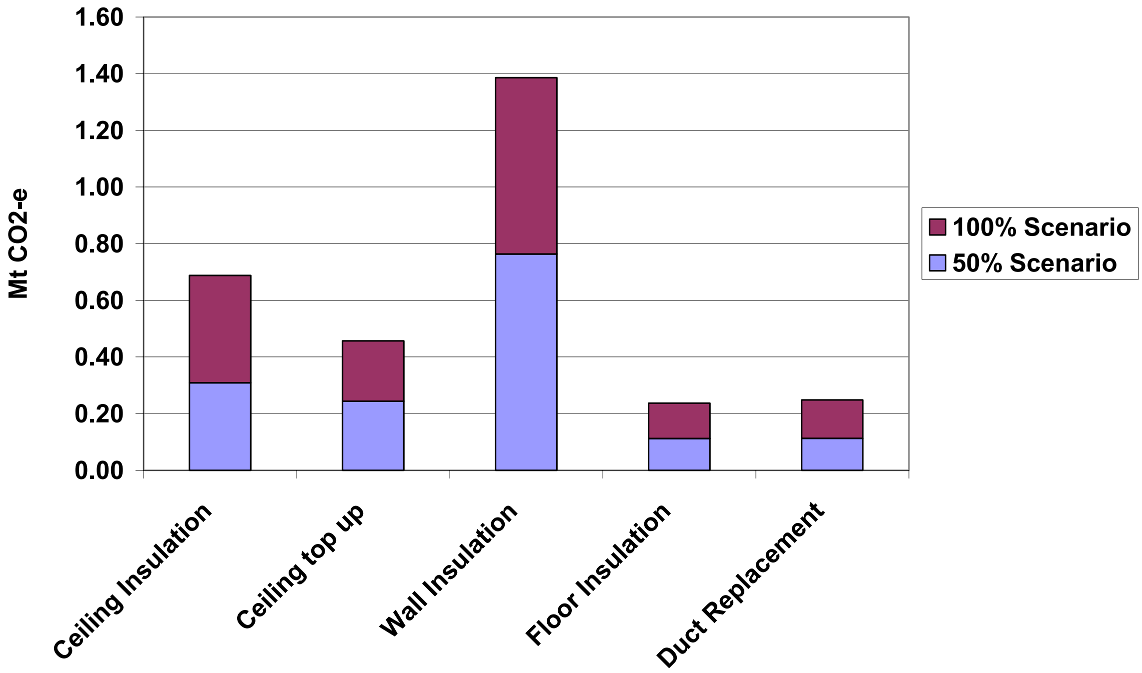


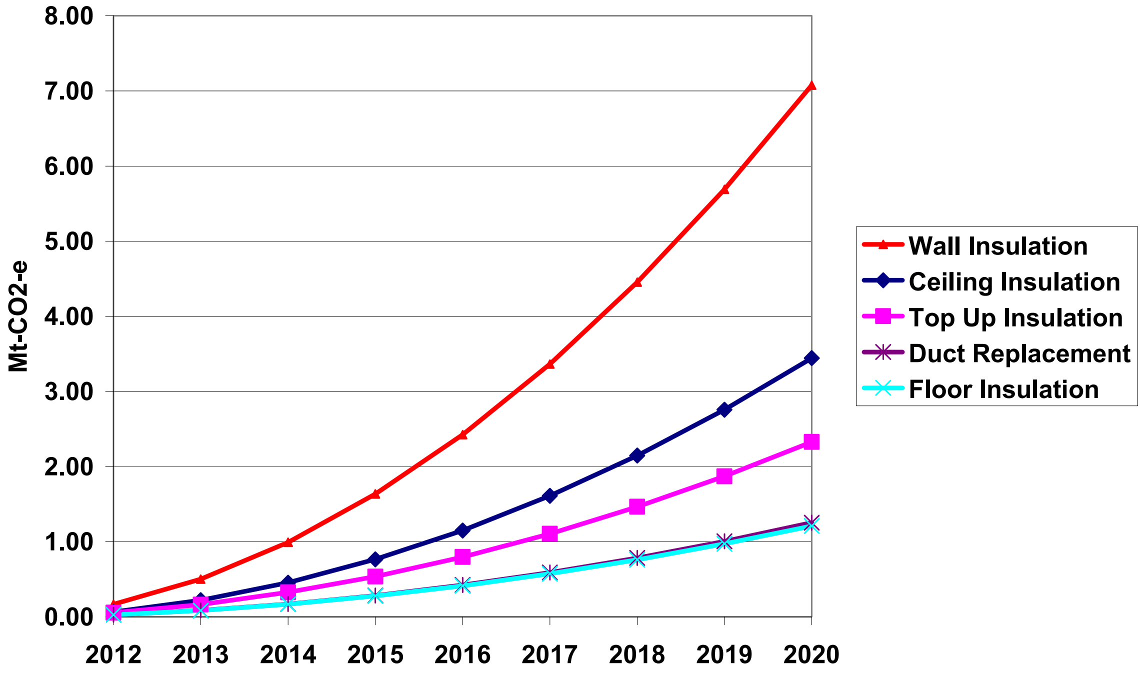
Table 46 provides state and national level estimates of projected potential cumulative greenhouse gas abatement to be realised between now and 2020 for each of the two implementation scenarios (see section 1.3.2) examined in this study. Figure 13 provides a graphical illustration of these savings at a national level.

As can be seen from Table 46, cumulative national savings in greenhouse gas emissions range from 1.2 to 7.1 million tonnes of CO2-e abatement depending upon the ESM adopted.

Table 46 : Potential Cumulative Greenhouse Gas Abatement by 2020 by Scenario (Mt CO2-e)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
With Ceiling Insulation Retrofit									
50% Scenario	0.86	0.24	0.26	0.04	0.07	0.00	0.03	0.02	1.51
100% Scenario	1.71	0.63	0.54	0.17	0.22	0.02	0.06	0.08	3.44
With Ceiling Insulation Top Up									
50% Scenario	0.22	0.71	0.03	0.13	0.06	0.02	0.00	0.06	1.24
100% Scenario	0.41	1.33	0.06	0.25	0.12	0.03	0.01	0.12	2.33
With Wall Insulation Retrofit									
50% Scenario	0.95	1.93	0.36	0.27	0.20	0.04	0.02	0.12	3.90
100% Scenario	1.72	3.50	0.66	0.49	0.36	0.08	0.04	0.22	7.08
With Floor Insulation Retrofit									
50% Scenario	0.12	0.39	0.01	0.02	0.01	0.01	0.00	0.02	0.57
100% Scenario	0.25	0.83	0.02	0.04	0.02	0.02	0.00	0.03	1.21
With Duct Replacement (Ducted Gas)									
50% Scenario	0.02	0.37	0.00	0.00	0.00	0.00	0.00	0.02	0.41
100% Scenario	0.04	0.82	0.00	0.01	0.01	0.00	0.00	0.03	0.91
With Duct Replacement (Ducted Reverse Cycle)									
50% Scenario	0.05	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.09
100% Scenario	0.11	0.03	0.02	0.03	0.01	0.00	0.00	0.01	0.21
With Duct Replacement (Ducted Cooling)									
50% Scenario	0.02	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.06
100% Scenario	0.06	0.01	0.02	0.02	0.02	0.00	0.01	0.00	0.14
With Duct Replacement (All Types)									
50% Scenario	0.09	0.39	0.02	0.03	0.02	0.00	0.01	0.02	0.57
100% Scenario	0.21	0.85	0.04	0.06	0.03	0.00	0.02	0.04	1.25

Figure 13 : Potential Projected Cumulative National Greenhouse Gas Savings (100% Scenario)



4.6 Peak Load Reduction Benefits

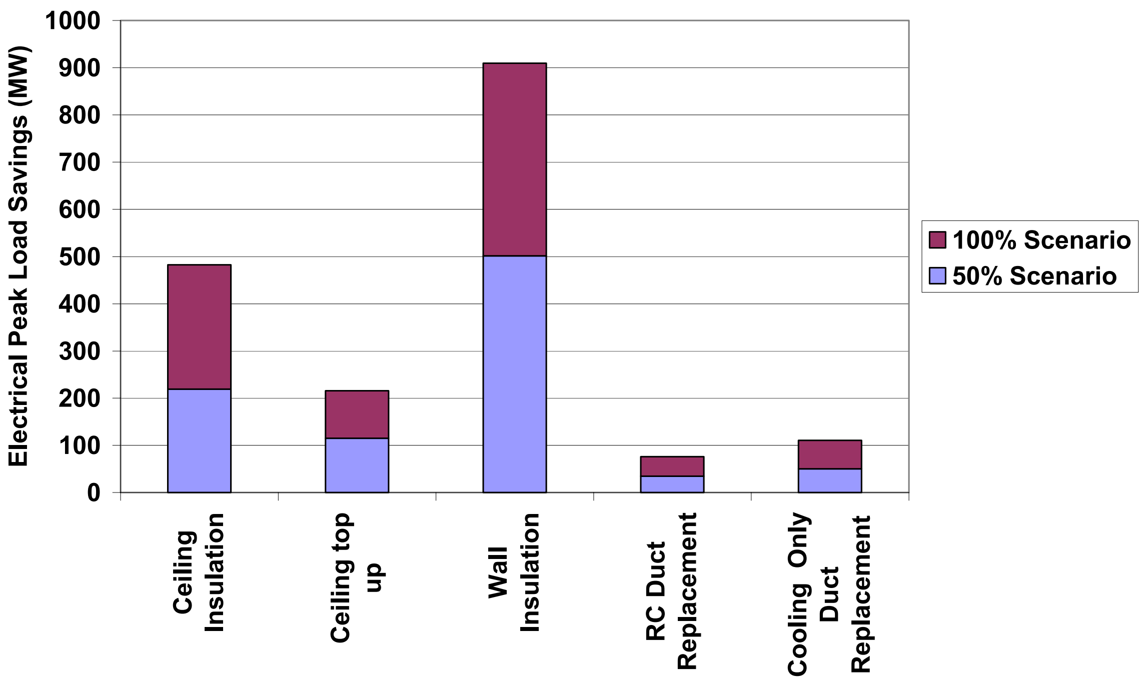
By applying the peak load assessment methodology (see Appendix 4 : Modelling Methodology – Peak Load) to the maximum space conditioning demand data extracted from the AccuRate simulations, the average per household peak summer electrical savings attributable to the retrofit of the various insulation based energy saving measures were determined. These reductions represent the predicted savings in required generating/transmission capacity during a summer maximum electrical demand event. Because the focus is upon summertime electrical peak demand, no assessment was undertaken for either ducted gas heater system duct replacement or floor insulation as neither of these two energy saving measures contribute to summertime electrical peak load reduction.

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 3.3 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 47. The peak load results are also shown graphically (at a national level) in Figure 14.

Table 47 : Estimated Potential Peak Load Savings by 2020 – by Scenario (MW)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
With Ceiling Insulation Retrofit									
50% Scenario	102.8	12.4	68.0	8.1	19.7	0.6	6.5	0.8	**218.9**
100% Scenario	205.5	30.8	141.9	26.6	57.7	4.1	12.7	3.0	**482.2**
With Ceiling Insulation Top Up									
50% Scenario	26.3	36.6	11.0	18.0	16.3	3.5	0.6	2.5	**114.9**
100% Scenario	49.4	68.6	20.7	33.9	30.7	6.6	1.2	4.6	**215.6**
With Wall Insulation Retrofit									
50% Scenario	148.2	109.0	124.0	45.4	58.9	9.5	3.1	3.6	**501.5**
100% Scenario	268.9	197.8	224.9	82.3	106.8	17.2	5.6	6.5	**910.0**
With Duct Replacement (Ducted Reverse Cycle)									
50% Scenario	17.1	4.2	2.6	7.3	2.4	0.2	0.2	0.7	**34.6**
100% Scenario	37.6	9.3	5.6	16.1	5.2	0.5	0.3	1.5	**76.1**
With Duct Replacement (Ducted Cooling)									
50% Scenario	18.0	10.8	3.6	9.8	6.5	0.2	0.7	0.6	**50.3**
100% Scenario	39.6	23.8	7.8	21.6	14.2	0.5	1.6	1.3	**110.5**

Figure 14 Estimated National Potential Peak Load Savings by 2020 – by Scenario (MW)



As can be seen from Table 47, potential national peak electrical load reductions by 2020 range between 100 MW and 900 MW depending upon the ESM and the retrofit scenario adopted.

In the study undertaken by the Institute of Sustainable Futures and Energetics for DCCEE (UTS 2010) estimates 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 47 the estimated monetary value of savings in peak load capacity attributable to the retrofit of the various insulation based energy savings measures can be determined, see Table 48. The values of peak load capacity avoided by jurisdiction from the ISF/Energetics study are shown in Table 48 (at the top of the table), along with the estimated $ savings in peak load capacity attributable to the retrofit of the various insulation based energy savings measures examined in this study. Table 49 shows the estimated cumulative $ savings in peak load capacity attributable to the retrofit of ceiling insulation.

By comparing the values in Table 48 : Estimated Potential Annual Peak Load Savings by 2020 – by Scenario ($ Million) with the values in Table 39 : Estimated State and National Level Fuel Cost Savings by 2020 ($M/annum), it can be seen that the annual savings in electrical system capacity costs add a benefit of between 30% and 50% in the case of the various insulating strategies. In the case of duct replacement, the benefits associated with peak load reduction in fact exceed the benefits that are derived from fuel cost savings.

Table 48 : Estimated Potential Annual Peak Load Savings by 2020 – by Scenario ($ Million)

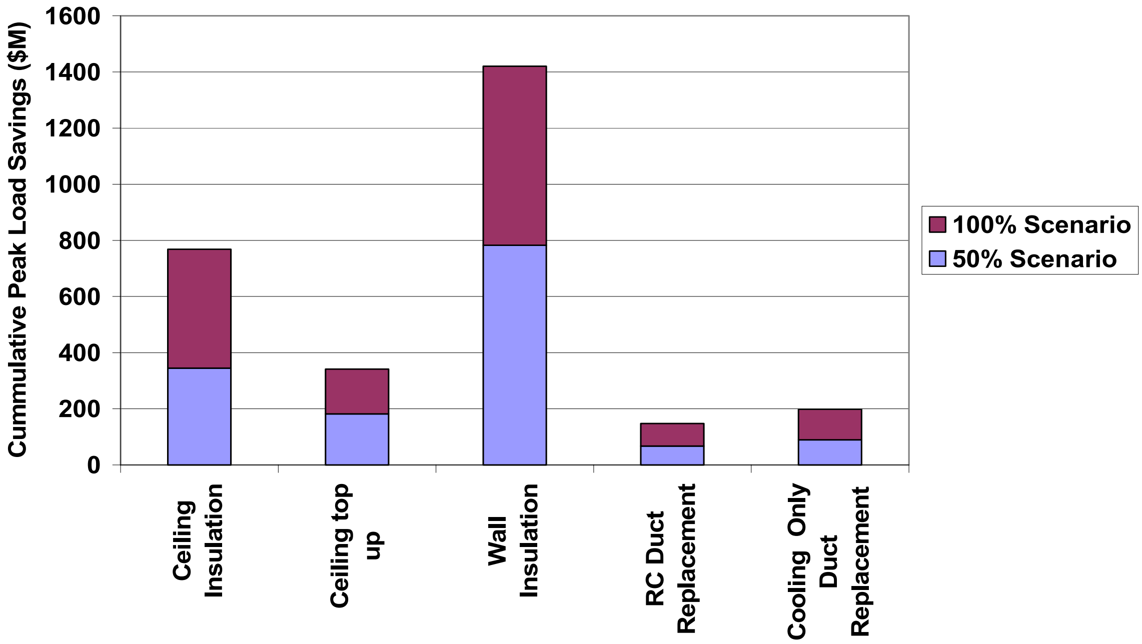
Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Value of avoidable generation transmission and distribution (UTS 2010)									
($m/MW/year)	**0.39**	**0.23**	**0.27**	**0.53**	**0.22**	**0.14**	**0.22***	**0.39**	**N/A**
With Ceiling Insulation Retrofit									
50% Scenario	40.1	2.8	18.4	4.3	4.3	0.1	1.4	0.3	**71.8**
100% Scenario	80.1	7.1	38.3	14.1	12.7	0.6	2.8	1.2	**156.8**
With Ceiling Insulation Top Up									
50% Scenario	10.3	8.4	3.0	9.6	3.6	0.5	0.1	1.0	**36.4**
100% Scenario	19.3	15.8	5.6	17.9	6.8	0.9	0.3	1.8	**68.3**
With Wall Insulation Retrofit									
50% Scenario	57.8	25.1	33.5	24.0	13.0	1.3	0.7	1.4	**156.7**
100% Scenario	104.9	45.5	60.7	43.6	23.5	2.4	1.2	2.5	**284.4**
With Duct Replacement (Ducted Reverse Cycle)									
50% Scenario	6.7	1.0	0.7	3.9	0.5	0.0	0.0	0.3	**13.1**
100% Scenario	14.7	2.1	1.5	8.5	1.1	0.1	0.1	0.6	**28.7**
With Duct Replacement (Ducted Cooling)									
50% Scenario	7.0	2.5	1.0	5.2	1.4	0.0	0.2	0.2	**17.5**
100% Scenario	15.4	5.5	2.1	11.4	3.1	0.1	0.4	0.5	**38.5**

* No NT value is available. Cost factor has been assumed to be the same as for WA

Table 49 : Estimated Potential Cumulative Peak load savings by 2020 – by Scenario ($ Million)

Estimate	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
With Ceiling Insulation Retrofit									
50% Scenario	199.4	13.0	90.0	16.3	17.4	0.0	7.1	1.1	**344.3**
100% Scenario	399.2	34.1	189.6	65.7	58.3	2.4	14.0	5.4	**768.5**
With Ceiling Insulation Top Up									
50% Scenario	51.2	42.0	14.8	48.3	17.6	2.4	0.7	4.8	**181.8**
100% Scenario	96.2	78.8	27.9	90.6	33.0	4.5	1.3	9.1	**341.4**
With Wall Insulation Retrofit									
50% Scenario	288.6	125.1	167.2	121.5	63.4	6.5	3.4	7.0	**782.8**
100% Scenario	523.7	227.0	303.3	220.5	115.1	11.8	6.2	12.8	**1420**
With Duct Replacement (Ducted Reverse Cycle)									
50% Scenario	34.1	4.9	3.5	19.8	2.6	0.1	0.2	1.4	**66.7**
100% Scenario	75.6	10.9	7.8	43.9	5.8	0.3	0.4	3.1	**147.7**
With Duct Replacement (Ducted Cooling)									
50% Scenario	35.9	12.6	4.9	26.6	7.2	0.2	0.8	1.2	**89.4**
100% Scenario	79.6	27.9	10.8	59.0	16.0	0.4	1.8	2.6	**198.0**

Figure 15: Estimated Potential Cumulative Peak load savings by 2020 – by Scenario ($ Million)



As can be seen from Table 49, by 2020, potential national cumulative saving in capital investment in infrastructure required to meet peak load peak electrical demand range between $0.1 billion and $1.4 billion depending upon the ESM and the scenario adopted.

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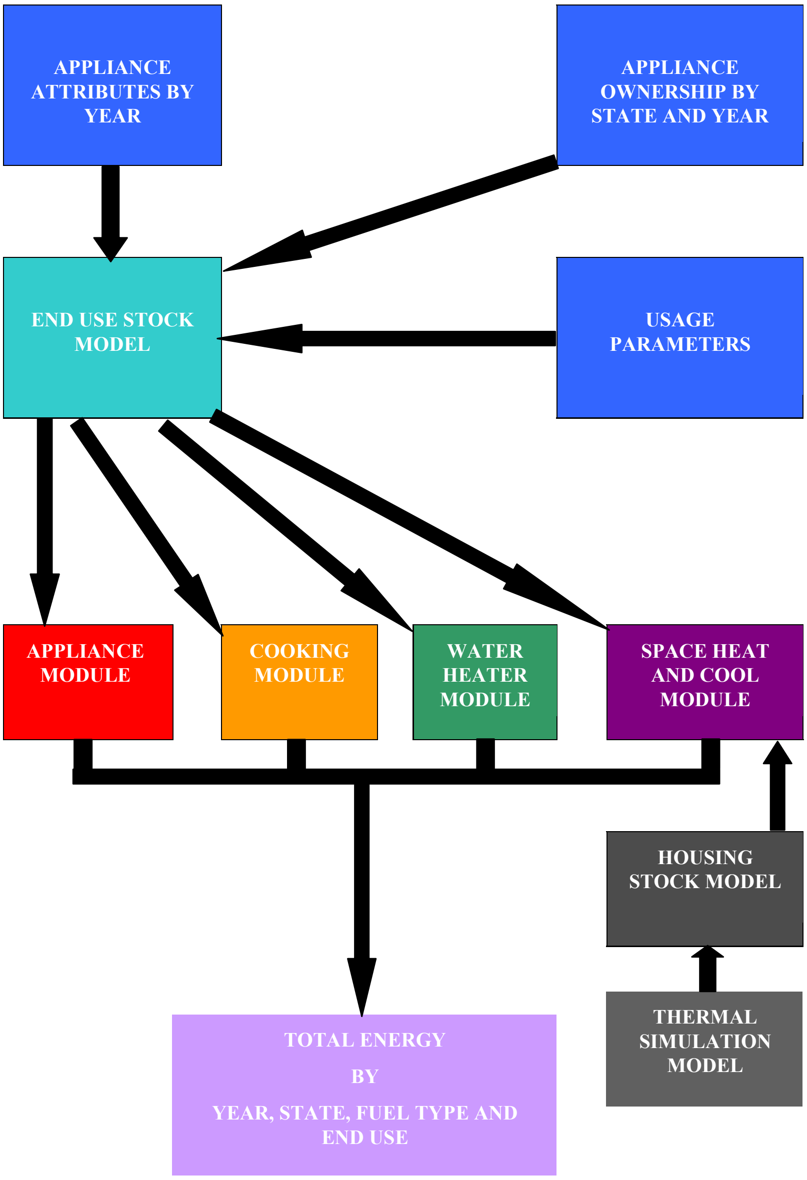
Appendix 1: Modelling Methodology – Energy

Overview

In this study the method for modelling household energy use (with and without energy saving measures 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 16. This is believed to be the most comprehensive "bottom up" model of residential energy use available and has been verified against top down (BREE) data.

Figure 16 : 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 two different cases; a base case without the energy savings measure and an improved case with the energy savings measure.

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 that 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 17. 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 50. 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 assumed not to be eligible to receive the proposed energy savings measures).

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 50 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 17 : Schematic of Housing Stock Model

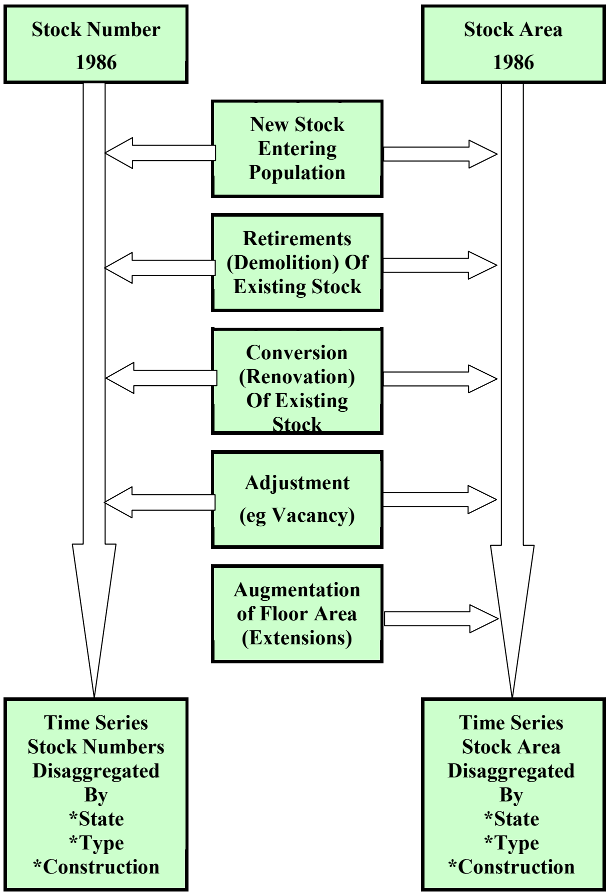


Table 50 : Penetration of Dwelling Types by State/Territory

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 52 (heating) and Table 53 (cooling).

Table 51 : 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 52 : 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

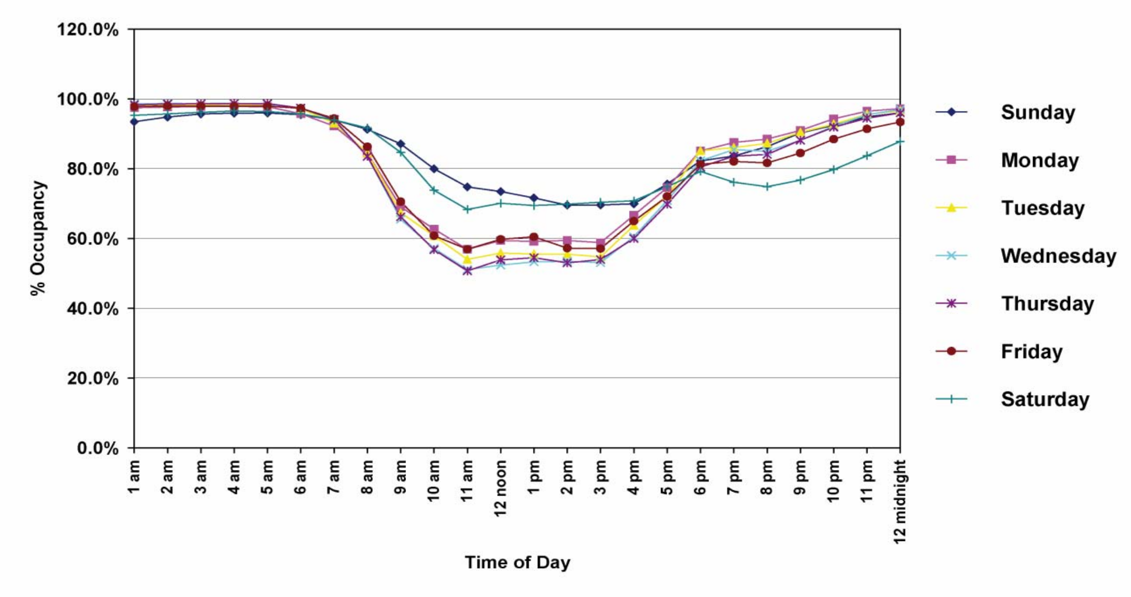
Adjustments for Occupancy

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 18 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 18. 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 18 : 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. 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 those examined in this study.

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 the range of energy savings measures examined in this study 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 16 and in more detail in section 6 of the study Energy Use in the Australian Residential Sector 1986-2020 (EES 2008)[11]. 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.

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.

[11] 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.

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 53).

Duct Retrofitting analysis

Estimates of energy savings relating to space conditioning duct replacement used the heating and cooling load calculations based on the AccuRate thermal performance modelling as described in the preceding sections.

In the analysis undertaken, the space conditioning equipment attributes were adjusted, in terms of the expected duct losses, so as to model both the BAU case (ie ductwork installed prior to the mid 1990s) and the improved cases as detailed in section 1.3.6.

The base case for heating applications was based on a study by Graham Palmer from the School of Aerospace, Mechanical and Manufacturing Engineering RMIT University entitled Field study on gas ducted heating systems in Victoria (September 2008). This study surveyed the efficiency of installed ductwork in 10 different dwellings ranging from 9 to 33 years old. The results of that analysis are plotted in Figure 19. From these results it can be seen that duct efficiencies can vary considerably from over 80% to as low as 50% with a clear trend towards declining efficiency with age of installation (in this analysis “efficiency” refers to the % of heating or cooling output from the space conditioning unit that is actually delivered to the internal spaces).

Table 53 : 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

For this study we are assuming that replacements will be undertaken to ductwork that is 15 or more years old (the shaded area in Figure 19). In this shaded area the trend line ranges from 70% efficiency to just below 60% efficiency, consequently it was assumed that the average efficiency of ductwork more than 15 years old was 65%.

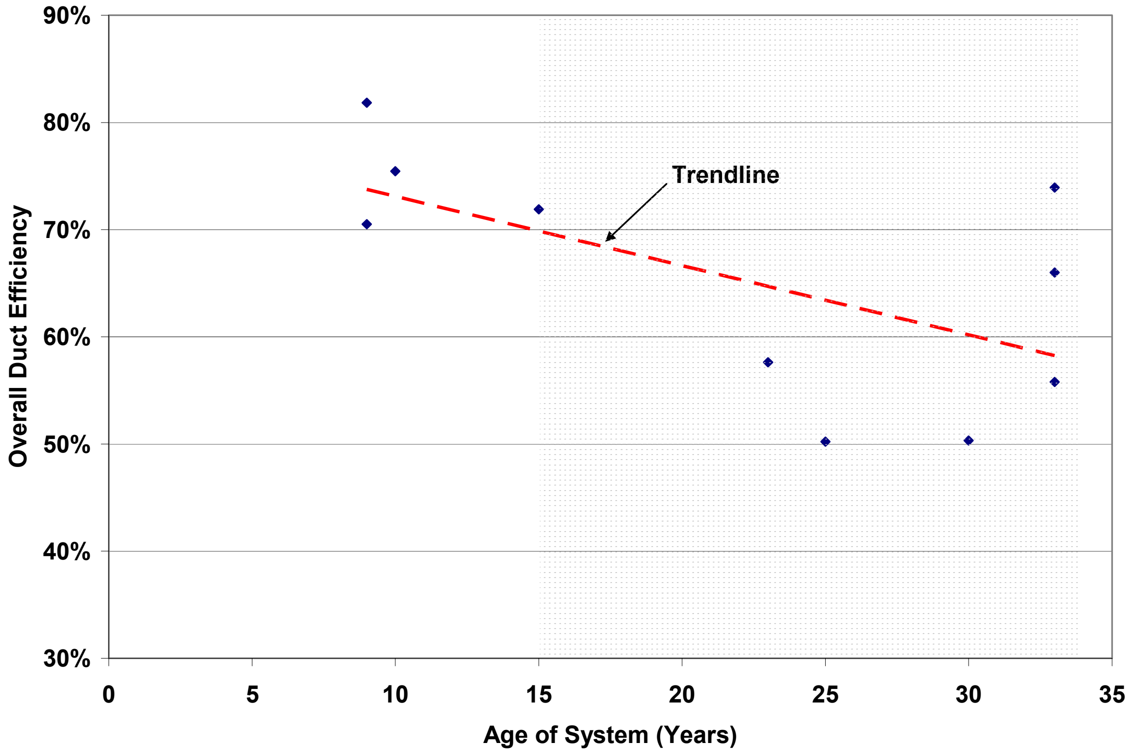
For the cooling mode efficiencies reference was made to a study undertaken by the University of South Australia entitled Development of an Evaluation Process for In Situ Measurement of the Impact of Ducting on Air Conditioning Systems (UNSA 2012). That study found that the replacement of older ducting with new R1.5 ducting resulted in an average reduction in energy consumption of 45%.

This value of 45% suggests an existing duct efficiency of approximately 50%[12] which is on par with the lowest field measured values found in the Victorian study. It should be noted that the Victorian study was focused on gas heating which in Victoria is most often underfloor whereas the SA study was focused on reverse cycle air-conditioning which is predominantly ducted through ceiling spaces. Through ceiling ducting, particularly in summer is subjected to a particularly severe environment with high

[12] This was in fact confirmed with the author of the report

temperatures and significant radiation gains. Consequently, for this study it has been assumed that in cooling mode the base case efficiency estimated in the SA study is a more appropriate value to use compared to the value derived in the Victorian study for underfloor gas ducted heating. However, the assumed base case ducting efficiency was set at a more conservative 57.5% ie mid way between the SA estimate (50%) and the Victorian estimate (65% for 15 year old ducting).

Figure 19 : Heating Duct Efficiency by Year of Installation (Palmer 2008)



Replacement ductwork was assumed to have the following efficiencies:

- R1 = 80% (from Pathways report – 2010)*
- R1.5 = 83%
- R2 = 85% (from Pathways report – 2010)*

These values were derived from estimates undertaken by Pitt and Sherry for the Department of Climate Change and Energy Efficiency in the study Pathway to 2020 for Increased Stringency in New Building Energy Efficiency Standards (DCCEE 2012).

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 1.3.7), the key aspects of the financial analysis included:

- The assumed cost of the investment in the particular energy saving measure
- 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 the particular energy savings measure.

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 each of the energy savings measures examined in this study were determined by ICANZ for each jurisdiction via a survey of its key members. The results of that survey are shown in Table 54. These prices are retail process and include the full cost of installation.

Table 54 : Average Cost of Retrofitting Ceiling Insulation (ICANZ 2011)

Type	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Ceiling Insulation costs								
R2 Batt	$6.90	$6.90	$6.90	$7.70	$9.90	$8.45	$7.75	$6.90
R2.5 Batt	$7.80	$7.80	$7.80	$8.60	$10.80	$9.35	$8.65	$7.80
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
Wall Insulation								
Common price for all jurisdictions as follows: • Option 1: Current Price Structure: $3,000 for an average (160m2) sized dwelling ie approx $18.75/m^2 of floor area • Option 2: Improved Price Structure assuming economies of scale: $2,000 for an average (160m2) sized dwelling ie approx $12.50/m^2 of floor area								
Floor Insulation								
R1.5	$17.35	$17.35	$17.35	$17.35	$17.35	$17.35	$17.35	$17.35
R2.0-2.1	$18.00	$18.00	$18.00	$18.00	$18.00	$18.00	$18.00	$18.00
R2.5	$18.65	$18.65	$18.65	$18.65	$18.65	$18.65	$18.65	$18.65
Duct Replacement*								
R1.0	$10.25	$10.25	$10.25	$10.25	$10.25	$10.25	$10.25	$10.25
R1.5	$13.05	$13.05	$13.05	$13.05	$13.05	$13.05	$13.05	$13.05
R2.0	$19.05	$19.05	$19.05	$19.05	$19.05	$19.05	$19.05	$19.05

* Note that the duct replacement rates are per m2 of conditioned floor area and include both supply and installation of new ducting as well as removal and disposal of old ducting

Fuel Costs

As noted in section 1.3.7, for this study three fuel pricing scenarios were examined, these were:

- BAU (Business as usual case, including the current carbon tax)
- BAU + (Business as usual case, including the current carbon tax but with a higher assumed rate of increase in the carbon tax between now and 2020)

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. Two alternative cases were assumed. Scenario 1, BAU where 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; the Scenario 2, BAU+ 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 retrofit of the various energy savings measures were made in this study (see

Table 47).

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 the particular energy savings measure through summertime peak load reduction (as reported in Table 48).

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 55. (UTS 2010)

Table 55 : 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 the proposed energy savings measures 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 56 (Electricity) and Table 57 (all other fuels).

Table 56 : 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 57 : 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 various energy savings measures. 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 those examined in this study.

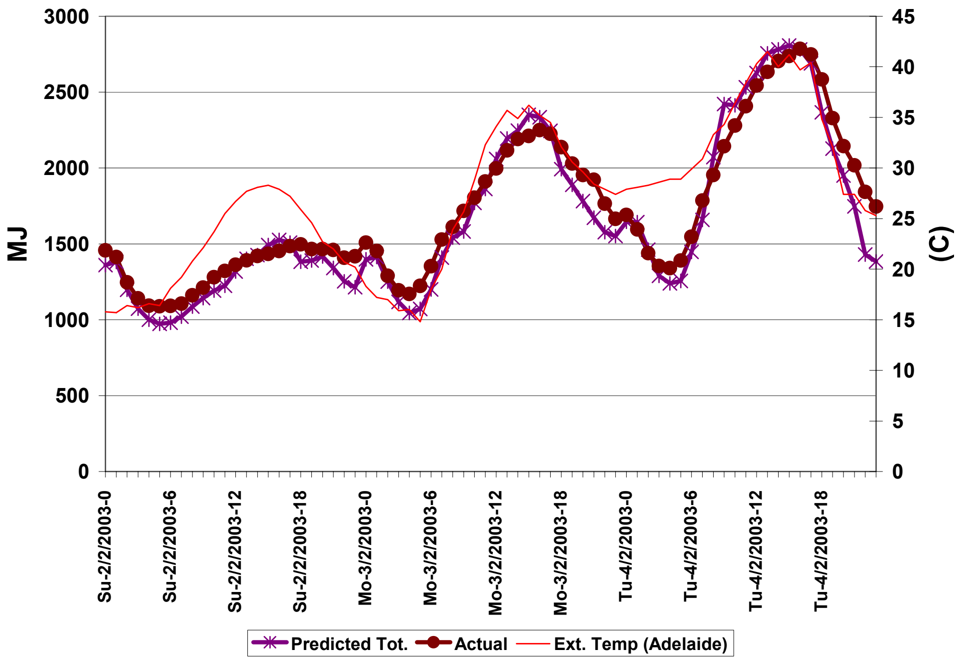
In 2004 Energy Efficient Strategies developed a model of Victoria's electrical peak load for VENCORP (The Victorian Energy Networks Corporation) and for the Australian Greenhouse Office (now The Department of Climate change and Energy Efficiency). The study that accompanied the model was entitled *Electrical 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 20.

Figure 20 : 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 various energy saving measures.

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 energy saving 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 the various energy saving measures examined in this study.

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 (AC) with a relatively peaky performance throughout the year, the CLF value is much lower, typically between 0.01 and 0.1. High AC demand is weather related so that AC 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 58. As expected for air conditioning, the smallest CFL occurs for the mildest climate where AC use is rarer, while the largest value occurs for the Florida climate where AC 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 59 were determined for each jurisdiction in Australia (noting that the EES model has only been rigorously tested in Victoria and South Australia).

Table 58: 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 59: 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 59 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 58) 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 59 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 energy saving measures. 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 the various insulation options 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. In the case of duct replacement a more conservative estimate of 20 years was adopted in consideration of the fact that in the future some of the retrofitted ducted systems may be replaced with non ducted systems.

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 60 below presents these results.

Table 60 Changes in Use of Heaters after the Installation of Insulation (Gas and Fuel 1991)

User Behavior 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.