REPORT

Energy Efficiency Upgrade Potential of Existing Victorian Houses

Sustainability Victoria

VICTORIA State Government

Energy Efficiency Upgrade Potential
of Existing Victorian Houses

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Foreword

There is a general recognition that the existing housing stock represents the largest potential for energy saving and greenhouse abatement in the residential sector. However, few studies have looked at how inefficient existing houses actually are, the extent to which their level of energy efficiency can be practically upgraded, or the cost and cost-effectiveness of doing this.

In 2009 Sustainability Victoria commenced a program of work to address these information gaps. Through the On-Ground Assessment study data was collected from a reasonably representative sample of 60 existing (pre-2005) Victorian houses and used to: determine the energy efficiency status of the houses; identify the energy efficiency upgrades which could be practically applied to the houses; and, to estimate the upgrade costs and energy bill savings which could be achieved.

The results of an initial pilot study based on 15 houses were published in 2010[1]. In this new report we present the results of our analysis for all 60 houses studied. Our latest results differ from the results presented in the initial pilot study report as we have used updated and improved methodologies in our analysis, and we have also used updated energy tariffs for our cost-benefit analysis.

A summary of results from this more comprehensive study of 60 houses was published in 2014[2]. Based on feedback received we reviewed and updated the costs for the ceiling and underfloor insulation measures; ceiling insulation costs were reduced while floor insulation costs were increased slightly. This has resulted in shorter paybacks for the various ceiling insulation measures and longer paybacks for underfloor insulation compared to the results published in 2014.

The report presents data on the average energy efficiency of the building shells of existing Victorian houses, as measured by their House Energy Ratings, and investigates the extent to which this level of energy efficiency can be increased through a range of common building shell upgrades. We also investigate the costs and benefits (energy saving, $ and greenhouse gas savings) of applying a range of building shell, lighting and appliance upgrades to the houses, allowing a comparison of the cost-effectiveness of different upgrade measures to be made.

In addition to presenting data on the average impact of different energy efficiency upgrades, we present data on the diversity of outcomes which can be achieved across the stock of 60 houses studied, for the individual upgrade measures as well as all upgrade measures.

The results from our On-Ground Assessment study are relevant to individual households which are assessing different energy efficiency upgrade options, and also give an insight into what could be achieved across the stock of existing (pre-2005) houses from the more widespread application of energy efficiency upgrades.

1 On-Ground Assessment of the Energy Efficiency Potential of Victorian Houses: Report on Pilot Study, MEFL for Sustainability Victoria, March 2010.

2 Victorian Households Energy Report, Sustainability Victoria, May 2014.

When reading this report it is important to keep in mind that the costs are based on the commercial cost of undertaking the upgrades, and do not include any government financial incentives which are available[3]. In some cases the upgrades can be undertaken as a DIY project, reducing the costs, and where government incentives are available these will also reduce costs to the householder. Further, in some cases the costs of the upgrades are decreasing and the economics of the upgrades are likely to improve over time. This is the case for LED lighting, television and heat pump clothes dryer upgrades.

The savings documented in the report are based only on the energy (and in some cases water) bill savings which result directly from the upgrades studied. We have not included any value associated with the greenhouse gas savings resulting from the upgrades, or comfort or health improvements which could result from the building shell upgrades. Currently, there is not widespread agreement on how to include the value of greenhouse abatement in such analysis, and as yet there is no evidence base which would allow the comfort and health benefits for households in Victoria to be included. While some of these benefits might accrue directly to the households, they will be shared with governments and society more broadly.

The energy (and water) bill savings are based on the energy (and water) tariffs which applied at the time the analysis was undertaken. In general, these are on an upward trend, which means that the value of the savings should increase in real terms over time.

Taken together, the costs and savings assumptions which have been used as the basis of the analysis presented in this report mean that we present a reasonably conservative picture of the economics of upgrading the energy efficiency of existing Victorian houses.

The results presented in this report are estimates based on modelling, using data collected from real houses which have been assessed to identify the upgrades which can be practically applied. The next phase of our work on the existing housing stock is to implement energy efficiency upgrades in houses and assess the impacts achieved. Through the Residential Energy Efficiency Retrofit Trials we are implementing key energy efficiency retrofits[4] in existing houses and monitoring the impact to assess the actual costs and savings, the impact of the upgrades on the level of energy service provided, and the householder perceptions and acceptance of the upgrade measures. The results of this work will be published in a forthcoming series of reports.

3 The Victorian *Energy Saver Incentive* Scheme enables Victorian households to obtain a subsidy for a wide range of energy efficiency upgrades, and in some cases the upgrades are free. Small Technology Certificates (STCs) also support the installation of solar water heaters.

4 To end 2015 we have trialled halogen lighting replacements, comprehensive air sealing, pump-in cavity wall insulation, gas heating ductwork upgrades, window film secondary glazing, combined ductwork and gas heating upgrades, solar air heaters, heat pump clothes dryers, pool pump upgrades, gas water heater upgrades, halogen downlight replacement combined with ceiling insulation remediation, and comprehensive (whole house) upgrades.

Acknowledgements

This study is based on the analysis of data collected from 60 Victorian houses. We would like to especially thank these households for their participation in the study by allowing access to their houses to enable data collection relating to the design and construction of their houses as well as data collection on appliances and lighting, the conduct of blower door (air pressurisation tests) to measure air leakage rates, providing gas billing data, and undertaking surveys relating to their use of heating and cooling and other appliances.

For the study Sustainability Victoria contracted Moreland Energy Foundation Limited (MEFL) to manage household recruitment, data collection, some data analysis and report writing. In particular we would like to thank Govind Maksay, who was MEFL's project manager for this work. MEFL sub-contracted a number of organisations and individuals to undertake elements of the project. We have acknowledged the different organisations which were involved below.

	Initial Pilot Project	Follow On Projects
Project conception, design & funding, and project oversight	Sustainability Victoria	
Lead contractor / project manager	MEFL	
Household recruitment and liaison	MEFL	
Air leakage testing and draught proofing cost estimates	Air Barrier Technologies	
Building shell data collection & FirstRate5 modelling, building shell upgrade cost estimates	Mitsouri Architects, Greencheck, Nycole Wood & Tony Isaacs	Energy Makeovers, RMIT Centre for Design, MEFL
Appliance data collection	Peter Kennedy, Kevin Fregon & Ross Mulder	Energy Makeovers
Analysis & reporting for individual projects	MEFL, Energy Consult	RMIT Centre for Design, MEFL
Overall analysis of 60 houses and final report	Sustainability Victoria	

Contents

Abbreviations and Acronyms

ABS	Australian Bureau of Statistics - www.abs.gov.au
BoM	Bureau of Meteorology - www.bom.gov.au
CEC	Comparative Energy Consumption
CFL	Compact Fluorescent Lamp
COAC	Cooling Only Air Conditioner
CoP	Coefficient of Performance
DG	Double glazing
EER	Energy Efficiency Ratio
Elec	Electricity
HER	House Energy Rating
kW	kilowatt
LED	Light Emitting Diode, a type of lamp
MEFL	Moreland Energy Foundation Limited
MJ	Mega joules
OGA	On-Ground Assessment
RAC	Reverse-cycle air conditioner
RMIT	RMIT University Centre for Design
SV	Sustainability Victoria

Glossary

Adjusted capital cost

Cost which has been adjusted for all appliance upgrade measures, to take into account the fact that most appliances will only be upgraded at the end of their useful life. The adjusted cost takes into account the age of the appliance, the typical replacement life of the appliance, and the differential cost between a high efficiency upgrade appliance and the average new appliance sold.

Building shell

The key (external) elements of a house, including walls, roof/ceiling, floor and windows.

Capacity

A measure of the "size" of an appliance, which relates to the level of energy service being provided. It is different for different appliance types – for example the volume in litres for refrigerators, the rated heat output in kilowatts (kW) for a heater, or the rated number of place settings for a dishwasher.

Coefficient of Performance (CoP)

Used to define the efficiency of a refrigerative air conditioner when heating. Is the rated heat output (kW) divided by the rated power input (kW) on the heating cycle.

Comparative Energy Consumption (CEC)

Figure provided on the Energy Rating label for electrical appliances. Gives the annual energy consumption in kWh, when the appliance is tested under standard conditions.

Conversion efficiency

The ratio of the useful energy output divided by the energy input.

Energy Efficiency Ratio (EER)

Used to define the efficiency of a refrigerative air conditioner when cooling. Is the rated cooling output (kW) divided by the rated power input (kW) on the cooling cycle.

Heating & cooling load

Annual energy output of heating/cooling devices required to maintain certain thermal comfort conditions inside the home.

Imported hot water

Hot water imported into a clothes washer or dishwasher from a water heater.

Maintenance rate

Fixed daily energy consumption required for some gas water heaters and heaters. Can be related to energy use by a pilot light (water heaters and heaters) and/or heat losses through the walls of the hot water cylinder.

Ownership (of appliances)

Average number of appliances found in households which have at least one of the specific appliance type in question.

Penetration (of appliances)

Percentage of households which have at least one of a particular appliance type.

Refrigerative air conditioner

Air conditioner which uses a heat pump cycle to provide either heating or cooling, or both.

Reverse-cycle air conditioner

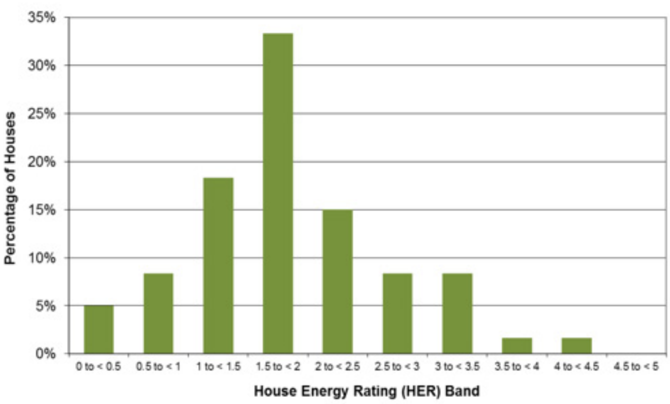
A refrigerative air conditioner which can provide both heating and cooling.

Executive Summary

Sustainability Victoria's On-Ground Assessment study involved the collection and analysis of energy efficiency data from a reasonably representative sample of 60 existing (pre-2005) class 1 Victorian dwellings. This data was analysed to estimate the energy efficiency upgrade potential of Victoria's existing housing stock. We determined the energy efficiency status of the houses' existing building shells (as measured by their House Energy Ratings) as well as the energy performance of the existing lighting and key appliances. We then estimated the costs and savings (energy, $ and greenhouse gas) which could be achieved through the building shell, lighting and key appliance upgrades which were both possible and practical for the houses, to help identify those energy efficiency upgrades which can provide the "biggest bang for buck". In addition to providing information on the impact of the various upgrades studied when they are applied, this work has also given an insight into the impacts which could be achieved across the Victorian housing stock.

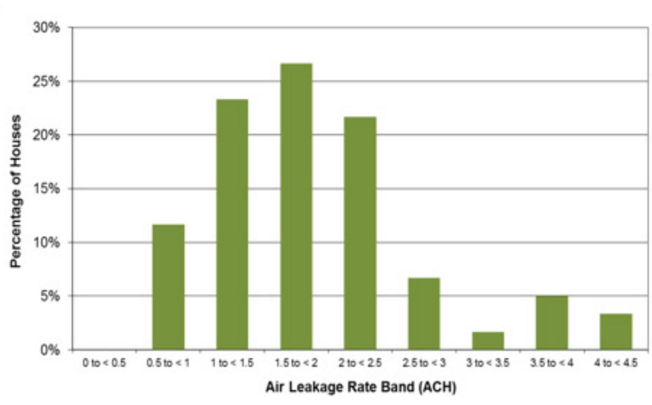
The average House Energy Rating (HER) of the 60 OGA study houses was 1.81 Stars, making these houses considerably less efficient than new 6 Star houses constructed today. The average HER of the houses increased steadily over the last century, with a significant increase evident from the 1990s, corresponding to the introduction of mandatory insulation requirements for new houses in Victoria in 1991. The average HER of houses constructed prior to 1990 was 1.57 Stars and the average HER of the houses constructed between 1990 and 2005 was 3.14 Stars. In addition to the mandatory insulation requirements introduced in 1991, certain trends in the construction of houses are also likely to have contributed to the observed increase in efficiency, including the shift to concrete slab-on-ground construction for floors and the elimination of wall vents from most houses constructed since the 1990s.

DISTRIBUTION OF HERS FOR THE OGA STUDY HOUSES



One reason for the low level of energy efficiency of the existing houses studied was a high level of air leakage. The natural average air leakage rate for the OGA study houses was 1.90 air changes per hour (ACH), with houses constructed prior to 1990 having a slightly higher average natural air leakage rate (2.02 ACH) and houses constructed between 1990 and 2005 having a considerably lower natural air leakage rate (1.20 ACH). Much of this difference is likely to be related to the changing trends in house construction noted above, as well as the impact of "wear and tear" on older houses.

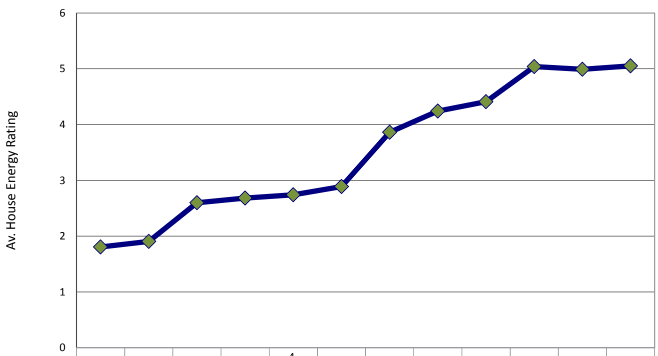
DISTRIBUTION OF MEASURED AIR LEAKAGE RATES FOR THE OGA STUDY HOUSES



As well as the existing houses having quite inefficient building shells, the lighting and appliances found in the OGA study houses was considerably less energy efficient than new lighting and appliances which are available today. This was particularly the case for the lighting, heating and cooling, water heating, refrigerators and televisions.

The impact on the House Energy Rating of applying a total of 11 different building shell upgrades to the OGA study houses was modelled. Through the application of all measures we estimate that the average HER of the houses could be increased from 1.81 Stars to 5.05 Stars, an increase of 3.24 Stars. The average HER of the pre-1990 houses was increased from 1.57 Stars to 5.00 Stars (an increase of 3.42 Stars) while the average HER of the post-1990 houses was increased from 3.14 Stars to 5.37 Stars (an increase of 2.23 Stars), only slightly higher than the pre-1990 houses. The wall insulation upgrade was the main energy efficiency measure which was responsible for bringing the HERs of the pre- and post-1990 houses much closer together.

STOCK AVERAGE HER AS BUILDING SHELL UPGRADES PROGRESSIVELY APPLIED



	Existing House	1. Ceiling Insul. (easy)	2. Draught sealing	3. Seal Wall Cavity	4. Reduce Sub-Floor Vent.	5. Under floor insul.	6. Wall insul.	7. Ceiling insul. (difficult)	8. Ceiling insul. top-up	9. Double glazing	9a. Drapes & Pelmets	10. External Shading
Av. HER	1.81	1.91	2.60	2.68	2.74	2.89	3.86	4.24	4.41	5.04	4.99	5.05

Wall insulation (0.97 Star increase), draught sealing (0.69 Stars), double glazing (0.63 Stars) and drapes and pelmets (0.58 Stars) were the building shell upgrade measures which had the biggest impact on increasing the average HER of the OGA study houses.

These measures all had quite a large impact when implemented and also had a high level of applicability across the stock of OGA study houses. Ceiling insulation measures had a large impact when implemented but as they had a much lower level of applicability – most houses already have a certain level of ceiling insulation – they had a lower impact on the average HER of the houses.

The average cost of increasing the HER of the existing houses to just above 5 Stars was $11,405 if it was assumed that only drapes and pelmets were used (and not double glazing) and $24,742 if it was assumed that double glazing was used (and not drapes and pelmets). The average cost of upgrading the pre- and post-1990 houses was quite similar.

IMPACT OF ALL MODELLED UPGRADE MEASURES, ACROSS THE STOCK OF 60 HOUSES

		Av. Energy Saving (MJ/Yr)						
Across stock	**% Houses Applied To**	**Gas**	**Elec**	**Total**	**Av. GHG Saving (Kg/Yr)**	**Av. Saving ($/Yr)**	**Av. Cost ($)**	**Av. Payback (Yrs)**
LF Shower Rose	56.7%	1,333	69	**1,402**	95	$57.9	$48.8	0.8
Ceiling Insulation (easy)	11.7%	958	32	**990**	64	$19.3	$78.6	4.1
Lighting	93.3%	-	1,202	**1,202**	365	$93.5	$535.8	5.7
Draught Sealing	98.3%	7,809	221	**8,030**	496	$153.9	$1,019.8	6.6
Clothes Washer	55.0%	135	16	**152**	12	$24.9	$190.9	7.7
Water Heater – High Eff. Gas	58.3%	460	1,004	**1,463**	330	$58.2	$477.3	8.2
Ceiling Insulation (difficult)	33.3%	1,630	68	**1,698**	111	$33.8	$278.2	8.2
Heating	80.0%	6,239	215	**6,454**	411	$125.9	$1,110.6	8.8
Refrigerator	86.7%	-	1,202	**1,202**	365	$93.5	$1,103.7	11.8
Reduce Sub-Floor Ventilation	21.7%	589	12	**601**	36	$11.2	$166.7	14.9
Seal Wall Cavity	50.0%	903	24	**927**	57	$17.6	$270.4	15.3
TV	95.0%	-	696	**696**	273	$54.1	$964.3	17.8
Ceiling Insulation (Top Up)	43.3%	853	22	**875**	54	$16.6	$335.3	20.2
Underfloor Insulation	40.0%	1,803	10	**1,813**	102	$32.4	$784.7	24.3
Dishwasher	43.3%	-	112	**112**	34	$10.4	$258.1	24.9
Clothes Dryer – Heat Pump	45.0%	-	353	**353**	107	$27.5	$727.7	26.5
Cooling	40.0%	-	160	**160**	49	$12.5	$464.8	37.3
Wall Insulation	95.0%	5,283	130	**5,412**	331	$102.5	$3,958.7	38.6
Drapes & Pelmets	100.0%	2,209	54	**2,263**	139	$42.9	$2,035.9	47.5
Double Glazing	100.0%	2,278	66	**2,344**	146	$45.0	$12,145	270
External Shading	31.7%	-	9	**9**	3	$0.7	$463.6	694
Total (ex Double Glazing)		**30,203**	**5,610**	**35,813**	**3,434**	**$989**	**$15,274**	**15.4**
Total (ex Drapes)		**30,273**	**5,621**	**35,894**	**3,441**	**$991**	**$25,383**	**25.6**

In addition to modelling the impact of building shell upgrades on the HER of the houses we modelled the costs and benefits (energy saving, $ and greenhouse gas savings) of a range of building shell, lighting and appliance upgrades. Across the stock of OGA study houses it was estimated that the application of all relevant building shell upgrade measures could achieve average energy savings of around 22,600 MJ/yr (dominated by gas), average energy bill savings of $430 per year, and annual greenhouse gas savings of around 1.4 Tonnes/yr. The average cost of these upgrades was $9,392 if drapes and pelmets were used and $19,501 if double glazing was used. Draught sealing, wall insulation, double glazing and drapes and pelmets provided the largest overall savings across the stock of houses. Draught sealing (6.6 year payback), and insulating an uninsulated ceiling (4.1 year and 8.2 year payback for the easy and difficult cases respectively) were the most cost-effective upgrade measures.

The application of the lighting and appliance upgrade measures to the OGA study houses was estimated to achieve average energy savings of around 13,200 MJ/yr (more evenly split between electricity and gas) , average energy (and water) bill savings of $558 per year, and annual greenhouse gas saving of around 2.0 Tonnes/yr. The average cost of these upgrades was $5,882, making the lighting and appliance upgrades more cost effective overall than the building shell upgrades. The largest average savings were provided by the heating, low flow shower rose, water heating, lighting and refrigerator upgrades. Low flow shower rose (0.8 year payback), lighting (5.7 year payback), clothes washer (7.7 year payback), water heating (8.2 year payback) and heating (8.8 year payback) upgrades were the most cost effective upgrade measures.

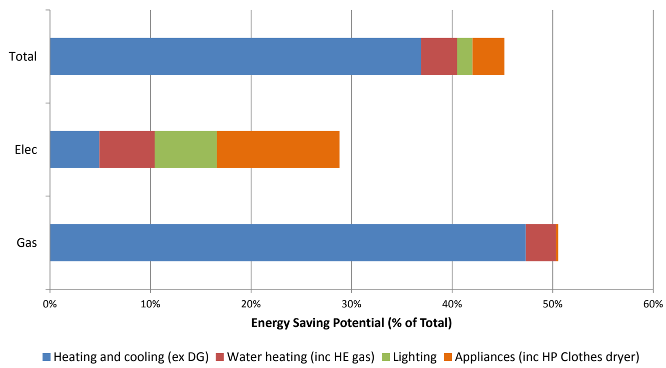
Overall we estimate that by applying all energy efficiency upgrade measures modelled in the OGA study houses it would be possible to achieve average energy savings of around 35,800 MJ/yr (split approximately 84% - 16% between electricity and gas) for an average bill saving of around $990 per year, and average greenhouse gas savings of around 3.4 Tonnes/yr. The average cost of all the upgrades was $15,274 if drapes and pelmets were used and $25,383 if double glazing was used. The results of our modelling for all energy efficiency upgrade measures are shown in the table above.

If all of the energy efficiency upgrade potential identified in our main analysis was applied to the existing (Pre-2005) houses that are still standing today, we estimate that this would generate total annual energy bill savings of at least $1,500 Million per year and total annual greenhouse gas abatement of at least 5,200 kT per year. Even if only the more cost-effective energy efficiency upgrades were applied to all existing houses, the energy and greenhouse savings would still be very significant. If all measures with a payback up to 10 years were applied across the existing housing stock we estimate that this would generate annual energy bill savings of at least $900 Million per year and total annual greenhouse gas abatement of at least 3,100 kT per year.

Our analysis found that there was a very wide diversity in the energy savings (and consequently paybacks) which could be achieved for any given energy efficiency upgrade measure. Much of this diversity is due to the level of energy service which was being provided in a particular house (related to the number of occupants, size of the house and appliance settings) and to how different appliances are used. This high level of diversity means that while the average results presented in this report can be used as a guide for the most cost-effective energy efficiency upgrade options, careful assessment is required for each individual household to identify the appropriate and most cost effective upgrade options.

Our analysis suggests that the total energy saving potential from all the main measures modelled in this study is 45.2% of total energy use, 50.5% of total gas use and 28.8% of total electricity use. Both the overall energy saving potential and the gas saving potential are dominated by the heating and cooling measures. In contrast, the electricity saving potential is dominated by the appliance upgrade measures, with the savings potential for lighting and water heating also being significant.

ESTIMATED ENERGY SAVING POTENTIAL OF OGA STUDY HOUSES



While the results of our study are based on modelling for the 60 selected houses, we believe that they give a good indication of the energy saving potential and the economics of energy efficiency upgrades across the wider stock of existing (pre-2005) Victorian houses. If anything, the characteristics of the houses included in our study suggest that slightly higher savings might be possible. Further, the energy efficiency upgrade measures which we have assessed as part of this study do not cover all possible measures, which suggests that larger overall energy savings could be achieved.

The OGA study has focussed exclusively on "hardware" measures, and significant additional savings – of the order of 10% to 20% - could be possible through better energy use practices, requiring behaviour change. In addition to any savings which might be possible through behaviour change, there are a range of "hardware" measures which we have not modelled in this study which could yield additional energy savings:

- Installation of rooftop photovoltaic (PV) panels to generate electricity, while not an energy efficiency measure as such, could easily reduce mains electricity consumption for the average household by 12% to 24% as well as feeding electricity into the grid. The PV panels do not save electricity, but they do off-set some of the mains electricity consumption;
- replacement of old existing gas heating ductwork with high efficiency new ductwork could give additional savings of up to 25% in the houses in which this measure is possible;
- installation of Standby Power Controllers (SPCs) attached to nests of home entertainment equipment and computer equipment can automatically reduce standby power use, which accounts for around 10% of overall electricity consumption;
- remediation of ceiling insulation, especially where downlights have been used as the main form of lighting, could give further savings on heating and cooling energy use;
- installation of solar air heating devices to provide supplementary heating;
- installation of "grey water" heat recovery systems to recover heat from the shower drain; and,
- the use of voltage optimisation devices connected to a house's electrical switchboard may be able to achieve further electricity savings.

Also, it is important to keep in mind that the analysis presented in this report is based on a snapshot in time. The housing stock is dynamic and changes from year to year. While the building shells of the houses are likely to change quite slowly, the stock of lighting and appliances changes much more rapidly. Given this, it is likely that some of the energy efficiency upgrade potential identified in this report has already been taken up, and that under business-as-usual more of the energy efficiency potential will be progressively taken up over time due to a combination of: general improvement in the energy efficiency of lighting and appliances as time goes on; government regulations relating to minimum energy performance standards (MEPS) for appliances and energy efficiency regulations which apply to home renovations; and increasing consumer preference for higher efficiency lighting and appliances in response to increasing energy prices.

The costs used as the basis of the analysis in this report are based on the commercial cost of undertaking the upgrades, and do not include any of the government financial incentives that are available to Victorian households, including subsidies through the Energy Saver Incentive and Small Technology Certificates (STCs). In some cases the upgrades can be undertaken as a DIY project, reducing the costs, and where government incentives are available these will reduce the cost to the householder. In some cases the costs of the upgrades are decreasing and the economics of the upgrades is likely to improve over time. This is the case for LED lighting, televisions and heat pump clothes dryers. There may also be some areas where further market development and increased competition could result in lower upgrade costs, for example, pump in cavity wall insulation.

The savings documented in the report are based only on the energy (and in some cases water) bill savings which result directly from the upgrades studied. We have not included any value associated with the greenhouse gas savings resulting from the upgrades, or comfort or health improvements which could result from the building shell upgrades. Currently, there is not widespread agreement on how to include the value of greenhouse abatement in such analysis, and as yet there is no evidence base which would allow the comfort and health benefits for households in Victoria to be included. While some of these benefits might accrue directly to the households, they will be shared with governments and society more broadly.

Energy efficiency upgrades which improve the energy efficiency of the building shell will result in improved occupant comfort in both summer and winter and could have significant health benefits, especially for low income households. Studies evaluating the costs and benefits of large-scale insulation programs undertaken in New Zealand[5] suggest that the associated health benefits could be at least one and a half times the value of the energy bill savings. There have been no similar studies in Australia to date.

There are also a range of additional co-benefits which are likely to result from the application of energy efficiency upgrades, especially if there is widespread uptake across the existing Victorian housing stock:

- Energy efficiency upgrades which result in electricity savings help to put downward pressure on the price of electricity by reducing future investment in electricity generation and supply infrastructure. Further, as residential electricity consumption is concentrated morning and evening peaks in the electricity supply system the resulting electricity demand savings help to supress the wholesale price of electricity;
- There are potentially significant flow-on economic benefits from the more widespread uptake of energy efficiency. Many energy efficiency upgrades are quite labour intensive, so there is significant potential to generate local employment. Further, the energy bill savings mean that households have greater disposable income, and this can generate further benefits as it is spent and flows through the economy.

The energy (and water) bill savings are based on the energy (and water) tariffs which applied at the time the analysis was undertaken. As energy prices seem likely to continue to rise in real terms, the cost-effectiveness of many of the energy efficiency upgrades studied in this report are likely to improve.

Taken together, the costs and savings assumptions which have been used as the basis of the analysis presented in this report mean that we present a reasonably conservative picture of the economics of upgrading the energy efficiency of existing Victorian houses.

5 *Retrofitting houses with insulation: a cost-benefit analysis of a randomised community trial,* Dr Ralph Chapman *et al,* February 2007, funded by NZ Health and Research Council & Energy Efficiency and Conservation Authority; *Cost Benefit Analysis of the Warm Up New Zealand Heat Smart Program,* Arthur Grimes *et al,* prepared for the Ministry of Economic Development, October 2012.

1. Introduction

Reasons for the study

There is a general recognition that the existing housing stock represents the largest potential for energy saving and greenhouse abatement in the residential sector. However, few studies have looked at how inefficient existing houses actually are, the extent to which their level of energy efficiency can be practically upgraded, or the cost and cost-effectiveness of doing this.

In 2009 Sustainability Victoria commenced a program of work to address these information gaps. Through the On-Ground Assessment project data was collected from a reasonably representative sample of 60 existing (pre-2005) stand-alone Victorian houses and used to: determine the energy efficiency status of the houses; identify the energy efficiency upgrades which could be practically applied to the houses; and, estimate the upgrade costs and energy bill savings from implementing the upgrades.

The analysis undertaken for this project is based on key building shell, lighting and appliance upgrades. It provides a perspective from both the individual household level and also across the stock of 60 houses which were analysed. This means that the learnings from the study will be useful for providing better information on the likely cost, savings and cost-effectiveness of different energy efficiency upgrade options to households, and also for giving an indication of what could be achieved across the Victorian housing stock from a range of energy efficiency upgrade measures.

How the study was undertaken

The On-Ground Assessment study was conceived, designed and funded by Sustainability Victoria, although the management of key elements of the project was contracted out to the Moreland Energy Foundation Limited (MEFL), who engaged a range of sub-contractors to undertake certain functions (see the Acknowledgements section of this report).

The study was undertaken in five main stages over a number of years:

1. An initial pilot project was undertaken in 2009. Data was collected from a total of 15 houses, analysed and a report published [MEFL/SV 2010]. A subsequent analysis of gas billing data for these houses found that the analysis methodology used in the pilot study was substantially over-estimating the energy savings from the building shell upgrade measures. Sustainability Victoria worked with MEFL to develop a better analysis methodology based on more accurate modelling of the heating/cooling usage profile of the houses, which was then used in subsequent stages of the study;
2. In 2010, data was collected and analysed for an additional 30 houses. The improved energy saving estimation methodology was used for the building shell analysis, two additional building shell upgrades were modelled, and data on shower rose flow rates was also collected and analysed;
3. In 2011, MEFL was engaged to re-analyse the building shell data from the initial pilot project of 15 houses, to collect shower-rose flow rate data from these houses, and to re-do the building shell energy saving estimates so that they were consistent with the stage 2 study;
4. In 2012, data was collected from the final 15 houses and the building shell upgrade analysis undertaken for these houses;
5. In 2012/13, the data from all 60 houses was re-analysed by Sustainability Victoria. The analysis methodologies used for all of the energy efficiency upgrades were reviewed and most revised to ensure that the estimates were as accurate as possible. In particular, a different approach was used to estimate the energy savings resulting from building shell and heating upgrades. Rather than using the modelled heat loads for the houses to estimate the heating energy savings directly, the modelled heating energy savings were converted to percentages and applied to an estimate of the houses' actual annual heating energy use derived from gas billing data. This approach avoids the problem – evident in some recent studies – where the estimated total heating energy savings substantially exceed the houses' likely heating energy use. We believe that it gives a more accurate estimate of the savings which can be achieved in practice.

Overview of study methodology

The On-Ground Assessment study methodology involved seven main elements:

1. Data was collected from a reasonably representative sample of pre-2005 stand-alone houses located in Melbourne and regional Victoria through site visits;
2. Building shell data collected from each of the houses was used in a FirstRate5 analysis to calculate the House Energy Rating of each house before and after the building shell upgrades were applied;
3. Annual heating energy use of the houses was estimated from gas billing data;
4. A modified FirsRate5 analysis was undertaken for each house to estimate the likely impact of the building shell upgrades on the actual heating and cooling loads of the houses;
5. The costs and savings of the building shell upgrades were calculated for each house;
6. Lighting and appliance data collected from each of the houses was analysed to estimate the likely costs and savings from a range of energy efficiency upgrades;
7. Combined analysis of all energy efficiency upgrade measures to produce upgrade cost-curves.

A brief description of each of these elements is provided below, and a more detailed description of the methodologies used is provided in the relevant part of the report.

It is important to note that while the On-Ground Assessment study has relied on data collected from actual houses, the impact of the energy efficiency upgrades has been modelled, and no actual upgrades have been undertaken in the 60 houses studied. This next step is the focus of the Residential Energy Efficiency Retrofit Trial project. Through this subsequent project Sustainability Victoria is undertaking key energy efficiency upgrades in a selection of houses to assess the practical issues involved, the actual costs and savings achieved in practice, and the householder experience and acceptance of the upgrade measures.

On-Ground data collection

The On-Ground Assessment study has relied on data collected from actual Victorian houses. This is in contrast to some other studies which have relied on statistical data, often self-reported, as the basis of estimating the energy efficiency status of the housing stock and the corresponding energy efficiency upgrade potential. The data collected from each house included:

- Demographic data, including location and the number of occupants;
- House design and construction details, suitable for input into the FirstRate5 house thermal modelling program;
- Air pressurisation (blower door) test to measure the air leakage rate of the house;
- Details of the type, number and wattage of lighting used in different areas;
- Flow rates of all shower roses;
- Details – including type, brand, model number, age and, where available, Energy Rating Label information – of the heaters, coolers, water heater, washing machine, clothes dryer, dishwasher, televisions and computers. Information on how the appliances were used was also obtained for each house.

FirstRate5 analysis to determine HER

The house design and construction details were entered into the FirstRate5 house thermal modelling program to determine the House Energy Rating (HER) of the house in its initial state, as well as the HER after each of the building shell upgrades was applied. The building shell upgrades were applied progressively in a pre-determined order, to avoid over estimating the energy saving impact once all upgrades had been applied. Only those building shell upgrade measures which were relevant to each house, and which could be practically applied, were modelled.

The measured air leakage rate for each house was incorporated into the FirstRate5 analysis, using a technique developed by Sustainability Victoria. The air leakage rate was converted into an equivalent number of ceiling exhaust fans, and these were then included in the house design input to FirstRate5. This approach was necessary so that it would be possible to assess the impact of applying draught sealing measures to each house.

Estimation of annual heating energy use

The majority of the houses included in the study used gas for heating, and for 53 of the 60 houses it was possible to obtain historical gas billing data. As gas is used for only a limited number of end uses – heating, water heating and sometimes cooking – and as the heating energy use is concentrated during the cooler months, it is possible to use the bi-monthly gas billing data to estimate the annual energy use of the gas heating[6]. Where possible, estimates were undertaken for a number of recent years for each house, temperature corrected[7] using Bureau of Meteorology (BoM) data, and then the average annual gas use for heating calculated.

Modified FirstRate5 Analysis to estimate actual heating and cooling loads

Used in its standard "rating" mode, FirstRate5 calculates the HER (or Star Rating) for a particular house design and this is used as the basis of minimum efficiency regulations for new houses or to determine the level of energy efficiency of a particular design.

To determine the HER, FirstRate5 first calculates the heating/cooling energy which must be provided throughout a typical year to maintain specified thermal comfort conditions within the house during the day and night[8], and this is used as the basis of assigning the rating: the greater the amount of energy which has to be provided to maintain thermal comfort conditions, the less efficient the house is and the lower its HER will be. In this "rating" mode, FirstRate5 does not – and is not intended to – estimate the actual annual heating and cooling energy use of the house. However, the FirstRate5 program does allow some customisation of the usage profile[9] of the heating and cooling equipment, thermostat setting selection and the areas of the house which are heated and cooled. This allows a more accurate estimate of the actual annual heating and cooling load of the house to be obtained, and this can be combined with heater/cooler conversion efficiency data to obtain an estimate of actual annual energy use of the heater/cooler.

Householder surveys were used to obtain information on the typical usage profile of heating and cooling equipment during the week, typical thermostat settings and the areas of the house which were heated and cooled, and this information was used to construct customised profiles for each house which were then modelled in FirstRate5. Most households had two or three different usage profiles during the week. Each profile was modelled separately and the results then weighted and combined to produce the overall estimate of the actual heating and cooling load for the house. The modelling was undertaken for each house in its original state and after each building shell upgrade was applied, so that the incremental impact of each of the building shell upgrades could be determined.

6 Daily gas use during the summer months was assumed to be entirely due to water heating and cooking. Except where gas-boosted solar water heating was present, annual average daily use for water heating and cooking was taken to be 1.2 times the summer use. This was used to estimate annual use for water heating and cooking, and then subtracted from the total annual gas use to estimate gas use for heating.

7 The length and severity of winters varies from year-to-year, and so gas heating energy use also shows significant annual variability. BoM data was obtained for relevant locations for the period 2000 to 2012, and the number of Heating Degree Days (18oC base) calculated for each year. The average number of Heating Degree Days was calculated for 2000 to 2012 and used as the reference. The number of Heating Degree Days was then calculated for each year of billing data and used to derive an index to temperature correct the gas heating use for that year.

8 This is known as the heating/cooling load and is expressed in MJ/m^2/year. It corresponds to the output of the heating and cooling equipment which would be necessary to maintain thermal comfort for every square metre of conditioned floor space. In most cases this will be significantly higher than the actual heating/cooling load of the house.

9 This is the time of day during which the heating/cooling is assumed to be operating.

Cost-Benefit analysis of building shell upgrades

The cost of each of the building shell upgrades applied to the houses was estimated by MEFL, and the impact of each of the upgrades on heating/cooling loads was obtained from the modified FirstRate5 analysis. The heating and cooling loads (MJ/m^2/yr) were multiplied by the floor area heated/cooled (m^2) to obtain the total heating/cooling load (MJ/yr) for the house, and this was then divided by the conversion efficiency[10] of the heating and cooling system to estimate the actual energy[11] used for heating/cooling (MJ/yr), and the energy saving achieved when each upgrade was applied. This was expressed in both absolute terms (MJ/yr) and also as a percentage of the initial heating and cooling energy use prior to any upgrades.

For the 53 houses where an estimate of the actual heating energy use had been obtained from gas billing data the actual heating energy saving was estimated by applying the percentage saving resulting from the upgrade to the actual initial heating energy use. For all other houses and for cooling, the energy saving estimate was obtained directly from the modified FirstRate5 analysis, as described in the paragraph above.

Current electricity and gas tariffs were applied to the energy saving estimates to estimate the annual energy bill savings, and these were combined with the cost data to calculate the simple payback for each of the building shell upgrades.

Appliance and Lighting Analysis

The detailed data collected on the lighting and key appliances found in the houses was used to identify those houses where an energy efficiency upgrade could be undertaken – the upgrade options chosen were based on currently available high efficiency equipment, and were selected to have a similar capacity[12] (or size) to the equipment being replaced. Where the house already had efficient lighting and appliances, no upgrades were modelled.

The estimated energy use before and after upgrade was based on the assumed usage of the appliances/lighting, and on the estimated efficiency of the appliances/lighting before and after upgrade. For some appliances (washing machines, clothes dryer, dishwasher) usage was based on the usage reported by the householders, and for other appliances the assumed usage was based on average usage for a given household size. Lighting usage was based on average usage for lighting in different areas of the home.

The cost of the energy efficiency upgrades was based on data obtained from appliance price comparison websites, and the energy bill savings based on current electricity and gas tariffs. For wet appliances – low flow shower roses, washing machines and dishwashers – the water savings were also estimated and added to the energy bill savings to obtain an overall bill saving. As with the building shell upgrades the cost data was combined with the savings data to obtain the simple payback for each of the measures.

More detail on the methodologies used for each of the appliance and lighting upgrades is provided in Appendix A4.

Combined Analysis

In the first instance the data from each of the upgrade types modelled in the 60 houses was combined, and used to estimate the average cost, savings and payback for each measure. This allowed a comparison of the cost effectiveness of the different upgrade measures to be made. The data for each measure was also used to produce a "cost curve" for the upgrade measure. To produce this, each individual upgrade was ranked in ascending order of payback (smallest to largest), and then the cumulative greenhouse abatement (or energy saving) was plotted against payback as the payback period was increased. The curves show the amount of greenhouse abatement (or energy saving) which can be achieved below a certain payback point, and also highlight the diversity of outcomes which are possible from different upgrade measures.

Secondly, the data from all of the building shell upgrades and all of the lighting and appliance upgrades for the 60 houses was combined, and used to produce cost curves based on all the energy efficiency upgrades modelled for the study. This gives an indication of the amount of greenhouse abatement (or energy saving) which can be achieved below a certain payback point across the stock of existing houses in Victoria.

Overview of report

Chapter 2 of the report describes the sample of houses which participated in the On-Ground Assessment study, and provides an overview of the current energy efficiency status of these houses.

Chapter 3 of the report presents the results of our analysis of the impact that a range of common building shell energy efficiency upgrades would have on the House Energy Ratings (HER) of the houses. Increasing the HER of the houses means that they would have increased thermal comfort and therefore reduced heating and cooling energy use.

Chapter 4 of the report presents the results of our analysis on the costs and savings (energy, $ and greenhouse) which could be achieved by applying a range of building shell, lighting and appliance upgrades to the houses. The emphasis in this chapter is on providing a comparison of the different energy efficiency upgrades which have been modelled, as well as showing the potential impact of all upgrade measures across the existing housing stock. More detailed analysis of the individual building shell upgrades (A3) and the individual lighting and appliance upgrades (A4) is provided in the Appendices.

Chapter 5 of the report presents our conclusions and learnings from the On-Ground Assessment study.

A summary of the data collected for each house which participated in the study is provided in Appendix A1, and details of the building shell upgrades applied to the houses is provided in Appendix A2. In Appendix A5 we present our analysis of the impact that the application order has on the energy savings achieved. In Appendix A6 we provide the energy tariff and greenhouse gas coefficient assumptions which have been used in our analysis, as well as the underlying cost assumptions for the building shell upgrades. In Appendix A7 we provide copies of all the cumulative cost curves for the various scenarios modelled.

10 This is the ratio of the heating (or cooling) energy output of the equipment and the energy input.

11 For heating this was mainly gas, although some houses had electrical heating. For cooling this was electricity.

12 What is meant by capacity varies between appliance types. For example, for fridges it is the volume in Litres, for washing machines and clothes dryers it is load capacity in kg, and for heaters it is the heating output in kW.

2. Energy Efficiency Status of Existing Houses

Overview of the housing sample used

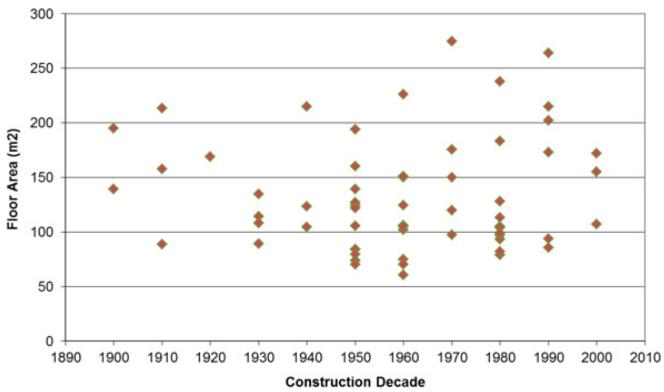
Between 2009 and 2012 a total of 60 households were recruited by MEFL[13] to participate in the On-Ground Assessment (OGA) study. The houses were all constructed prior to 2005, when the 5 Star minimum efficiency standard for new houses was first introduced, and so were expected to have relatively inefficient building shells. The focus of the study was on class 1 - stand-alone and semi-detached - houses. In 2005 these accounted for just over 80% of the total Victorian housing stock and, due to both their larger size and greater number of occupants, would have accounted for significantly more than 80% of total residential energy use.

The houses were selected so that they would be reasonably representative of the existing Victorian housing stock in terms of construction era, construction type (particularly wall construction) and floor area. Houses were recruited from both Melbourne (46) and regional Victoria (14). The regional houses were drawn from the Geelong (8) and Ballarat (6) areas.

For the initial pilot study only houses from Melbourne were used and the main emphasis was on selecting a range of different building types and ages. RMIT Centre for Design subsequently used ABS[14] data to develop a target list of houses based on wall construction type, construction era and number of bedrooms, and this was used by MEFL during the recruitment and vetting process to help ensure that the desired sample of houses was recruited.

Table 1 compares the target sample and the actual OGA study sample in terms of construction period and size (based on number of bedrooms). While the actual sample of houses matches the target sample for the construction period, and is a reasonably close match for the house size for the larger houses (3 or more bedrooms), it was more difficult to match the target sample for the smaller houses, especially for 1 bedroom houses. Figure 1 shows the floor areas of the 60 houses plotted against the construction decade of the houses. The average floor area of the sample of houses was 133 m^2.

FIGURE 1: FLOOR AREA VS CONSTRUCTION DECADE FOR HOUSING SAMPLE



Wall and floor construction details for the sample of houses are shown in Tables 2 and 3 respectively. The main wall construction types of the OGA sample were a reasonably good match for the wall construction types found in Victoria in 2005, although lightweight wall constructions (weatherboard and fibro-cement) were slightly over-represented and heavy weight wall constructions (cavity brick) were slightly under represented.

TABLE 1: TARGET SAMPLE VS ACTUAL SAMPLE

Construction Period	1 bedroom		2 bedroom		3 bedroom		4+ bedrooms		All Sizes	
	Target	Actual	Target	Actual	Target	Actual	Target	Actual	Target	Actual
1990 - 2004	0	0	2	0	5	7	2	2	9	9
1980s	0	0	2	1	6	7	2	2	10	10
1950s / 60s / 70s	1	0	5	6	16	16	6	6	28	28
1940s or earlier	0	0	2	2	8	8	3	3	13	13
Total	**1**	**0**	**11**	**9**	**35**	**38**	**13**	**13**	**60**	**60**

13 Recruitment was undertaken through MEFLs existing networks, as well as local government, community and government networks. An on-line registration of interest process was employed, and a screening process was used to identify houses which had undertaken recent renovations or which may have had a "green" bias, and eliminate these from further consideration.

14 ABS4182.0 Australian Housing Survey – Housing Characteristics, Costs and Conditions, 1999 – Victorian data cubes

TABLE 2: WALL CONSTRUCTION TYPE OF SAMPLE VS VICTORIAN HOUSING STOCK

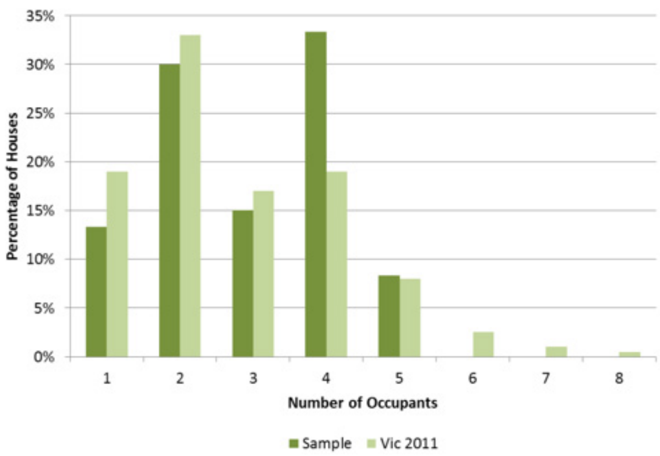
Main wall construction type	Sample	Victoria 2005[15]
Brick veneer	63.3%	63.9%
Weatherboard / Fibro-cement	28.3%	21.9%
Cavity brick	8.3%	11.5%
Total	**100.0%**	**97.2%**

TABLE 3: FLOOR CONSTRUCTION TYPE OF SAMPLE

Main floor type	Sample
Suspended timber	68.3%
Concrete slab on ground	20.0%
Mixed	11.7%
Total	**100.0%**

The occupancy profile of the sample of houses is shown in Figure 2 and compared to the occupancy profile for all Victorian class 1 houses. The average number of occupants for the OGA study houses was 2.93, slightly higher than the Victorian average of 2.78[16]. From Figure 2 it is evident that the main reason for this was that the proportion of 4-bedroom houses in the OGA study sample was significantly higher than the Victorian average.

FIGURE 2: OCCUPANCY PROFILE OF OGA SAMPLE VS VICTORIAN PROFILE



For the building shell upgrades another key consideration is the heating and cooling equipment used in the houses, as the type of heating/cooling equipment will have a strong influence on heating/cooling costs and therefore the value of the energy savings achieved from building shell and heating/cooling equipment upgrades.

TABLE 4: MAIN HEATING TYPES USED IN OGA SAMPLE VS VICTORIA

Main Heating Type	Sample	Victoria 2011[17]
Central gas	50.0%	41.9%
Room gas	40.0%	26.8%
Central electric resistance heating	-	1.9%
Ducted reverse cycle air conditioner	-	2.7%
Room reverse-cycle air conditioner	6.7%	8.2%
Electric room	3.3%	7.8%
Wood / other heating	-	7.0%
Total	**100.0%**	**96.3%**

The main heating equipment found in the OGA study houses is documented in Table 4, and compared to the heating equipment found in all Victorian houses. There is a reasonable match between the OGA sample and the Victorian stock, although the use of gas heating was higher in the OGA sample and electric room heating was under represented – the effect of this is probably off-set by the higher incidence of gas central heating in the OGA study houses. Wood heating was not used as the main form of heating in any of the OGA study houses, and is largely confined to regional Victoria. Two relatively minor types of heating – ducted reverse-cycle air conditioning and central electric resistance heating – were not present in any of the OGA study houses.

TABLE 5: MAIN COOLING TYPES USED IN OGA SAMPLE VS VICTORIA

Main Cooling Type	Sample	Victoria 2011[18]
Refrigerative room air conditioner	43.3%	46.1%
Ducted refrigerative	-	6.9%
Ducted evaporative	15.0%	19.3%
Portable	-	3.2%
None	41.7%	24.5%
Total	**100.0%**	**100.0%**

15 Based on ABS4602.0 Environmental Issues: People's Views and Practices, March 2005, with "don't knows" netted out.
16 ABS Census 2011, Victorian data.
17 Data derived from [ABS 2011b].
18 Data derived from [ABS 2011a].

The main cooling equipment which was found in the OGA study houses is shown in Table 5 and compared to the Victorian housing stock. There is a reasonable match between the percentage of room air conditioners and ducted evaporative coolers, although in both cases the penetration in the OGA study houses is lower than in the Victorian stock. The main difference was that a much higher proportion of the OGA study houses had no fixed cooling and ducted refrigerative cooling was not present in any of the OGA study houses. The impact of this is to reduce the cooling energy savings resulting from the building shell and cooling upgrade measures. However, as heating and cooling energy use in Victoria is dominated by heating, this will have a relatively small impact on the energy savings and paybacks which have been calculated for these measures.

The OGA study analysis did not take into account any secondary heating or cooling equipment[19] which means that it underestimates to some extent the energy savings which can be achieved by the building shell upgrades.

Efficiency status of the building shell of existing houses

A summary of the construction characteristics of the 60 houses which participated in the OGA study is provided in Appendix A1. This includes information on the nature of the houses, wall and floor construction type, construction decade, floor area, insulation status and the main type of fixed heating and cooling equipment found in the houses.

This information, along with other detailed information collected on-site, was input into the FirstRate5 program to calculate at the House Energy Rating (HER) of the houses in their existing state. The HER is a measure of the energy efficiency of a house's building shell. Houses which have higher HERs are more naturally comfortable, have lower heating and cooling requirements, and therefore are more energy efficient. As noted in Chapter 2, blower door tests were undertaken at each house to measure their air leakage rate, and this was incorporated into the FirstRate5 analysis using a technique developed by Sustainability Victoria.

During the blower door tests the houses were pressurised and depressurised at different pressures in the range of 15 to 60 Pascals, and the air leakage rate (m^3/hr) determined at 50 Pascals and a number of different pressure settings. The air leakage rate measured at a pressure differential of 50 Pascals was divided by the volume of the house (m^3) to calculate the air leakage rate expressed as Air Changes per Hour (ACH@50) – this represents the number of times the total volume of air in the house changes in one hour at a 50 Pascals pressure differential. The ACH@50 result was divided by 20 to estimate the natural air leakage rate (ACH), and this figure was used as the basis of the input to FirstRate5 to account for the measured air leakage rate.

The air leakage rates for each of the 60 houses are given in Appendix A1. The average natural air leakage rate was 1.90 ACH – the post-1990 houses had a natural average air leakage rate of 1.20 ACH, substantially lower than the average for the pre-1990 houses of 2.02 ACH. The distribution of the measured natural air leakage rates is shown in Figure 3. While the majority of houses (71.7%) had a natural air leakage rate in the range of 1 to 2.5 ACH, there is a small minority of houses (10.0%) with very high natural air leakage rates, in excess of 3 ACH. The greater the air leakage rate, the harder the house will be to heat in winter as the air which leaks out of the house is replaced by cold outside air which then has to be re-heated. The draughts created by the air leakage can also reduce the comfort of occupants. Similarly, houses with higher air leakage rates will also be harder to cool in summer during the heat of the day.

FIGURE 3: DISTRIBUTION OF MEASURED NATURAL AIR LEAKAGE RATES FOR THE OGA STUDY HOUSES

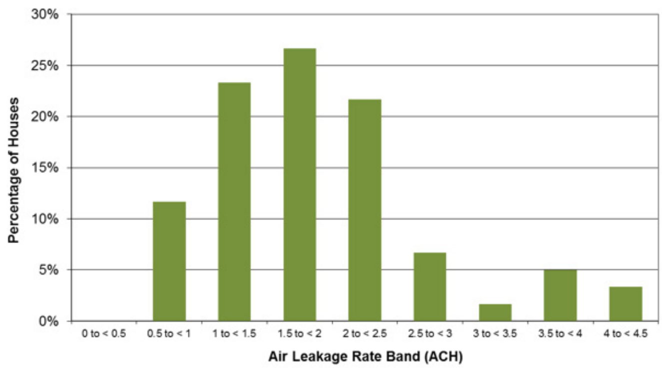


FIGURE 4: HOUSE ENERGY RATING (HER) OF THE 60 OGA STUDY HOUSES

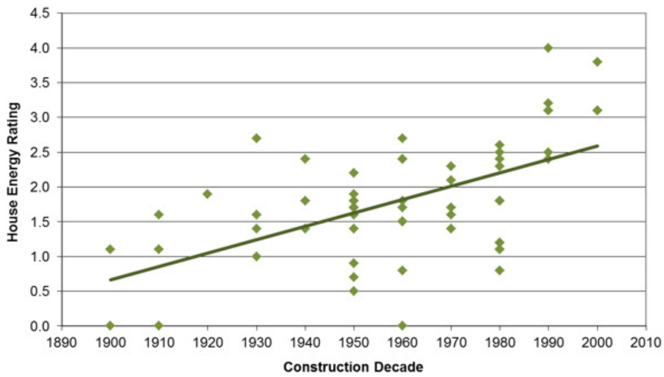
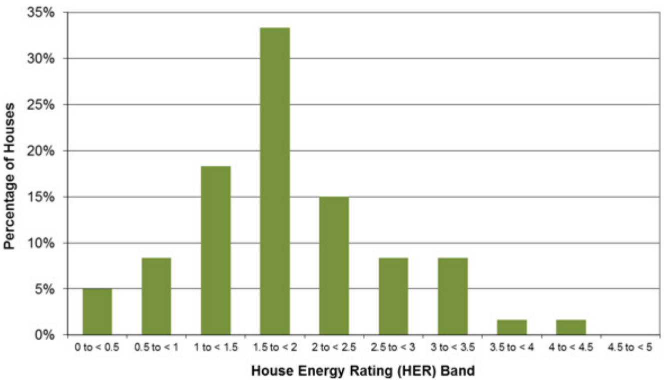


Figure 4 shows the HERs of the 60 OGA study houses plotted against their initial construction decade, as well as trend line showing how the average HER has changed over time, and Figure 5 shows the distribution of the HERs for the houses. The average HER of the houses was 1.81 Stars. From Figure 4 it is evident that the average HER of the houses has increased steadily over the last century and, in particular, that the HER of houses has increased significantly since the 1990s, corresponding to the introduction of mandatory insulation requirements in Victoria in 1991. The average HER of the pre-1990 houses was 1.57 Stars, substantially lower than the average HER of the post-1990 houses of 3.14 Stars. More recently, housing minimum efficiency regulations have required new houses to be designed to achieve a minimum HER of 5 Stars (2005), and this was increased to a minimum of 6 Stars in 2011, meaning that there is a very large efficiency gap between the pre-2005 and post-2005 housing stock.

19 There has been very little work on this area to date, and it is much more challenging to accurately model the energy use of these secondary heating – often portable electric heaters – and cooling appliances.

FIGURE 5: DISTRIBUTION OF HERS FOR THE OGA STUDY HOUSES



The data from the OGA study houses has been analysed to obtain a deeper insight into the factors which are driving the differences in HER which have been observed across the sample. Table 6 provides data on the average HER and average air leakage rate for different types of wall and floor construction.

TABLE 6: AVERAGE HER FOR DIFFERENT WALL AND FLOOR CONSTRUCTION TYPES

Wall Construction Type	Number	Av. HER	Av. ACH
Weatherboard / Fibro-cement	17	1.45	1.78
Brick Veneer	38	2.00	1.94
Cavity Brick	5	1.56	1.99
Floor Construction Type	**Number**	**Av. HER**	**Av. ACH**
Suspended timber	41	1.63	2.00
Concrete slab-on-ground	12	2.62	1.43
Mixed construction	7	1.44	2.08

Houses with brick veneer walls were found to have a higher average HER than houses with either cavity-brick or lightweight (weatherboard or fibro-cement) wall construction. A key reason for this seems to be that these houses were generally newer, with brick-veneer being the dominant type of wall construction (90% +) for the houses constructed from the 1960s onwards. The newer brick veneer houses had a range of construction features (slab-on-ground floors, higher incidence of wall and ceiling insulation) which contributed to the higher HERs observed in Figure 4. While in theory cavity brick wall construction should have some efficiency advantages over other types of wall construction – due to the higher level of internal thermal mass – these houses had a lower average HER than the brick veneer houses. Again, this seems to have been mainly related to the older age of these houses.

Houses with suspended timber floors and mixed construction floors (usually resulting from a renovation) had much lower average HERs than houses with a concrete slab-on-ground floor construction, and also had somewhat higher air leakage rates. This is likely to be due to the lower level of heat loss (winter) and gain (summer) through the floor in slab-on-ground floors, the increased thermal mass of the concrete slab-on-ground floor, and also due to the lower level of air leakage from this construction – in timber floors air leakage can occur through gaps between floorboards as well as gaps between the walls and floor. Also, the houses with concrete slab-on-ground floor construction were relatively new, with all of these types of houses being constructed from the 1980s onwards and being by far the most dominant form of floor construction from the 1990s onwards (89%).

The general increase in the energy efficiency of the houses over the last century can be explained by a number of factors, including building regulations and changes in the dominant type of house construction:

- The biggest factor was the introduction of mandatory minimum insulation standards in Victoria in 1991, which resulted in a significant increase in HER. The use of adequate levels of insulation on the ceiling and in walls, and under a suspended timber floor, are one of the critical construction elements required to achieve a high HER;
- Houses constructed since 1990 are much more likely to have wall insulation (78% of houses) than houses constructed prior to this. This has been driven by the mandatory insulation standards which operated from 1991 to 2005;
- The number of houses using slab-on-ground floor construction has increased significantly from the 1980's onwards. As noted above this contributes to increased energy efficiency in a number of ways;
- The incidence of multi-storey houses increased from the 1970's onwards. These houses tend to have a more efficient building shell as the ceiling area to volume ratio is lower than for single storey houses;
- Older houses are more likely to have a higher air leakage rate. They are more likely to have suffered some degradation of the building shell over time (e.g. the development of cracks and gaps), the use of fixed ventilation such as wall vents was much more common prior to the 1990s and these houses were also more likely to have open fireplaces.

Efficiency status of existing lighting and appliances

A range of information and data was collected for the lighting and main appliance types found in the OGA study houses. This included information on the brand, model, type, size/capacity and age of appliances and, where available, details from any Energy Rating labels which remained fixed to the appliances. For the appliances, this information was used to estimate the energy efficiency status of the existing appliance stock using information taken from the Energy Rating labels, through accessing historical databases of appliance Energy Rating label information[20], or by using the age and type of appliance and linking this to lists of the average efficiency of appliances sold in certain years[21].

An overview of the energy efficiency status and upgrade potential of the lighting and appliances found in the houses is provided in Table 7. More detailed information on the efficiency status of the different appliance groups found in the houses is provided below. In particular, we look at the penetration and ownership[22] of the different appliances, their average age and age profile, and their average efficiency and efficiency profile.

The average age and age profile of the appliance stock, coupled with the typical life of the appliance type, gives an idea of how quickly the appliance stock is likely to turn over in the future. In most cases an existing appliance will only be replaced with a new, more efficient, appliance when it reaches the end of its useful life and this is also the most cost-effective time to undertake an efficiency upgrade.

The average efficiency of the appliance – expressed as a Star Rating or in some cases as a conversion efficiency – and the efficiency profile of the stock also provide an insight into the potential to upgrade the efficiency of the existing stock.

20 Historical appliance registration lists available from the Equipment Energy Efficiency (E3) Program contain the energy rating details of all electrical energy labelled appliances extending back to the early 1990s. Similarly, historical copies of the Australian Gas Association's Directory of Certified Appliances (http://www.aga.asn.au/product_directory) can be used to identify the energy rating details of older gas appliances. Further details are provided for each appliance in Appendix A4.

21 The publication Energy Use in the Australian Residential Sector 1986 – 2020 [EES 2008] contains lists of the typical energy performance characteristics of appliances sold in certain years.

22 Penetration is the percentage of houses with a particular appliance. Ownership is the average number of appliances per house in houses where that appliance is present.

TABLE 7: OVERVIEW OF THE ENERGY EFFICIENCY STATUS OF THE LIGHTING AND APPLIANCES STOCK IN OGA STUDY HOUSES

Appliance category	Penetration / Ownership	Av. Age (Yrs)	Average Efficiency Characteristics	Upgrade Potential
Lighting	Average of 30.4 lamps per house	N.A.	53% of installed lamps were inefficient incandescent or 12 volt halogen lamps.	Significant savings possible by replacing inefficient lamps with either compact fluorescent or LED lamps.
Heating	Penetration: 100%	12.1	Gas ducted (central) heating – 3.1 Stars. Gas room heating – 2.8 Stars. Reverse-cycle air conditioners 3.3 Stars (2000 rating scale).	Significant savings possible by replacing inefficient gas ducted heaters and gas room heaters with a new efficient heater, and by replacing electric heating with either an efficient gas heater or reverse-cycle air conditioner.
Cooling	Penetration: 58%	9.2	Refrigerative air conditioners – 3.2 Stars (2000 rating scale).	Savings possible by replacing older, inefficient air conditioners with a new high efficiency model.
Water heating	Penetration: 100%	8.9	Gas storage water heaters – 3.6 Stars. Gas instantaneous water heaters – 4.8 Stars. 5 houses with electric storage water heaters.	Good savings possible by replacing existing electric water heaters with a gas or solar water heating option. Reasonable savings possible by replacing inefficient gas water heaters, especially older storage systems, with high efficiency new gas water heaters. Larger savings possible by replacing gas water heaters with solar, but this is less cost-effective.
Shower rose	Penetration: 100% Ownership: 1.45	N.A.	55% of shower roses are not low flow (e.g. have a flow rate > 9 L/min).	Reasonable and cost-effective savings from replacing the inefficient shower roses with low flow models.
Refrigerator	Penetration: 100% Ownership: 1.25	9.4	1.3 Stars (2010 rating scale).	Reasonable savings possible by replacing old inefficient refrigerators with new high efficiency models.
Clothes washer	Penetration: 100%	6.3	Overall average – 2.9 Stars. Top loaders – 1.9 Stars. Front loaders – 3.7 Stars.	Small energy savings and good water savings possible from replacing inefficient top loaders with high efficiency front loaders.
Dishwasher	Penetration: 67%	7.0	2.7 Stars.	Small savings possible by replacing old inefficient models with high efficiency new models.
Clothes dryer	Penetration: 45%	8.8	2.0 Stars.	Main savings potential is to replace existing clothes dryers with heat pump or gas clothes dryer.
Television	Penetration: 95% Ownership: 1.91	5.8	2.7 Stars (2009).	Good savings possible by replacing old inefficient models with new high efficiency models.
Computer	Penetration: 98% Ownership: 1.56	3.4	45% of computers are laptops 91% have monitors with LCD screens.	Computer stock is transforming to a higher level of efficiency under business-as-usual.

Lighting

Details of the lighting found in all areas of the home were collected from the OGA study houses during the site visits, and these are summarised in Figure 6 and Table 8. Inefficient lighting types – incandescent[23] light globes and 12 volt halogen downlights – accounted for 53% of the installed lamps. It is important to note that the types of lighting found in homes is changing quite rapidly over time, due to government incentive schemes such as the Energy Saver Incentive and the cost of efficient lighting options such as compact fluorescent lamps (CFLs) and LEDs reducing.

There is a significant potential to upgrade the efficiency of the lighting in the houses by replacing incandescent lamps with CFLs and either replacing the 12 volt halogen lamps with a suitable 12 volt LED lamp, or replacing the entire 12 volt halogen downlight fitting with a new low energy fitting (using CFL or LED lamps). Savings will be greatest when lights in the main living areas are replaced, as it is in these areas where lighting is used most frequently.

23 This includes both the older style lamps with tungsten-halogen filaments and the newer mains voltage halogen incandescent lamps.

FIGURE 6: SHARE OF MAIN LIGHTING TYPES IN OGA STUDY HOUSES

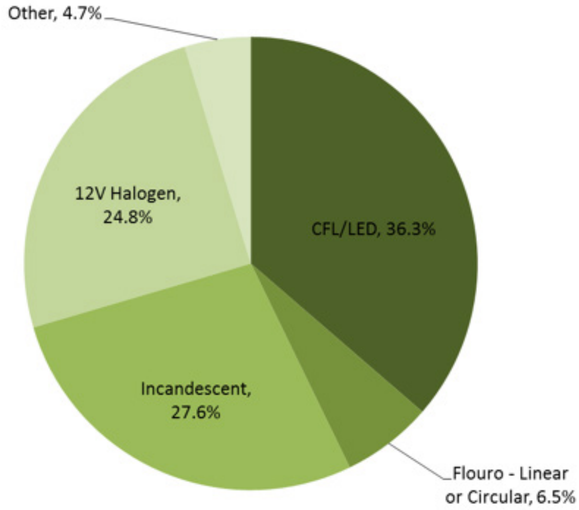


TABLE 8: DETAILS OF LIGHTING FOUND IN OGA STUDY HOUSES

	CFL / LED	Linear or Circular Fluorescent	Incandescent	Dimmable Incandescent	12 volt Halogen	Dimmable 12 volt Halogen	Other	Total
Av. Number	11.1	2.0	7.8	0.6	5.6	2.0	1.4	30.4
Share	36.3%	6.5%	25.7%	1.9%	18.4%	6.5%	4.7%	100.0%

Heating

All of the OGA study houses had some form of fixed heating. The main type of heating found in the houses is shown in Table 4 above and compared with current Victorian stock averages. Details of the main fixed heaters found in the houses are provided in Table 9 – note that some houses had multiple gas room heaters or reverse-cycle air conditioners. In addition to the estimated average Star Rating of the heaters which carry Energy Rating labels, we also provide the estimated average conversion efficiency, both the for the heater alone and for the heating system (if ducted).

The average age of the room reverse-cycle air conditioners (3.5 years) was significantly lower than the average age of both the gas central and gas room heaters. Historically, gas heating has been the main form of heating used in Victorian houses, but in recent years the popularity of reverse-cycle air conditioners – used for both heating and cooling – has increased. Also, gas central (mainly ducted) heating has overtaken gas room heating as the dominant form of gas heating. This is likely to explain the lower average age of the gas central heaters compared to the gas room heaters.

Gas heaters and reverse-cycle air conditioners carry Energy Rating labels, which allow the energy efficiency of different models to be compared. However, each labelling scheme is self-contained, and the labels do not allow a comparison across the different heater types. The conversion efficiency figures shown in Table 9 allow a more direct comparison to be made.

In the case of the gas heaters the average stock efficiency is significantly lower than what is currently available in the market: central gas heaters are available in both 5- and 6- Star models, and gas room heaters are available in 4- and 5-Star models. Similarly for the reverse-cycle air conditioners much more efficient models are now available – efficiency regulations require a conversion efficiency of at least 322% for medium sized air conditioners.

FIGURE 7: AGE PROFILE OF HEATERS

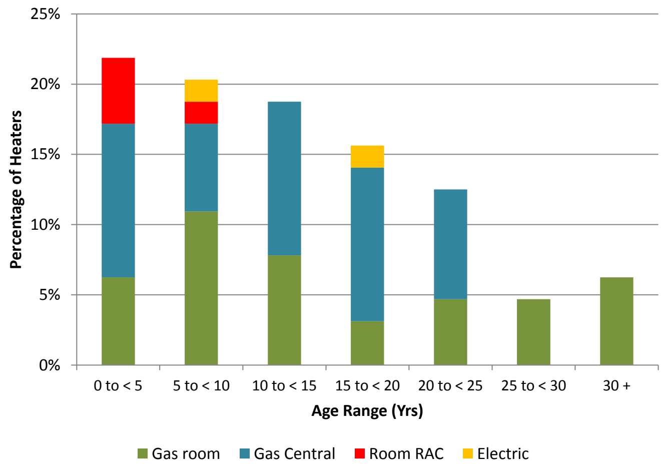


FIGURE 8: EFFICIENCY PROFILE OF HEATERS

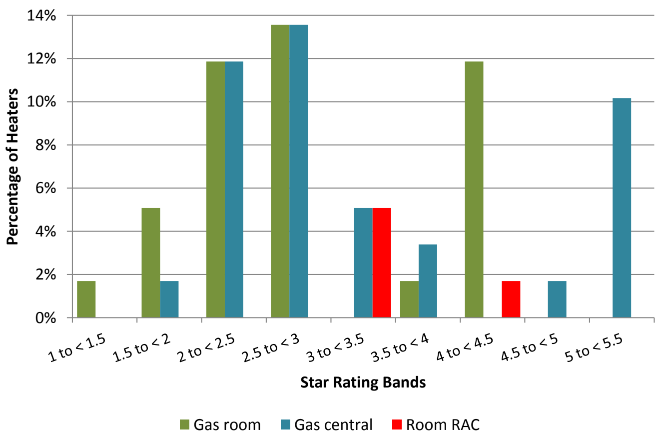


TABLE 9: DETAILS OF MAIN FIXED HEATERS IN OGA STUDY HOUSES

Type of Heating	Number	Share	Av. Age (Yrs)	Av. Star Rating*	Av. Conversion Efficiency - Heater	Av. Conversion Efficiency - System
Gas central[21]	30	46.9%	11.3	3.1	70.8%	57.1%
Gas Room	28	43.8%	14.3	2.8	69.7%	69.7%
Room RAC[22]	4	6.3%	3.5	3.3	299.2%	299.2%
Electric resistance	2	3.1%	11.0	-	100.0%	100.0%
Total	**64**	**100.0%**	**12.1**	**-**	**85.1%**	**78.6%**

* The Star Ratings of the Room RAC are based on the 2000 version of the label.

24 Gas central heaters were mainly ducted systems, although one house had a hydronic heating system.
25 Room reverse-cycle air conditioner (RAC).

Cooling

58.3% of the OGA study houses had some form of fixed cooling, with the majority of the coolers being room refrigerative air conditioners. The main type of cooling found in the houses is shown in Table 5 above and compared with current Victorian stock averages. Details of the main fixed coolers found in the houses are provided in Table 10. In addition to the estimated average Star Rating of the air conditioners, we also provide the estimated average conversion efficiency, both the for the cooler alone and for the cooling system (if ducted). Note that we have assumed that the older refrigerative air conditioners suffer some degradation in performance over time, which accounts for the slightly lower average conversion efficiency for this type of (non-ducted) cooler in the "System" column.

The average age of the ducted evaporative coolers (6.1 years) is lower than the average age of the room refrigerative air conditioners. All of the ducted evaporative coolers had been installed in the last 15 years, while around one-third of the refrigerative air conditioners had been installed more than 15 years ago. Nearly 70% of the coolers had been installed in the last 10 years, reflecting the significant growth in cooling in Victorian houses over the last decade: penetration has increased from only 43.5% in 1999 to 75.5% in 2011 [ABS 2008, ABS 2011].

Room refrigerative air conditioners carry Energy Rating labels. The average Star Rating of the air conditioners was 3.2 stars (based on the 2000 version of the labels) – this corresponds to only around a 1 Star rating on the current rating scale, and would not be efficient enough to qualify for the current air conditioner minimum efficiency standards. The average conversion efficiency figures allow a comparison between the refrigerative and evaporative coolers[26].

New air conditioners are significantly more efficient that the average air conditioner found in the OGA study houses, with conversion efficiencies in the range of 350% to 375% (2.5 to 3 Stars on the current rating scale). They are also likely to be the more efficient inverter-type air conditioners. More efficient evaporative coolers, with inverter driven fan motors, are also available.

26 Evaporative coolers use significantly less energy to cool a given area than refrigerative air conditioners as they rely on the evaporation of water to provide the cooling effect. The conversion efficiency used for evaporative coolers is an estimate based on rated evaporative cooler power input and effective cooling outputs in a Melbourne climate. Actual cooling capacity depends on outside air temperature and humidity.

FIGURE 9: AGE PROFILE OF COOLERS

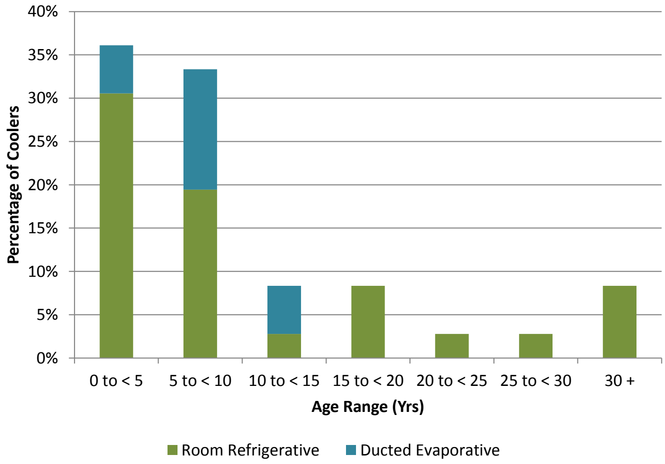


FIGURE 10: EFFICIENCY PROFILE OF AIR CONDITIONERS

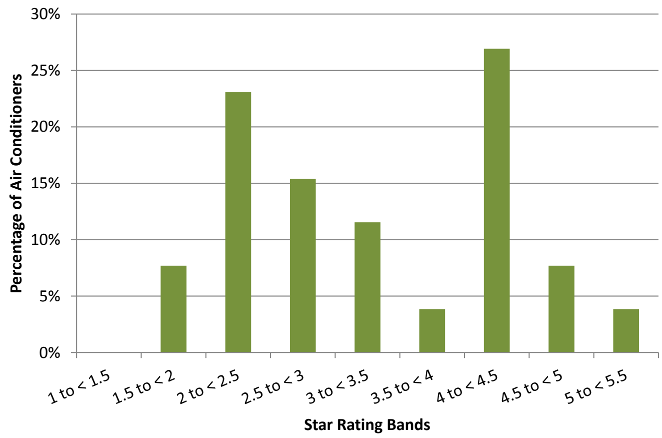


TABLE 10: DETAILS OF MAIN FIXED COOLERS IN OGA STUDY HOUSES

Type of Cooling	Number	Share	Av. Age (Yrs)	Av. Star Rating*	Av. Conversion Efficiency - Cooler	Av. Conversion Efficiency - System
Room Refrigerative	27	75.0%	10.2	3.2	267%	252%
Ducted Evaporative	9	25.0%	6.1	-	1,478%	1,282%
Total	**36**	**100.0%**	**9.2**	**-**	**570%**	**509%**

* The Star Ratings of the Room Refrigerative air conditioners are based on the 2000 version of the label.

Water heating

Details of the water heaters found in the OGA study houses are provided in Table 11. The dominant form of water heating was gas (83.3%), with the majority of these (55.0%) being gas storage units. This is significantly higher than the current Victorian penetration of gas water heaters of 67.8% [ABS 2011a], although it is more in line with the penetration of gas water heaters in Melbourne (75.6%) [ABS 2008][27]. The penetration of solar water heaters in the OGA study houses (8.4%) was also higher than the current Victorian average of 3.8%, while the penetration of electric water heaters in the OGA study houses (8.3%) is significantly lower than the Victorian penetration of 28.2% [ABS 2011a]. The gas-boosted solar water heaters tended to be found in the larger households, with an average occupancy of 4.3 people compared with the average occupancy of 2.9 people.

The average age of the OGA study water heaters was 8.9 years. The average age of the electric water heaters was above the OGA stock average, and this may be because electric water heaters are progressively being replaced by gas, solar and heat pump water heaters. As expected, the average age of the solar water heaters is significantly below the OGA stock average, as most of these units have been installed in the last 10 years.

Gas water heaters have Energy Rating labels which allow the efficiency of different models to be compared. The overall average star rating of the gas water heaters was 4.0 Stars, although the gas instantaneous units (4.8 Stars) had a higher average efficiency than the gas storage units (3.6 Stars).

The average conversion efficiency and maintenance rate data in Table 11 allows a more direct comparison between the energy performance of the different types of water heater. In terms of energy efficiency the electric storage water heaters are more efficient than the gas water heaters; however, as gas is a cheaper fuel and less greenhouse intensive, the gas water heaters have a lower running cost and lower greenhouse gas emissions. The data provided for the gas- and electric-boosted solar water heaters is based on the reference water heater, and does not take into account the solar contribution for these water heaters – typically 60 to 70% - which results in a significantly lower energy usage for these systems compared to conventional gas and electric water heaters.

New gas water heaters are significantly more efficient that than the OGA study stock averages. A range of 5-Star gas storage water heaters are available and gas instantaneous units with a 6-Star rating, and claimed performance significantly better than a 6-Star unit, are available. Similarly, many solar and heat pump water heaters are available which have a much lower energy use than the conventional gas or electric water heaters they are designed to replace.

FIGURE 11: AGE PROFILE OF WATER HEATERS

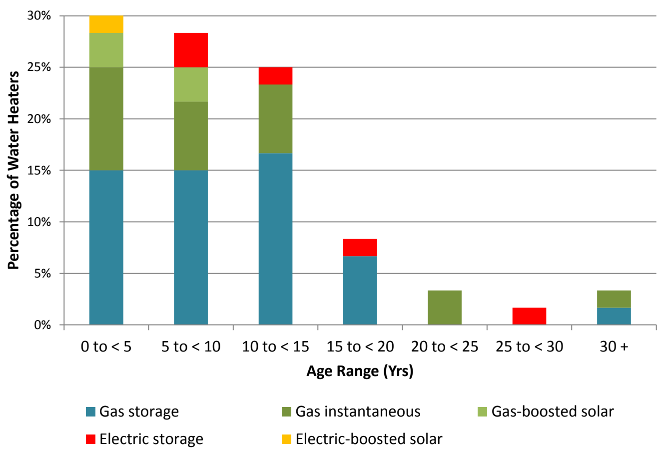
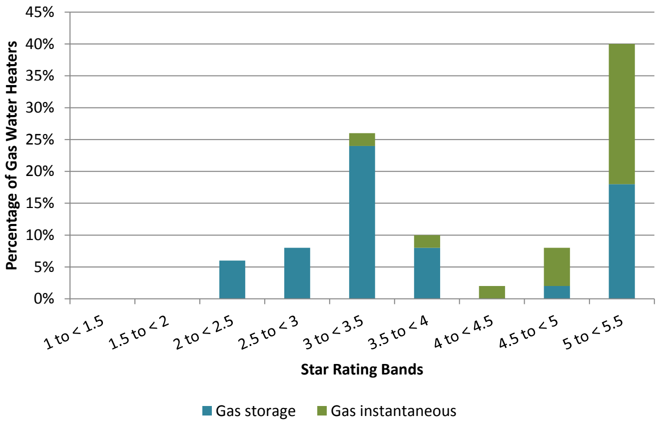


FIGURE 12: EFFICIENCY PROFILE OF GAS WATER HEATERS



27 More detailed data breakdowns of ABS data for 2005 suggest a penetration of 81% for gas water heaters and 17.5% for electric water heaters for detached dwellings in Melbourne.

TABLE 11: DETAILS OF WATER HEATERS IN OGA STUDY HOUSES

Type of Water Heating	Number	Share	Av. Number of People	Av. Age (Yrs)	Av. Star Rating	Av. Conversion Efficiency	Av. Maintenance Rate (MJ/day)
Gas storage	33	55.0%	2.8	9.0	3.6	77.9%	16.1
Gas instantaneous	17	28.3%	2.8	8.8	4.8	67.3%	1.5
Gas-boosted solar	4	6.7%	4.3	4.0	-	75.0%	18.0
Electric storage	5	8.3%	3.0	13.8	-	98.0%	9.4
Electric-boosted solar	1	1.7%	3.0	3.0	-	98.0%	9.6
Total	**60**	**100.0%**	**2.9**	**8.9**	**4.0**	**76.7%**	**9.2**

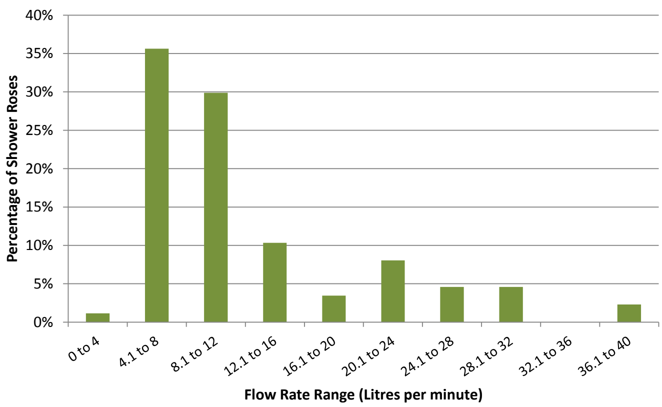
Shower rose

The shower rose has significant influence on the amount of hot water used in homes and therefore on the total energy used for water heating. Modelling undertaken for this study suggests that around 63% of all hot water is used for showering. The presence of a low flow shower rose can significantly reduce the amount of hot water used for showering.

A total of 87 shower roses were found in the OGA study houses, or an average of 1.45 per house. The flow rate of these shower roses was measured when the cold water tap was turned to the fully on position, and the distribution of the measured flow rates is shown in Figure 12. The average flow rate was found to be 12.6 litres per minute, with an average of 7.6 litres per minute for the low flow shower roses and 18.8 litres per minute for the other shower roses. Only 45% of the shower roses were found to be low flow models, with a flow rate less than 9 litres per minute.

While this data suggests a very significant potential for reducing the amount of hot water used for showering, a recent study by Yarra Valley Water [YVW 2011] found that households that don't have low flow shower roses tend to self-regulate the flow rate to a much lower level when showering. Measurements undertaken when the showers were in use found an average flow rate of 7.3 litres per minute for all shower roses, 6.3 litres per minute for the low flow shower roses and only 8.7 litres per minute for the other (non-low flow) shower roses. Nonetheless over a year the replacement of the higher flow shower roses with low flow shower roses can still generate significant energy and water savings for only a modest investment.

FIGURE 13: MEASURED FLOW RATES OF SHOWER ROSES IN THE OGA STUDY HOUSES



Refrigerators

Details of the refrigerators found in OGA study houses are provided in Table 12. All houses had some type of refrigerator and a number of houses had multiple units, giving an average ownership of 1.25 per house. The refrigerator stock was dominated by the 2-door fridges (80%), with the majority of these (69.3% of all refrigerators) being 2-door frost free models. The average total volume for the 2-door fridges was around 417 litres, significantly higher than the average volume for the 1-door fridges and both types of freezer.

TABLE 12: DETAILS OF REFRIGERATORS IN OGA STUDY HOUSES

Type of Refrigerator	Number	Share	Av. Age (Yrs)	Av. Fresh Food Volume (L)	Av. Freezer Volume (L)	Av. Star Rating	Av. CEC (kWh/Yr)
2-door fridge	60	80.0%	8.2	287.8	128.7	1.37	662.7
1- door fridge	8	10.7%	13.3	215.3	0.0	0.17	416.1
chest freezer	3	4.0%	14.7	0.0	215.7	2.13	393.7
upright freezer	4	5.3%	16.0	0.0	169.8	1.66	467.0
Total	**75**	**100.0%**	**9.4**	**253.3**	**123.9**	**1.30**	**615.2**

The average age of the OGA study refrigerators was 9.4 years, with the average age of the 2-door fridges (8.2 years) being significantly lower than the average age of the 1-door fridges and all types of freezer. This is consistent with an expected longer life for freezers compared with refrigerators. Also, 1-door fridges tend to be an older style of refrigerator, although in more recent times 1-door fridges have been sold with companion upright freezers as part of a so-called pigeon pair.

All refrigerators and freezers have Energy Rating labels which allow consumers to compare the energy efficiency of different models of the same type of refrigerator. The CEC (comparative energy consumption) – shown in Table 12 - is the annual energy consumption of the refrigerators when tested under laboratory conditions.

The average Star Rating of all refrigerators was 1.3 Stars, based on the 2010 rating scale, and an average CEC of 615 kWh per year. The average Star Rating of the dominant 2-door fridges was 1.37 stars, and the average CEC was 663 kWh per year.

Modern refrigerators are much more efficient than the stock average efficiency of the refrigerators found in the OGA study houses. The most efficient 2-door fridges now rate 4.0 Stars, while for the other types of refrigerator the current highest efficiency is 3.5 Stars (1-door), 4.0 Stars (chest freezer) and 3.5 Stars (upright freezer). Each increase of 1 star represents an energy saving of 23%.

FIGURE 14: AGE PROFILE OF REFRIGERATORS

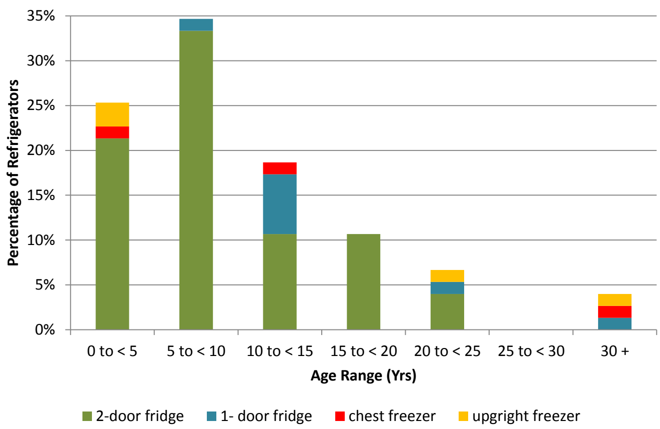
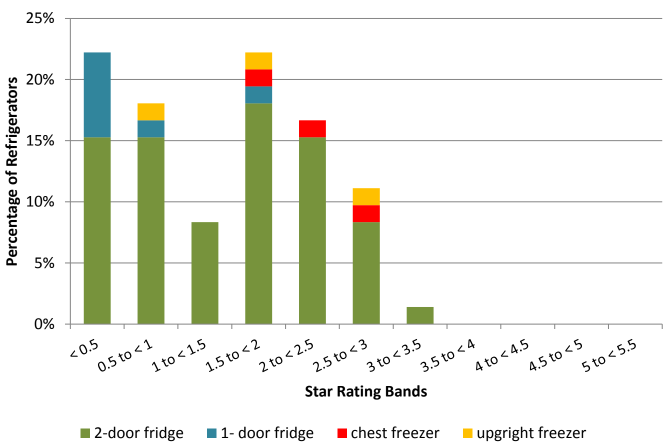


FIGURE 15: EFFICIENCY PROFILE OF REFRIGERATORS



Clothes washers

Details of the clothes washers (washing machines) found in the OGA study houses are provided in Table 13. All houses had a clothes washer, with the front loader machines (55%) dominating the stock. This is significantly higher than the Victorian penetration for front loaders of 33.5% [ABS 2011a]. There was little difference in the average load capacity of the different clothes washer types, reflecting the fact that the load capacity of the front loader machines has increased significantly in the last decade or so although, as expected, the average water use of the front loader machines was significantly less than the top loader machines – 66 litres per cycle vs 124 litres pre cycle. The average use of the clothes washers in the OGA study houses was estimated to be 253 loads washed per year – 4.9 loads per week. This compares favourably to an average of 4.7 loads per week for an average occupancy of 2.9 people, based on a recent Yarra Valley Water study [YVW 2011].

TABLE 13: DETAILS OF CLOTHES WASHERS IN OGA STUDY HOUSES

Type of Machine	Number	Share	Av. Age (Yrs)	Av. Load Capacity (kg)	Av. Star Rating	Av. CEC (kWh/Yr)	Av. Water Use per Cycle (L)	Av. No of Loads per Year
Front loader	33	55.0%	4.1	6.5	3.7	262	66	264.7
Top loader	27	45.0%	8.9	6.4	1.9	545	124	238.8
Total	**60**	**100.0%**	**6.3**	**6.5**	**2.9**	**389**	**92**	**253.1**

The average age of the clothes washers in the OGA study houses was found to be 6.3 years, with the average age of the front loaders (4.1 years) being substantially lower than for the top loaders. All front loaders were purchased in the last 15 years and this is consistent with the fact that front loading machines have steadily gained market share over top loader machines since the late 1990s. ABS data suggests that the penetration of front loaders increased from 7.4% to 33.5% between 1999 and 2011 [ABS 2011a].

All clothes washers carry Energy Rating labels to allow consumers to compare efficiency. The average star rating of all clothes washers was 2.9 Stars with, as expected, the Star Rating of front loader machines (3.7 Stars) being much higher than for top loader machines (1.9 Stars). This higher level of energy efficiency translates to both a lower annual energy use and a lower annual water use.

Energy and water savings can be achieved by replacing the existing top loading clothes washers with high efficiency front loading clothes washers; the most efficient models rate 4.5 to 5 Stars. To maximise the energy savings it is important that dual hot and cold water front loading machines are used, as single cold water connection machines heat any hot water required with an internal electric element.

FIGURE 16: AGE PROFILE OF CLOTHES WASHERS

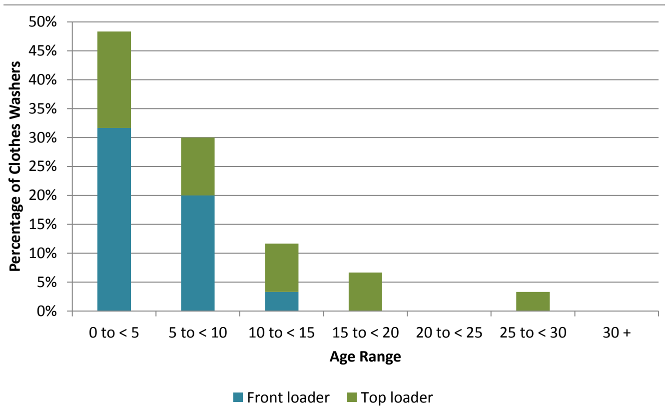
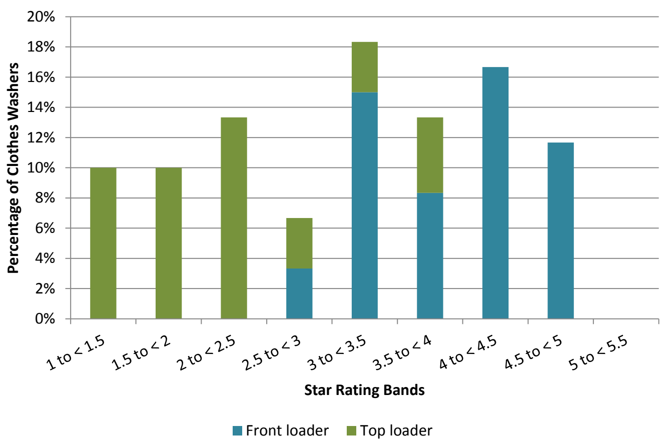


FIGURE 17: EFFICIENCY PROFILE OF CLOTHES WASHERS



Dishwashers

A total of 40 (67%) of the OGA study houses had a dishwasher, slightly higher than the current Victorian penetration of 58.4% [ABS 2011a]. The details of the dishwashers found in the houses are provided in Table 14. The average load capacity of the dishwashers was 13.2 place settings and the average water use per cycle was 18.1 litres. The average use of the dishwashers was estimated to be 239 loads washer per year – 4.6 loads washed per week - and this was higher than the average of 4.0 loads per week for a comparable occupancy level found in the Yarra Valley Water study [YVW 2011].

TABLE 14: DETAILS OF DISHWASHERS IN OGA STUDY HOUSES

Number	Av. Age (Yrs)	Av. Capacity (Place Settings)	Av. Star Rating	Av. CEC (kWh/ Yr)	Av. Water Use per Cycle (L)	Av. No of Loads per Year
40	7.0	13.2	2.7	325	18.1	239.1

The average age of the dishwashers was 7.0 years, with the majority of these (65%) purchased within the last 10 years. The penetration of dishwashers in Victorian houses has increased significantly over the last decade or so, from 37.4% in 1999 to 58.4% in 2011 [ABS 2011a, ABS 2008]. However, there was also a small number (12.5%) of the dishwashers which were more than 15 years old.

Dishwashers have Energy Rating labels to assist consumers to compare the efficiency of different models. The average Star Rating of the dishwashers was 2.7 stars, although one quarter of the dishwashers had a rating of less than 2.5 Stars.

The average dishwasher found in the OGA study houses is significantly less efficient than the highest efficiency models on the market. The most efficient 14 place setting dishwashers currently rate 4 Stars and have a CEC of 225 kWh per year (based on one load washed per day). While energy savings are possible from upgrading to a higher efficiency dishwasher, the energy and water savings which can be achieved are fairly modest for most households.

FIGURE 18: AGE PROFILE OF DISHWASHERS

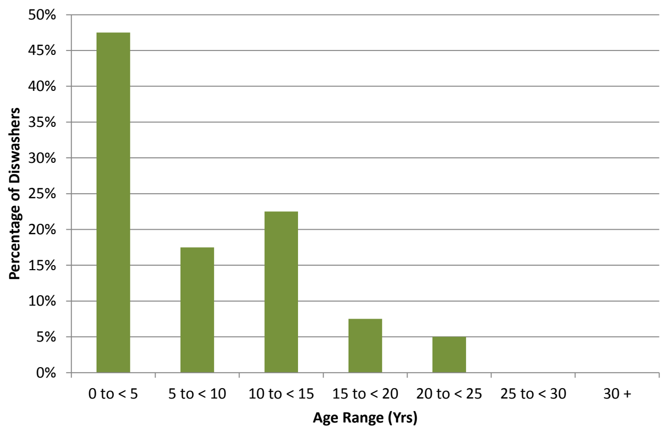
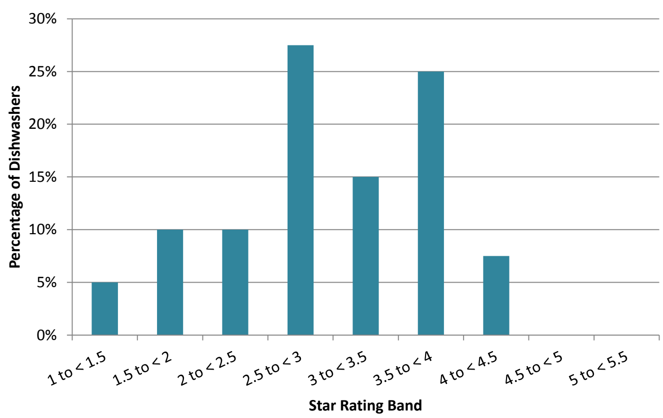


FIGURE 19: EFFICIENCY PROFILE OF DISHWASHERS



Clothes dryers

Clothes dryers were present in 27 (45%) of the OGA study houses, and this was lower than the current Victorian penetration of 54.1% [ABS 2011a]. The details of the clothes dryers found in the houses are provided in Table 15. The average load capacity of the clothes dryers was 4.8 kg. The average use of the clothes dryers was estimated to be 102 loads dried per year – this is somewhat higher than the 52 loads per year which the CEC figure on the clothes dryer Energy Rating labels is based on.

TABLE 15: DETAILS OF CLOTHES DRYERS IN OGA STUDY HOUSES

Number	Av. Age (Yrs)	Av. Capacity (Kg)	Av. Star Rating	Av. CEC (kWh/Yr)	Av. No of Loads per Year
27	8.8	4.8	2.0	229.3	102.1

The average age of the clothes dryers installed in the OGA study houses was 8.8 years, although the majority of the clothes dryers (55.6%) were more than 10 years old.

Electric clothes dryers have Energy Rating labels to allow consumers to compare the efficiency of different models. The average efficiency of the clothes dryers was 2 Stars. All of the clothes dryers were conventional electrical units which use an electric element to provide the heating, and this explains their relatively low efficiency.

There is little variation in the energy efficiency of the conventional electrical clothes dryers which are available on the market today. Significant energy savings are only possible by replacing conventional clothes dryers with heat pump clothes dryers, which work on a similar principle to a reverse-cycle air conditioner. An increasing number of heat pump clothes dryers are becoming available on the market with energy ratings typically between 6- and 8-Stars. Gas clothes dryers are also available and they offer lower running costs compared to the conventional electric dryers.

FIGURE 20: AGE PROFILE OF CLOTHES DRYERS

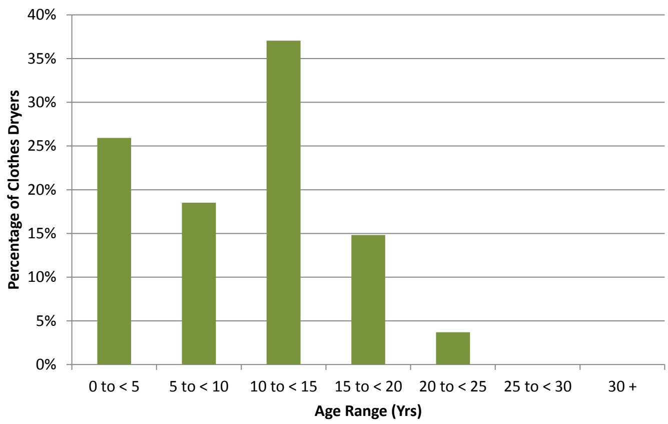
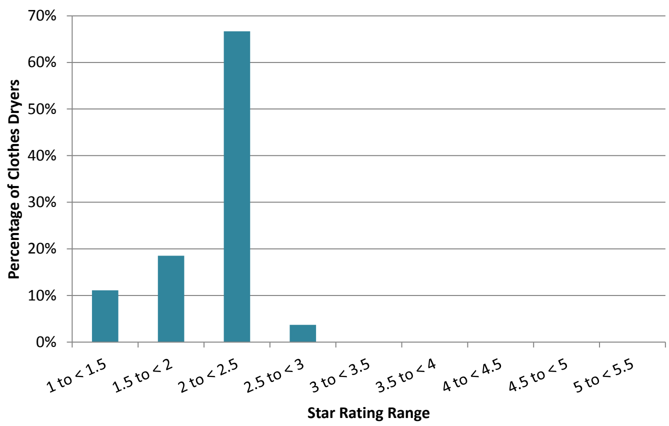


FIGURE 21: EFFICIENCY PROFILE OF CLOTHES DRYERS



Televisions

95% of the OGA study houses had at least one television, slightly lower than the current Victorian penetration of 99.2% [ABS 2011a]. Many houses now have multiple televisions. There were a total of 109 televisions in the 57 houses which did have one, or an average ownership of 1.91. The ownership profile for TVs in the OGA study houses is shown in Table 16.

TABLE 16: OWNERSHIP OF TVS IN OGA STUDY HOUSES

Number of TVs	Number of Houses	%
None	3	5.0%
1	23	38.3%
2	20	33.3%
3	11	18.3%
4	2	3.3%
5	1	1.7%
Total	**60**	**100.0%**

Details of the TVs which were found in the OGA study houses are provided in Table 17. The older CRT televisions (52.3%) were the dominant type of TV, followed by LCD (41.3%) and plasma. Except for the LCD televisions, the share of the different types of TV in the OGA study houses was quite different to the Victorian average reported in a recent ABS study [ABS, 2011b]:- CRT (36.8%), LCD (40.4%), plasma (20.9%) and other (1.9%). The average screen size of the televisions (measured across the diagonal) was 75.3 cm, with both the LCD and plasma televisions being significantly larger than the average. The increasing ownership of these larger "flat screen" televisions has been one factor putting upward pressure on residential electricity consumption over the last decade [EES 2008].

The average age of the TVs was 5.8 years, and the average age of the LCD (2.4 years) and plasma (2.3 years) TVs was much lower than this. This reflects the rapidly increasing penetration of these "flat screen" TVs over the last decade, with the majority of the LCD and plasma TVs having been purchased in the last 5 years.

The estimated average efficiency of the TVs was 2.7 Stars[28], with the efficiency of the LCD TVs (3.6 Stars) being above average, and the efficiency of both the plasma (1.5 Stars) and CRT TVs being below average.

The market for TVs is now dominated by the larger flat screen televisions, particularly the LCD televisions which currently account for around 85% of the flat screen market. The energy efficiency of new TVs has increased dramatically over the last 5 years: in 2013 the average LCD TV had a 6.3 Star rating and the average plasma TV a 5.2 Star rating (based on the 2009 version of the label)[29]. The most efficient TVs on the market currently receive an 8 to 9 Star rating under the old (2009) rating scale, with each extra star representing a 20% reduction in energy use. This trend to increasing efficiency is off-set to some extent to a trend to larger screen size.

FIGURE 22: AGE PROFILE OF TELEVISIONS

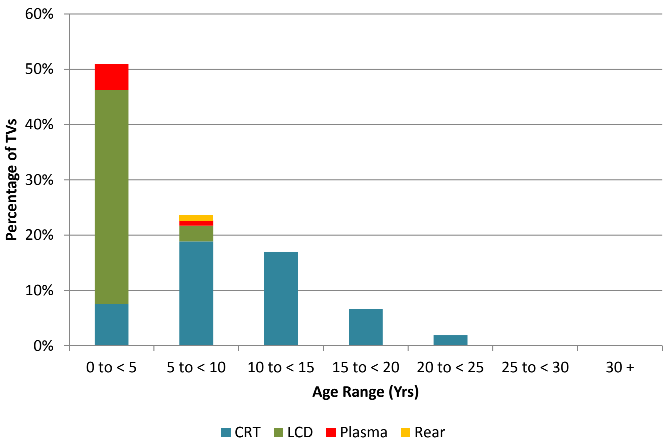
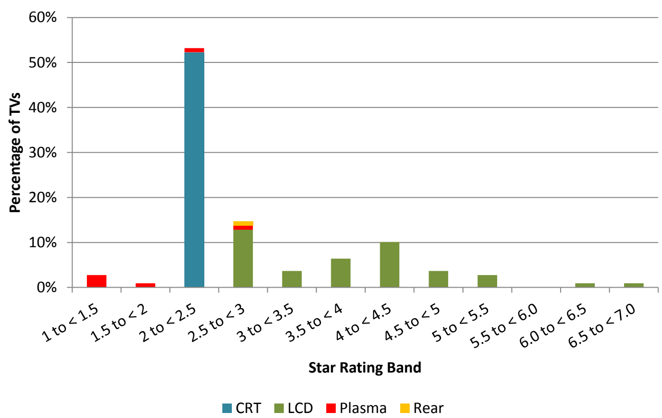


FIGURE 23: EFFICIENCY PROFILE OF TELEVISIONS



28 Energy Rating data was only available for the TVs sold from 2009. For TVs which were older than this the Energy Ratings were estimated based on the type and age of the television.

29 Based on SV analysis of GfK June 2013 flat screen TV sales data.

TABLE 17: DETAILS OF TVS IN OGA STUDY HOUSES

Type of TV	Number	Share	Av. Age (Yrs)	Av. Screen Size (cm)	Av. Star Rating*	Av. CEC (kWh/Yr)
CRT	57	52.3%	8.8	58.0	2.0	360
LCD	45	41.3%	2.4	90.7	3.6	468
Plasma	6	5.5%	2.3	117.7	1.5	1,087
Rear projection	1	0.9%	9.0	110.0	2.5	850
Total	**109**	**100.0%**	**5.8**	**75.3**	**2.7**	**446**

* The Star Ratings of the televisions are based on the 2009 version of the label.

Computers

98.3% of the OGA study houses had at least one computer. As with televisions, multiple-ownership of computers is becoming increasingly common. There were 92 computers in the 59 houses which had one, or an average ownership of 1.56. The ownership profile for computers in the OGA study houses is shown in Table 18.

TABLE 18: OWNERSHIP OF COMPUTERS IN OGA STUDY HOUSES

Number Per House	Number of Houses	%
0	1	1.7%
1	35	58.3%
2	16	26.7%
3	6	10.0%
4	1	1.7%
5	1	1.7%
Total	**60**	**100.0%**

Details of the computers found in the OGA study houses are provided in Table 19, and the details of the associated computer monitors are provided in Table 20. A large number of the computers were laptops, which have a substantially lower energy use than desktop computers as they are designed to run from their battery, use the more efficient LCD monitors and have a smaller screen size. Further, over 90% of the monitors used with the all of the computers were the more efficient LCD monitors.

The OGA study data suggests that the stock of residential computers is transforming fairly rapidly towards higher energy efficiency and lower energy use. This is supported by ABS data which shows that between 2008 and 2011 the penetration of laptops increased from 37.9% to 61.4% while the penetration of desktop computers decreased from 59.6% to 55.3% [ABS 2011a]. In addition to this the traditional role of computers is increasingly being taken over by a range of low power mobile devices. For this reason no analysis was undertaken of the potential to upgrade the efficiency of the computers found in Victorian houses.

TABLE 19: DETAILS OF COMPUTERS IN OGA STUDY HOUSES

			Age		Screen size	
Type	Number	%	Number Known	Av. Age (Yrs)	Number Known	Av. Size (cm)
Desktop	42	45.7%	39	3.9	34	47.9
Integrated	9	9.8%	9	2.8	8	54.6
Laptop	41	44.6%	38	3.1	9	40.2
Total	**92**	**100.0%**	**86**	**3.4**	**51**	**47.6**

TABLE 20: TYPE OF MONITOR ON OGA STUDY COMPUTERS

Type	No	%
CRT	8	8.7%
LCD	84	91.3%
Total	**92**	**100.0%**

3. Energy Efficiency Upgrade Potential of House Building Shells

Overview of the analysis methodology

The impact of eleven different building shell energy efficiency upgrade options were assessed in this study. The upgrade options and the way in which the different options were applied to the houses are shown in Table 21.

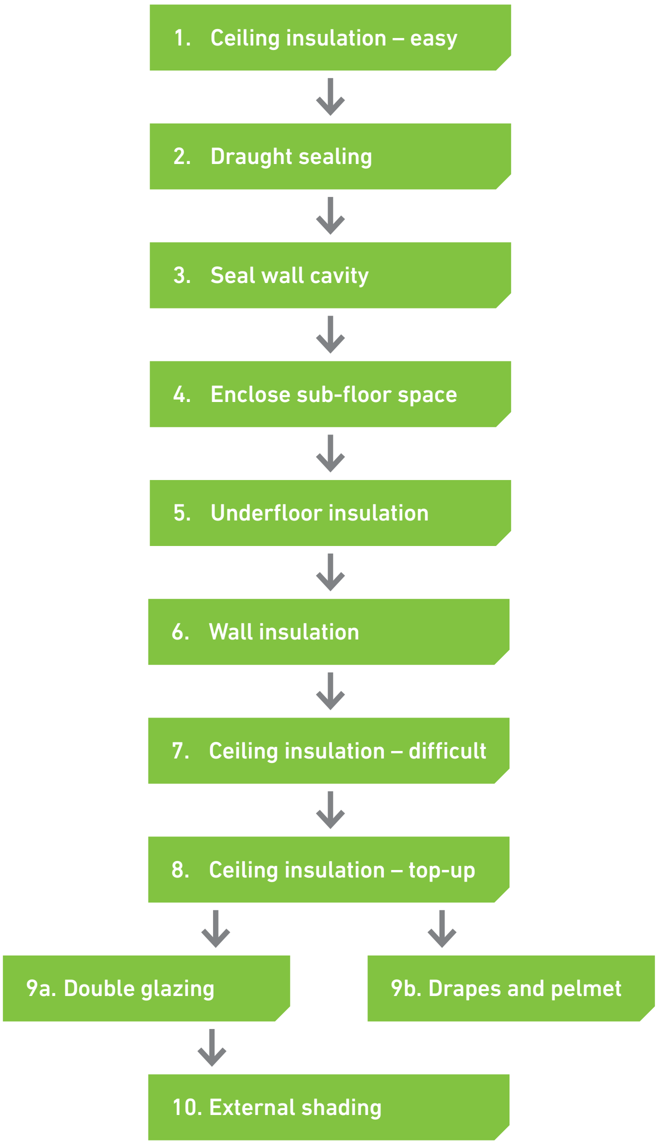
The 60 OGA study houses were assessed to identify the building shell energy efficiency upgrades which could be practically applied to each house, and the extent to which each upgrade could be applied. All possible upgrades were then modelled using the FirstRate5 program to determine the House Energy Rating (HER) of the house after each upgrade had been applied. The upgrades were applied progressively to the houses in the order shown in Table 21, rather than individually. This was to ensure that the impact of the overall package of upgrade measures applied to each house was modelled correctly. Due to potential interactions between different upgrade measures it is not possible to individually model each measure and then add up the individual impacts to determine the overall impact. However, this approach may mean that the impact of some measures applied later in the list are lower than if they had been applied as a one-off upgrade or had been applied earlier in the list.

TABLE 21: BUILDING SHELL ENERGY EFFICIENCY UPGRADE OPTIONS

Upgrade option	Description	Application of the upgrade option
1. Ceiling insulation – easy	Installation of R3.5 ceiling insulation where roof space is easily accessible and there is currently no ceiling insulation.	Applied to the entire uninsulated area.
2. Draught sealing	Comprehensive draught sealing to take each house from its initial state to an air leakage rate of 0.5 Air Changes per Hour.	Whole house, where necessary.
3. Sealing wall cavity	Seal wall cavity to reduce the circulation of air through the wall cavity.	Applied to houses with suspended floor and brick-veneer or cavity brick walls.
4. Enclose sub-floor space	Enclose open sub-floor space to reduce sub-floor ventilation.	Whole house, where necessary.
5. Underfloor insulation	Installation of R1.5 insulation batts to suspended floor where sub-floor space is easily accessible.	Applied to entire uninsulated area which is accessible.
6. Wall insulation	Installation of blow-in hydrophobic granulated Rockwool to all external walls.	R1.5 added to brick veneer walls with reflective foil laminate (RFL) wrapping on the frame and cavity brick walls. R3.5 added to brick veneer walls without RFL, and R2.5 added to 90 mm timber framed walls.
7. Ceiling insulation - difficult	Installation of R2.5 ceiling insulation where roof access is not straightforward, e.g. flat or raked ceilings, and there is no ceiling insulation currently installed.	All difficult to access ceiling spaces which are uninsulated.
8. Ceiling insulation top-up	Top-up of ceiling insulation to R3.5 where there is currently R2.0 or less, and the roof space is easily accessible.	Whole ceiling.
9a. Double glazing	Removal of existing single-glazed windows and replacement with double-glazed windows.	All windows in the conditioned zones of the house, excluding partially glazed doors and door sidelights.
9b. Drapes & pelmet	Installation of thick, close-fitting, drapes and box pelmets to windows.	All windows in the conditioned zones of the house, excluding bathroom and laundry windows, kitchen windows above cooking/cleaning areas, glazed doors, door sidelights and high windows that cannot be easily reached.
10. External shading	Installation of external awnings to all unshaded east, west and north facing windows.	All inadequately shaded windows in the conditioned zones of the house, excluding glazed doors, door sidelights and high windows that cannot be easily reached.

The window insulation measures – double glazing (9a) and drapes and pelmets (9b) – were applied separately in the modelling as shown in Figure 24. This was because they have a similar impact on the thermal performance of the windows – reducing heat losses in winter and conducted heat gains in summer – and modelling drapes and pelmets after double-glazing would have significantly reduced the impact of this measure, and vice versa.

FIGURE 24: APPLICATION OF THE ENERGY EFFICIENCY UPGRADE MEASURES IN FIRSTRATE5



In addition to modelling the impact of the upgrade measures on the HERs of the houses, the cost of each building shell upgrade was estimated. This was based on the type and extent of the upgrade applied and the cost assumptions which are detailed in Appendix A5.

Overall results of the building shell analysis

The impact of the building shell upgrades on the average HER of the stock of 60 houses, as the upgrades are progressively applied, is shown in Figure 25. The average HER increased from 1.81 (houses in their existing state) to 5.05 once all of the upgrades have been applied, an increase of 3.24 Stars. It is evident from Figure 25 that draught sealing, wall insulation and double-glazing (or drapes and pelmets) are the upgrade measures which have the biggest impact on the average HER of the stock. Together they are responsible for around 70% of the observed increase in the stock average HER.

FIGURE 25: STOCK AVERAGE HER AS BUILDING SHELL UPGRADES PROGRESSIVELY APPLIED

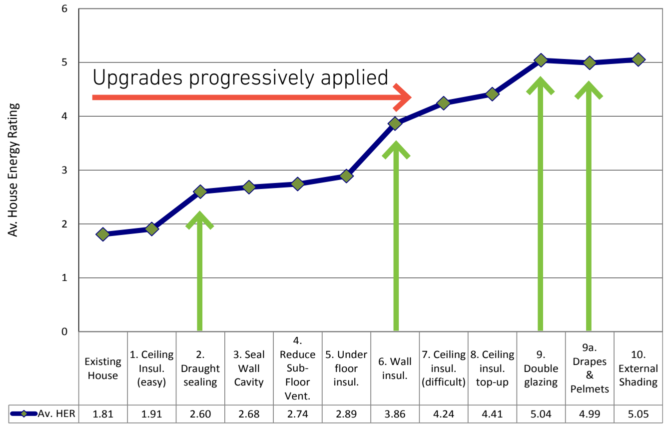


Figure 26 shows the distribution of the HERs of the stock of 60 houses before and after all of the upgrades have been applied. While the average HER of the stock after upgrade was 5.05, 40% of the existing houses could not be upgraded to a 5 Star HER. However, 25% of the houses could be upgraded to quite a high level of energy efficiency – a HER in the range of 5.5 to 7 Stars.

FIGURE 26: DISTRIBUTION OF HERS BEFORE AND AFTER UPGRADE

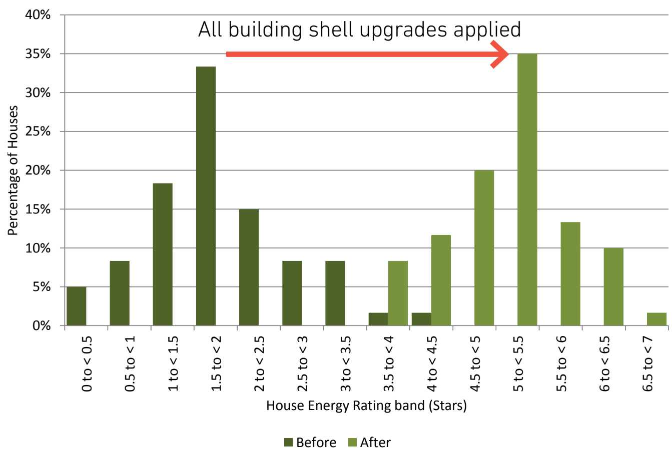
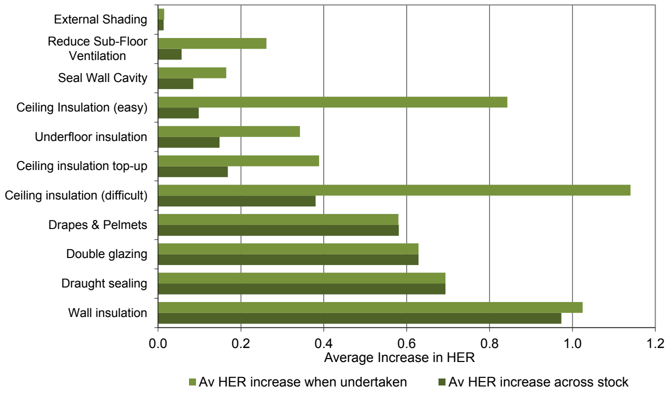


FIGURE 27: IMPACT OF INDIVIDUAL UPGRADES ON HER



The impact of the individual upgrade measures on the average HER of the houses is shown in Figure 27. The impact is shown for two situations:

1. only for those houses where the measure has been applied. This highlights those upgrade measures which can have a significant impact on HER – and therefore thermal comfort and heating and cooling costs – when they can be applied to a house. Insulating an uninsulated ceiling (whether easy or difficult), and wall insulation are the stand out measures;
2. across the stock of 60 houses. This highlights those measures which could have the biggest impact on HER if they were applied more generally across the existing Victorian housing stock. Wall insulation, draught sealing and double-glazing (or drapes and pelmets) provide the greatest increase in HER across the stock.

TABLE 22: IMPACT OF THE INDIVIDUAL BUILDING SHELL UPGRADE MEASURES

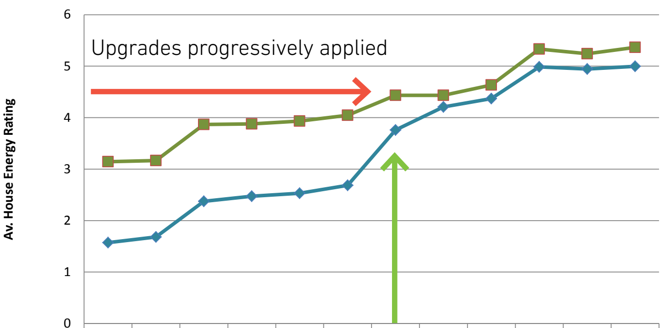
		When undertaken		Across house stock	
Upgrade Measure	% of Houses Applied To	Average improvement in HER	Average Cost per House	Average improvement in HER	Average Cost per house
Ceiling insulation (difficult)	33%	1.14	$835	0.38	$278
Wall insulation	95%	1.02	$4,171	0.97	$3,963
Ceiling Insulation (easy)	12%	0.84	$673	0.10	$79
Draught sealing	100%	0.69	$1,032	0.69	$1,032
Double glazing	100%	0.63	$16,168	0.63	$16,168
Drapes & Pelmets	100%	0.58	$2,832	0.58	$2,832
Ceiling insulation top-up	43%	0.39	$774	0.17	$335
Underfloor insulation	43%	0.34	$1,993	0.15	$863
Reduce Sub-Floor Ventilation	22%	0.26	$769	0.06	$167
Seal Wall Cavity	52%	0.16	$537	0.08	$277
External Shading	90%	0.01	$1,755	0.01	$1,579

For energy efficiency upgrade measures to have a large impact across the housing stock it is necessary for them to have both a large individual impact (e.g. when they are applied) and also to have a fairly large applicability across the stock. This is the key reason why wall insulation, draught sealing and double-glazing (or drapes and pelmets) have the largest impact. While the ceiling insulation measures have a large individual impact, they can only be applied to a fairly small percentage of the houses as the majority of Victorian houses already have ceiling insulation, so their overall impact across the stock is quite modest[30].

The impact and the average costs of the different upgrade measures are summarised in Table 22. The measures have been ranked in descending order, based on the average impact on HER when applied to a house. The average cost of applying the upgrades to the houses (to achieve the average HER of 5.05 Stars) was $11,405 if drapes and pelmets were used[31] and $24,742 if double-glazing was used. The most cost effective measures, in terms of cost per increase in HER, are the two ceiling insulation measures (easy and difficult) and draught sealing.

We have also investigated the effect that the housing cohort – pre-1990 versus post-1990 – has on the building shell upgrade potential. Figure 28 shows the how the average HER of the houses changes after the application of each building shell upgrades. While the average HER of the post-1990 houses (3.14) is substantially higher than the average HER of the pre-1990 houses (1.57), the HER of the houses once all upgrades had been applied are much closer. It is evident that installation of wall insulation is the main measure which is responsible for this. The average upgrade cost of the two housing cohorts was broadly similar: excluding double glazing the cost was $11,733 for the pre-1990 houses and $9,549 for the post-1990 houses; including double glazing the cost was $24,648 for the pre-1990 houses and $25,272 for the post-1990 houses.

FIGURE 28: EFFECT OF HOUSING COHORT ON IMPACT OF BUILDING SHELL UPGRADES



	Existing House	1. Ceiling Insul. (easy)	2. Draught sealing	3. Seal Wall Cavity	4. Reduce Sub-Floor Vent.	5. Underflo or insul.	6. Wall insul.	7. Ceiling insul. - difficult	8. Ceiling insul. top-up	9. Double glazing	9a. Drapes & Pelmets	10. External Shading
Pre 1990	1.57	1.68	2.37	2.47	2.53	2.68	3.76	4.21	4.37	4.99	4.94	5.00
Post 1990	3.14	3.17	3.87	3.88	3.93	4.04	4.43	4.43	4.63	5.33	5.24	5.37

30 ABS data suggests that around 88% of Victorian houses have an insulated ceiling [ABS 2011 a, ABS 2011 b]

31 Note that in rating mode the only internal window coverings which can be used are Holland blinds, so in a formal sense the use of drapes and pelmets could not give an average HER of 5.05. However, the houses would have a thermal performance which was similar to a house with this rating.

4. Cost-Benefit Analysis of Energy Efficiency Upgrades

Overview of the analysis methodology

The energy saving impact of a range of common building shell, lighting and appliance energy efficiency upgrades was assessed for the 60 OGA study houses. An overview of the general approach taken for this analysis is provided in Chapter 1. It involved estimating the cost of the upgrades which could be practically applied to each house, and modelling the annual energy (and in some cases also the water) savings which would result if the upgrades were applied.

The building shell upgrades modelled were the same as those shown in Table 21 in Chapter 3, although there were some variations in the way the upgrade measures were applied. Building shell upgrades only translate into an actual energy saving if they are applied to areas of a house which are heated and cooled[32], so in some cases upgrades which were applied for the HER analysis presented in Chapter 3 were either not applied for the cost-benefit analysis or were applied in a scaled-down form. All insulation measures, draught sealing, sealing the wall cavity and enclosing a sub-floor space were applied in the same way as for the HER analysis[33]. The key differences in the application of the measures were:

- Double-glazing and drapes and pelmets were only applied to those areas of the house which had fixed heating;
- External awnings were only applied to those areas of the house which had fixed cooling;
- In a few instances the building shell upgrades which were applied for the HER analysis were not applied for the cost-benefit analysis as they resulted in a net increase in the cost of heating and cooling energy. This occurred in some houses which were heated and cooled, and for measures such as under floor insulation, sealing the wall cavity and draught sealing which can increase the cooling load.

The type of heating and cooling equipment used in the houses, and the energy efficiency of this equipment, has a big impact on the houses' annual heating and cooling energy use (and energy bills), and therefore a big impact on the annual energy savings which are realised when building shell upgrades are applied. Thus the point in the upgrade process at which the heating and cooling equipment upgrades are assumed to be applied has a significant impact on the energy savings which are estimated for the building shell upgrades. For the OGA study analysis the heating and cooling equipment upgrades were applied between the underfloor insulation measure (building shell upgrade 5) and the wall insulation measure (building shell upgrade 6). The energy savings estimate for building shell upgrade measures 1 to 5 were based on the houses' existing fixed heating and cooling equipment, while the energy savings estimate for building shell upgrade measures 6 to 10 were based on the upgraded[34] fixed heating and cooling equipment.

32 For example the use of external shading will not result in an actual cooling energy saving if a house does not use supplementary cooling such as an air conditioner. It will however increase thermal comfort in summer.

33 While these measures could be applied selectively to only those areas of houses which are heated and cooled, it was felt that generally these measures would be applied to the whole of the house.

34 The heating and cooling equipment was only upgraded if it had a relatively low level of energy efficiency. Where high efficiency heating and cooling equipment was already present no upgrade was applied – refer Table 23 for further information.

Similarly, the energy savings estimates for upgrading the heating and cooling equipment were based on the heating and cooling loads of the houses after they had had all relevant building shell upgrade measures up to under floor insulation applied (upgrades 1 to 5)[35].

In addition to lighting, 9 different appliance and equipment upgrade options were assessed for the OGA study houses, as shown in Table 23. As with the building shell upgrades the lighting and appliance upgrades were only applied where it was both practical and possible to do so, based on the energy efficiency status of the existing equipment found in the houses (refer to Chapter 2). Where houses already had efficient lighting and appliances no upgrade was applied.

35 The effect of the application order on the building shell upgrades and the heating and cooling upgrades is explored further in Appendix A5.

TABLE 23: LIGHTING AND APPLIANCE UPGRADE OPTIONS

Upgrade option	Description	Application of the upgrade option
Lighting	Incandescent light globes replaced by compact fluorescent lamps. Halogen downlights replaced by LED downlights.	Lighting upgrades applied to all inefficient incandescent and 12 volt halogen downlights found in the houses.
Heating	Gas ducted heater < 5 Star upgraded to 6 Star ducted heater. Gas room heater < 4 Star upgraded to > 4 Star room heater. Electric heating upgraded to reverse-cycle air conditioner with CoP of 4.41. Reverse-cycle air conditioner with CoP < 3.5 upgraded to reverse-cycle air conditioner with CoP of 4.41.	All low efficiency fixed heating upgraded to a high efficiency heater.
Cooling	Refrigerative air conditioner with EER < 3.5 upgraded to refrigerative air conditioner with EER of 3.85.	All inefficient refrigerative air conditioners upgraded to a high efficiency unit. No upgrades applied where an evaporative cooler was the main form of fixed cooling.
Refrigerator (2010 ratings)	2-door refrigerator: <300L, 1.5 Stars or less and >300L, 2.5 Stars or less upgraded. 1-door refrigerator: <200L, 2.5 Stars or less and >200L, 1.5 Stars or less upgraded. Chest freezer: <250L, 2.5 Stars or less and >250L 2 Stars or less upgraded. Upright freezer 1 Star or less upgraded.	All inefficient refrigerators upgraded to a high efficiency unit (See Appendix A4 for further details). Replacement refrigerators were chosen to have a similar volume to the existing refrigerator, and Star Rating of replacement was dependent on refrigerator volume.
Television (2009 rating)	Televisions < 6 Stars upgraded to 8 Star unit.	All inefficient televisions upgraded to a high efficiency unit.
Shower rose	Standard (flow rate > 9 Litres per minute) shower roses replaced by low flow (< 9 Litres per minute) shower roses.	All standard shower roses replaced. This upgrade was applied before the water heating upgrade.
Water heating	Gas water heater < 5 Stars upgraded to high efficiency gas water heater – storage (5.2 Stars) and instantaneous (5.9 Stars). Electric storage water heater replaced by 5.2 Star gas storage water heater.	All inefficient gas water heaters and electric water heaters replaced by a high efficiency gas water heater. This upgrade was applied after the shower rose upgrade, and the energy savings based on the estimated water use of the household with low flow shower roses present.
Clothes washer (washing machine)	Clothes washer < 3.5 Stars replaced by 3.5 or 4 Star front loading clothes washer (depending on load capacity) with a hot and cold water connection.	All inefficient clothes washers replaced with an efficient front loading machine. This upgrade was applied after the water heating upgrade.
Dishwasher	10 place settings or less upgraded to 3 Star model; > 10 place settings upgraded to 4 Star model.	All inefficient dishwashers replaced with an efficient dishwasher. This upgrade was applied after the water heating upgrade.
Clothes dryer	Conventional electric clothes dryers replaced with a 6 or 7 Star heat pump clothes dryer, depending on load capacity.	All conventional electric clothes dryers replaced with a heat pump clothes dryer.

The order in which the upgrade measures relating to "wet"[36] appliances are applied has an impact on the energy savings estimated for each measure. As it was likely to be the most cost-effective measure, the shower rose upgrade was applied before the water heater upgrade. This meant that the household hot water use that the water heater upgrade analysis was based on may have been less than the current hot water usage of the household[37]. Similarly, the water heater upgrade was applied before the clothes washer and dishwasher upgrades and so the estimated energy savings for any (imported) hot water savings resulting from these upgrades was based on the upgraded water heater[38].

The upgrade costs for the lighting and appliances were based on data provided by MEFL, supplemented by recent price data from a number of price comparison websites. There are two possible options for calculating the cost of the appliance upgrades:

- Use the full capital and installation cost of the equipment;
- Use an adjusted capital cost to recognise the fact that the majority of the existing appliances and equipment will only be replaced when they are at or close to the end of their life. In general, this approach will give a lower cost than option 1.

For this study an adjusted capital cost was used as the basis for estimating the upgrade cost for all of the electrical and gas appliances. The full cost was used only for the lighting and shower rose upgrades. It was felt that this allows a fairer comparison of the cost-effectiveness of all of the upgrade measures - building shell, lighting and appliances – as most appliances are only replaced at or near the end of their useful life. The adjusted capital cost took into account the typical average life of the appliance type in question. The general approach used was to allocate the full capital and installation cost if the existing appliance was brand new and to allocate the differential cost between the high efficiency appliance and average new appliance sold if the age of the existing appliance meant that it was at or past the typical replacement age. The cost was allocated proportionally between these two points. More detail on the methodology used for particular appliance types is provided in Appendix A4.

36 This includes the shower rose, water heater, clothes washer and dishwasher.
37 This was the case where the household currently had standard shower roses.
38 The impact of reversing the order of the shower rose and water heater upgrades is explored in Appendix A5. The impact of changing the order of the washing machine and dishwasher upgrades was not explored, as this is likely to have only a minor impact on the savings achieved.

Estimated heating energy use

When considering the economics of the building shell upgrades it is important to understand that Victorian heating and cooling energy use is dominated by winter heating, especially in the more populous southern regions. This meant that it was important to have an accurate as possible estimate of the existing heating energy use of the OGA study houses, to ensure that the energy savings estimates would also be accurate and would not overestimate the savings which could be achieved. As noted in Chapter 1, the initial OGA pilot studies used FirstRate5 modelling to estimate the actual heating load of the houses and this tended to overestimate the heating energy use and therefore the savings. For this report, the heating energy use for most of the houses was based on an estimate derived from their gas bills. While this is still an estimate, we believe it is likely to be more accurate than an estimate based on a straight modelling approach.

The estimated gas consumption data for the 53 houses for which data was available is summarised in Table 24. The average annual gas use of the OGA study houses is quite close to the average gas use estimated in the Victorian Utility Consumption Household Survey 2007 [DHS 2008][39]. As expected, houses which have gas central heating had significantly higher annual gas consumption than houses which had only gas room heating. The estimated average annual heating gas use of the centrally heated houses was 61,190 MJ/yr, around two and a half times higher than the estimated average annual heating gas use of the houses heated by gas room heaters (24,119 MJ/yr). In both cases it is also evident that the gas used for heating dominates total household gas use.

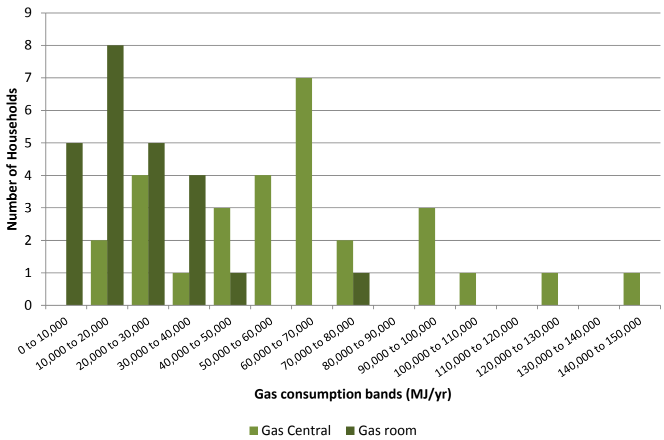
TABLE 24: ESTIMATED ANNUAL GAS HEATING ENERGY USE OF OGA STUDY HOUSES

	Av. Gas Use (MJ/Yr)	Av. Gas Use Heating (MJ/Yr)	Gas Heating Cost ($/Yr)*
Victorian Utility Consumption Survey			
Victorian Average 2007	62,539	-	-
OGA Study Houses			
All houses	59,759	42,360	$741.3
Central heating	80,766	61,190	$1,070.8
Room heating	36,815	24,119	$422.1

* Based on a natural gas tariff of 1.75 c/MJ. Electricity use by gas heaters can increase total heating costs

The estimated average annual cost of the gas used for heating is shown in Table 24. This gives an idea of the value of the energy savings which are possible from upgrading the building shell and the heating equipment. For example, achieving an overall 50% saving from the upgrades would save around $535 per annum for the average gas ducted heating household, but only around $211 per annum for the average household with gas room heating. To stay under a 10-year payback for the required building shell and/or heating upgrades would mean total expenditure of no more than $5,350 for the average central heating household and no more than $2,110 for the average room heating household.

FIGURE 29: DISTRIBUTION OF ANNUAL GAS HEATING CONSUMPTION FOR GAS HEATING HOUSEHOLDS



It is also important to understand that the average gas use figures in Table 24 hide a very high level of diversity in the way in which gas heating is used across the different OGA study households. The distribution of the annual gas heating energy use for the households is shown in Figure 29, broken down into the central heating and room heating households. There is quite a wide spread of gas use for both the room heating and central heating households, and especially so for the central heating households. There is also a significant overlap in the two distributions, so that some households with gas room heating use more gas than some households with central heating. This high level of diversity in gas use for heating has important implications for the economics of upgrading the building shell and heating in the households, and helps to explain the high diversity of outcomes which are observed for any particular building shell or heating upgrade in the OGA study houses (See Appendices A3 and A4). It also highlights the need for households to obtain specific, customised advice if they are assessing the energy efficiency upgrade options for their house.

39 Note that it is difficult to make direct comparisons between household gas use in one year compared to another, as gas use is very dependent on the severity of the winter and can change quite significantly from year to year.

Building shell upgrades

The average impacts of the building shell upgrade measures – cost, energy, greenhouse and monetary savings and average payback – for the houses in which the measures were modelled are shown in Table 25. The measures have been arranged in order of increasing payback, based on the stock average payback[40]. This table also shows the percentage of the 60 houses in which it was found to be both possible and practical to implement each measure in (% Houses Applied To).

As noted previously, the costings used in this analysis are based on the commercial cost of undertaking the upgrades and do not include any government financial incentives that are available. Upgrades such as draught sealing, the more straight forward ceiling insulation and ceiling insulation top-ups, underfloor insulation, and reducing sub-floor ventilation could be undertaken as DIY projects, thereby reducing costs, although it is important that all electrical, gas and other general safety requirements are complied with. In particular, working in confined spaces such as the roof space and sub-floor space where electrical wiring is likely to be present can be dangerous, and it is important that people undertaking DIY projects understand the safety requirements and comply with them.

40 This is the average cost of implementing the measure divided by the average value of the annual energy bill saving across the stock of houses. This is not the same as the average (or the median) of the paybacks achieved when each measure is implemented. Further information on the paybacks of the different measures is provided in appendix A3.

Through the *Victorian Energy Saver Incentive* scheme subsidies are available for the commercial installation of simple draught sealing measures, under-floor insulation and the installation of double-glazing or secondary glazing. Under this scheme eligible energy efficiency measures generate certificates which are purchased by the energy retailers who have obligations under the scheme. The value of the subsidy depends on the market value of the certificates at the time, the climate zone in which the house is located, and whether or not it is located in Melbourne or regional Victoria.

TABLE 25: AVERAGE IMPACT OF BUILDING SHELL MEASURES, WHEN IMPLEMENTED

		Av. Energy Saving (MJ/Yr)						
Measure	% Houses Applied To	Gas	Elec	Total	Av. GHG Saving (kg/Yr)	Av. Cost ($)	Av. Saving ($/Yr)	Av. Payback (Yrs)
Ceiling insulation (easy)	11.7%	8,210	277	**8,487**	546	$673	$165.2	4.1
Draught sealing[41]	98.3%	7,942	225	**8,167**	505	$1,037	$156.5	6.6
Ceiling insulation (difficult)	33.3%	4,891	204	**5,095**	333	$835	$101.5	8.2
Reduce sub-floor ventilation	21.7%	2,720	53	**2,774**	167	$769	$51.7	14.9
Seal wall cavity	50.0%	1,806	48	**1,853**	113	$541	$35.3	15.3
Ceiling insulation top-up	43.3%	1,970	50	**2,020**	124	$774	$38.4	20.3
Underfloor insulation	40.0%	4,507	25	**4,532**	255	$1,962	$80.9	24.3
Wall insulation	95.0%	5,561	136	**5,697**	349	$4,167	$107.9	39
Drapes & pelmets	100.0%	2,209	54	**2,263**	139	$2,036	$42.9	47
Double glazing	100.0%	2,278	66	**2,344**	146	$12,145	$45.0	270
External shading	31.7%	0	27	**27**	8	$1,464	$2.1	694

41 Note that these estimates are based on the assumption that houses can be taken from their initial air leakage rate to 0.5 ACH. Through our Residential Energy Efficiency Retrofit Trials we are investigating the outcomes of actual comprehensive air sealing on houses.

Table 26 shows the average impact of the building shell measures when considered from the perspective of the stock of 60 houses. Measures which have a high impact when implemented but can only be implemented in a small percentage of the houses only have a modest impact across the stock of houses. The total savings which can be achieved through using drapes and pelmets rather than double-glazing are quite similar, although the total cost when using drapes and pelmets ($9,392) is substantially lower than when double glazing is used ($19,501).

It is evident that the vast majority of the energy savings from the building shell measures are for gas. This partly reflects the dominance of gas heating in the OGA study sample of houses, but is also generally true across the Victorian housing stock.

TABLE 26: AVERAGE IMPACT OF BUILDING SHELL MEASURES, ACROSS THE STOCK OF 60 HOUSES

		Av. Energy Saving (MJ/Yr)						
Measure	**% Houses Applied to**	**Gas**	**Elec**	**Total**	**Av. GHG Saving (kg/Yr)**	**Av. Cost ($)**	**Av. Saving ($/Yr)**	**Av. Payback (Yrs)**
Ceiling insulation (easy)	11.7%	958	32	**990**	64	$79	$19.3	4.1
Draught sealing	98.3%	7,809	221	**8,030**	496	$1,020	$153.9	6.6
Ceiling insulation (difficult)	33.3%	1,630	68	**1,698**	111	$278	$33.8	8.2
Reduce sub-floor ventilation	21.7%	589	12	**601**	36	$167	$11.2	14.9
Seal wall cavity	50.0%	903	24	**927**	57	$270	$17.6	15.3
Ceiling insulation top-up	43.3%	853	22	**875**	54	$335	$16.6	20.2
Underfloor insulation	40.0%	1,803	10	**1,813**	102	$785	$32.4	24.3
Wall insulation	95.0%	5,283	130	**5,412**	331	$3,959	$102.5	39
Drapes & pelmets	100.0%	2,209	54	**2,263**	139	$2,036	$42.9	47
Double glazing	100.0%	2,278	66	**2,344**	146	$12,145	$45.0	270
External shading	31.7%	0	9	**9**	3	$464	$0.7	694
Total (ex Double glazing)		**22,037**	**581**	**22,618**	**1,392**	**$9,392**	**$430.9**	**21.8**
Total (ex Drapes & Pelmets)		**22,107**	**593**	**22,699**	**1,400**	**$19,501**	**$433.0**	**45.0**

The average savings achieved by the different building shell measures, expressed as a percentage of the initial heating and cooling energy use of the houses, is shown in Table 27[42]. Figures are provided both for the houses in which the measures were implemented and for their overall impact across the stock of OGA study houses. The heating savings comprise both gas and electricity savings, although as noted above the gas savings are dominant. The cooling savings are comprised of only electricity savings. The data suggests that across the housing stock around 50% of heating energy use could be saved if all building shell upgrade measures were implemented, and that between 26% to 30% of the cooling energy use could be saved. The cooling savings are lower than the heating savings because some building shell upgrades which reduce the heating load can increase the cooling loads in some houses.

It might be expected that the two ceiling insulation measures would have had a larger energy saving impact when implemented in a house. The reason that they didn't is that it was quite rare for the OGA study houses to have an entire ceiling which is uninsulated. Houses usually had only some sections of their ceiling which were uninsulated, so the impact of installing the insulation was somewhat lower than if the whole ceiling was uninsulated.

Note that while the underfloor insulation measure was found to achieve average heating energy savings of 8.2% when implemented, the modelling suggested that it would actually increase cooling energy use on average by 21.1%. While in winter the underfloor insulation reduces heat losses through the floor, in summer its effect is more complicated. When the underfloor space is hotter than inside it will reduce the heat conducted through the floor into the house. However, when the underfloor space is cooler than inside – which is most likely to occur during the night time – it will reduce the cooling effect of the underfloor space, and so can lead to an overall increase in the cooling load of the house and decrease in comfort levels. Underfloor insulation will have the biggest beneficial impact when the underfloor space is poorly enclosed, allowing cold air in winter and warm air in summer to circulate under the house. In all cases the installation of underfloor insulation to a house should be treated with some caution. Ideally it should be used in conjunction with good ceiling and wall insulation, good external shading and the provision of adequate cross ventilation.

42 Note that these are arithmetic averages of the % savings for each house. The stock averages for heating are divided by 60, while the stock averages for cooling are divided by 35, corresponding to the number of houses which had fixed cooling.

TABLE 27: AVERAGE PERCENTAGE SAVINGS FROM IMPLEMENTING BUILDING SHELL MEASURES

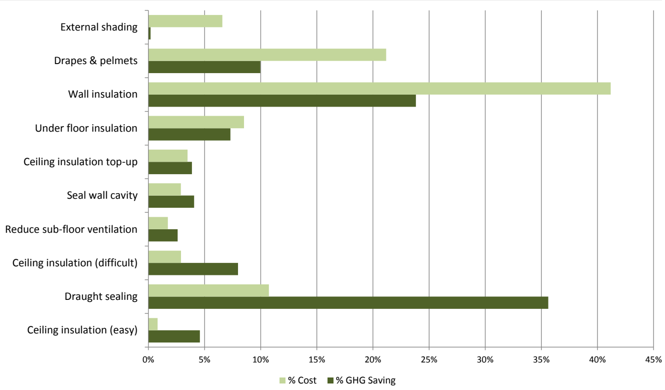
	Av. Saving Across Stock		Av. Saving When Implemented	
Measure	Heating	Cooling	Heating	Cooling
Draught sealing	18.0%	8.4%	18.3%	8.9%
Ceiling insulation (easy)	2.5%	1.6%	21.4%	13.9%
Ceiling insulation (difficult)	3.4%	4.7%	10.1%	16.4%
Reduce sub-floor ventilation	1.3%	0.3%	6.0%	2.4%
Seal wall cavity	2.0%	1.8%	3.9%	2.9%
Underfloor insulation	3.3%	-9.6%	8.2%	-21.1%
Ceiling insulation top-up	1.7%	2.8%	4.0%	7.6%
Wall insulation	12.5%	9.7%	13.1%	10.9%
Drapes & pelmets	5.9%	2.5%	5.9%	2.5%
Double glazing	5.7%	6.7%	5.7%	6.7%
External shading	-	3.7%	-	6.5%

The cost-effectiveness of different building shell retrofits is an important consideration. It is important to know which measures can deliver the "biggest bang for buck", so that investments in improving the energy efficiency of existing houses generate the largest return on the investment. A comparison of the cost-effectiveness of the different building shell upgrade measures is provided in Figure 30[43]. This is based on the stock of 60 OGA study houses and shows the proportion of the total upgrade cost which each measure is responsible for as well as the proportion of the total greenhouse gas savings which the measure generates. Measures such as draught sealing, ceiling insulation (easy & difficult), reducing sub-floor ventilation and sealing the wall cavity are the measures which have the greatest greenhouse saving impact for the money invested. Ceiling insulation top-ups, wall insulation, drapes and pelmets and external shading are the measures which have the least impact.

43 Note that this does not include double-glazing which has a very high average installation cost.

As noted in the discussion on the heating energy use above, averages can hide a considerable amount of diversity. All building shell measures display a range of outcomes in terms of the energy savings achieved in a certain house as well as the payback. Information on the diversity of outcomes for the different individual retrofit measures is provided in Appendix A3. Figure 31 shows the cumulative greenhouse gas abatement which can be achieved by all measures across the stock of OGA study houses, up to an including a certain payback point, segmented into the different building shell measures (excluding double glazing)[44]. Figure 32 is similar, but includes double glazing and excludes drapes and pelmets. The greenhouse savings have been normalised, so that they show the average greenhouse gas abatement per household up to a certain payback point. Similar graphs which show cumulative gas, electricity and total energy savings are provided in Appendix A7.

FIGURE 30: PROPORTION OF TOTAL COSTS AND SAVINGS FOR DIFFERENT BUILDING SHELL RETROFIT MEASURES



The graphs show that the more cost-effective building shell upgrade measures provide most of their greenhouse (and therefore energy) saving benefit at relatively low paybacks (15 years or less). This includes ceiling insulation (easy and difficult), draught sealing, under floor insulation, reducing sub-floor ventilation and sealing the wall cavity. Measures such as wall insulation, drapes and pelmets or double-glazing can generate significant savings, but generate most of their savings at relatively high paybacks (30 years or more).

The analysis of the OGA study houses suggests that average annual greenhouse savings of around 1,400 kg (or 1.4 Tonnes) per annum – corresponding to annual energy savings of around 22,600 MJ/yr – could be achieved in the average existing (pre-2005) house if all relevant building shell upgrades were applied. Much of this savings potential can be delivered at relatively low paybacks: 45% of the savings potential can be achieved from implementing measures with paybacks up to and including 10 years; 58% from implementing measures with paybacks up to 15 years; and, 69% from implementing measures with paybacks up to 20 years.

FIGURE 31: NORMALISED CUMULATIVE GREENHOUSE GAS ABATEMENT OF BUILDING SHELL MEASURES (EXCLUDING DOUBLE GLAZING)[45]

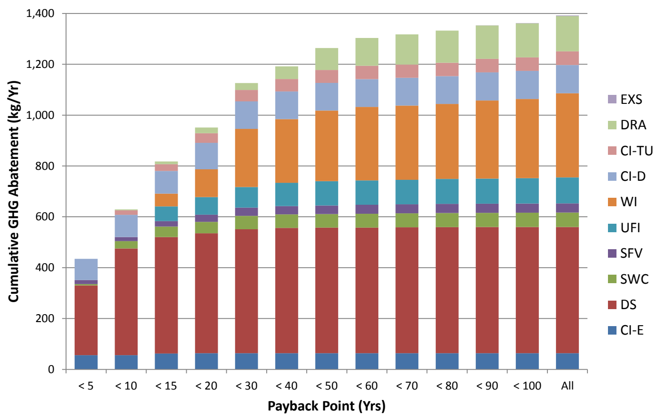
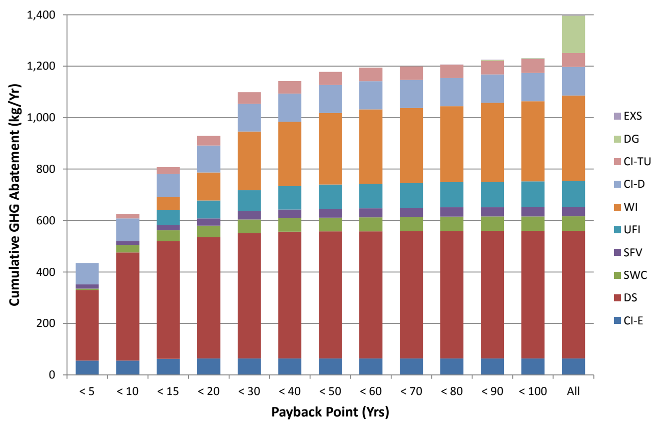


FIGURE 32: NORMALISED CUMULATIVE GREENHOUSE GAS ABATEMENT OF BUILDING SHELL MEASURES (EXCLUDING DRAPES)



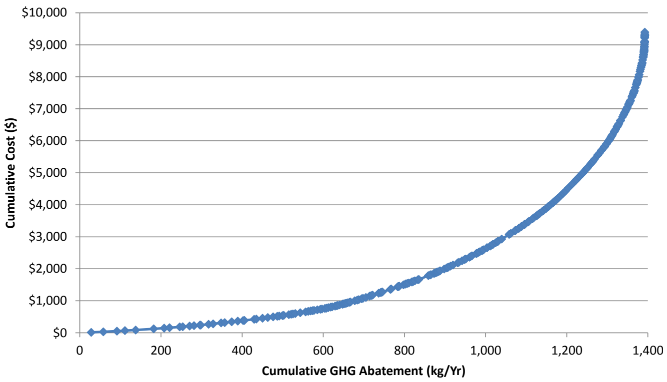
An alternative way to interpret the data is to look at the savings which can be achieved from a certain level of investment, starting with the most cost-effective (or lowest payback) measures. Figure 33 shows the cumulative greenhouse abatement which can be achieved for a certain level of total (or cumulative) investment in a package of building shell retrofit measures in the stock average house (excludes double glazing)[46]. This suggests that for an investment of $2,000 average greenhouse savings of around 898 kg/yr would be expected, while for an investment of $4,000 average greenhouse savings of 1,159 kg/yr would be expected

44 CI-E = ceiling insulation (easy); AS = air (or draught) sealing; SWC = seal wall cavity; SFV = reduced sub-floor ventilation; UFI = underfloor insulation; WI = wall insulation; CI-D = ceiling insulation (difficult); CI-TI = ceiling insulation top up; DRA = drapes and pelmets; DG = double glazing; EXS = external shading.

45 EXS = external shading, DRA = drapes & pelmets, DG = double glazing, CI-TU = ceiling insulation (top up), CI-D = ceiling insulation (difficult), WI = wall insulation, UFI = underfloor insulation, SFV = reduce sub-floor ventilation, SWC = seal wall cavity, DS = draught sealing, CI-E = ceiling insulation (easy).

46 A similar graph for all measures excluding drapes and pelmets is provided in Appendix A7.

FIGURE 33: NORMALISED CUMULATIVE COST OF BUILDING SHELL MEASURES VS CUMULATIVE GREENHOUSE ABATEMENT



Lighting and appliance upgrades

The average impacts of the lighting and appliance upgrade measures – cost, energy, greenhouse and monetary savings and payback – for the houses in which the measure were implemented are shown in Table 28. The measures have been arranged in the order of increasing payback, based on the stock average payback. This table also shows the percentage of the 60 houses in which it was found to be both possible and practical to implement each measure in (% Houses Applied To).

In the case of low flow shower roses, clothes washers and dishwashers the monetary savings and the paybacks include both the energy and water savings. For the low flow shower rose and clothes washer measures the value of the water savings are significant, and in the case of the clothes washers the water saving is the dominant saving. Information on the water savings which can be achieved by these measures is provided in Appendix A4.

As with the building shell upgrades the costs are based on the commercial costs and do not include any government incentives. In this case the scope for DIY projects is more limited, although simple light globe or lamp replacements and the installation of low flow shower roses can be undertaken by householders. *Victoria's Energy Saver Incentive* makes available a subsidy for incandescent and halogen downlight replacement – in many cases this is now free – the installation of low flow shower roses, the replacement of existing heating and water heating with high efficiency and low greenhouse options, and the purchase of high efficiency refrigerators, televisions and clothes dryers.

Table 29 shows the average impact of the lighting and appliance measures when considered from the perspective of the stock of 60 houses. In contrast to the building shell upgrade measures the energy savings are more evenly split between electricity and gas, with the vast majority of the gas savings coming from the heater upgrades and the installation of low flow shower roses. While the total average energy saving which can be achieved from the lighting and appliance upgrades is lower than for the buildings shell upgrades – 13,195 MJ/yr vs 22,618 MJ/yr – the total greenhouse and monetary savings from the lighting and appliance upgrades are somewhat larger. This reflects the greater electricity savings which can be achieved from the lighting and appliance upgrades.

TABLE 28: AVERAGE IMPACT OF LIGHTING AND APPLIANCE MEASURES, WHEN IMPLEMENTED

		Av. Energy Saving (MJ/Yr)						
Measure	% Houses Applied To	Gas	Elec	Total	Av. GHG Saving (Kg/Yr)	Av. Saving ($/Yr)	Av. Cost+ ($)	Payback (Yrs)
LF Shower Rose*	56.7%	2,352	122	**2,473**	167	$102.3	$86.0	0.8
Lighting	93.3%	-	1,288	**1,288**	391	$100.2	$574.1	5.7
Clothes Washer*	55.0%	246	30	**276**	23	$45.3	$347.2	7.7
Water Heater – High Eff. Gas	58.3%	788	1,721	**2,509**	566	$99.8	$818.3	8.2
Heating	80.0%	7,798	269	**8,067**	513	$157.4	$1,388.2	8.8
Refrigerator	86.7%	-	1,182	**1,182**	359	$91.9	$1,085.6	11.8
TV	95.0%	-	394	**394**	155	$30.6	$545.8	17.8
Dishwasher*	43.3%	-	258	**258**	79	$23.9	$595.5	25
Clothes Dryer – Heat Pump	60.0%	-	785	**785**	239	$61.0	$1,617.1	26
Cooling	40.0%	-	401	**401**	122	$31.2	$1,161.9	37

* The bill savings and paybacks include water as well as energy savings.

+ Except for lighting and low flow shower roses, the cost for the appliance upgrades is based on the "adjusted cost" which takes into account the age of the existing appliance.

TABLE 29: AVERAGE IMPACT OF LIGHTING AND APPLIANCE MEASURES, ACROSS THE STOCK OF 60 HOUSES

Measure	% Houses Applied To	Av. Energy Saving (MJ/Yr)			Av. GHG Saving (Kg/Yr)	Av. Saving ($/Yr)	Av. Cost+ ($)	Payback (Yrs)
		Gas	Elec	Total				
LF Shower Rose	56.7%	1,333	69	**1,402**	95	$57.9	$48.8	0.8
Lighting	93.3%	-	1,202	**1,202**	365	$93.5	$535.8	5.7
Clothes Washer	55.0%	135	16	**152**	12	$24.9	$190.9	7.7
Water Heater – High Eff. Gas	58.3%	460	1,004	**1,463**	330	$58.2	$477.3	8.2
Heating	80.0%	6,239	215	**6,454**	411	$125.9	$1,110.6	8.8
Refrigerator	86.7%	-	1,202	**1,202**	365	$93.5	$1,103.7	11.8
TV	95.0%	-	696	**696**	273	$54.1	$964.3	17.8
Dishwasher	43.3%	-	112	**112**	34	$10.4	$258.1	24.9
Clothes Dryer – Heat Pump	45.0%	-	353	**353**	107	$27.5	$727.7	26.5
Cooling	40.0%	-	160	**160**	49	$12.5	$464.8	37.3
Total		**8,166**	**5,029**	**13,195**	**2,042**	**$558.4**	**$5,882**	**10.5**

* The bill savings and paybacks include water as well as energy savings.
+ Except for lighting and low flow shower roses, the cost for the appliance upgrades is based on the "adjusted cost" which takes into account the age of the existing appliance.

A comparison of the cost-effectiveness of the different lighting and appliance upgrades is provided in Figure 34. This is based on the stock of 60 OGA study houses and shows the proportion of the total upgrade cost which each measure is responsible for as well as the proportion of the total greenhouse gas savings which the measure generates. The most cost-effective measures for greenhouse gas abatement are the low flow shower rose, lighting, clothes washer, water heating (replacing with a high efficiency gas water heater), and heating upgrades. Note that while the clothes washer upgrade is quite cost-effective, it only makes a relatively small contribution to greenhouse gas abatement. This is because most of the monetary savings come from the water and not the energy savings.

Upgrades to the dishwasher, clothes dryer (replacing with a heat pump clothes dryer) and cooling are the least cost-effective upgrades. The energy efficiency of new televisions available on the market has increased dramatically over the last three or so years, while the costs of these televisions has reduced. This trend is expected to continue, so the cost-effectiveness of replacing older existing televisions is likely to improve in future. Similarly, the cost of heat pump clothes dryers is starting to come down as more models become available on the market. The cost effectiveness of this measure could also improve in future years.

FIGURE 34: PROPORTION OF TOTAL COSTS AND SAVINGS FOR DIFFERENT LIGHTING & APPLIANCE MEASURES

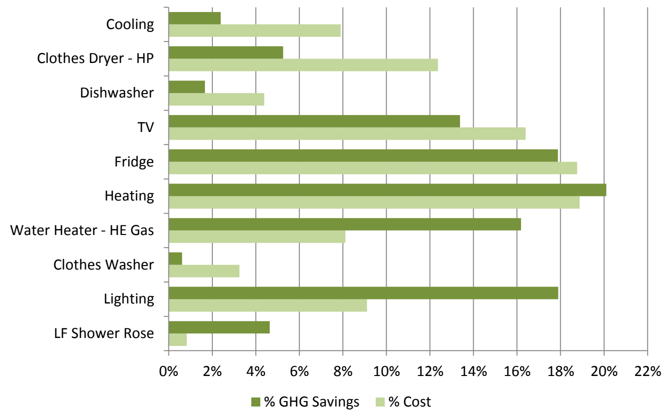


FIGURE 35: NORMALISED CUMULATIVE GREENHOUSE GAS ABATEMENT OF LIGHTING AND APPLIANCE MEASURES[47]

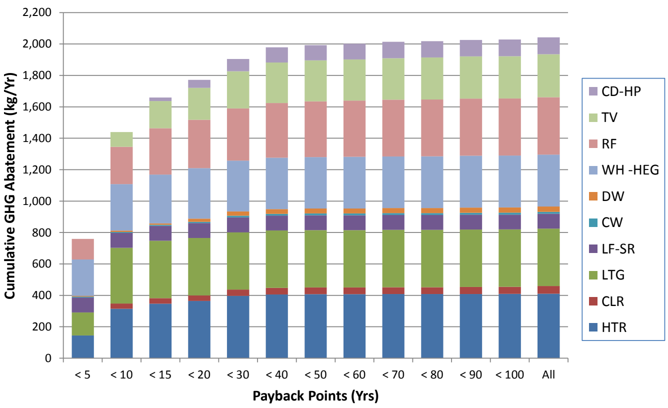


FIGURE 36: NORMALISED CUMULATIVE COST OF LIGHTING & APPLIANCE MEASURES VS CUMULATIVE GREENHOUSE ABATEMENT

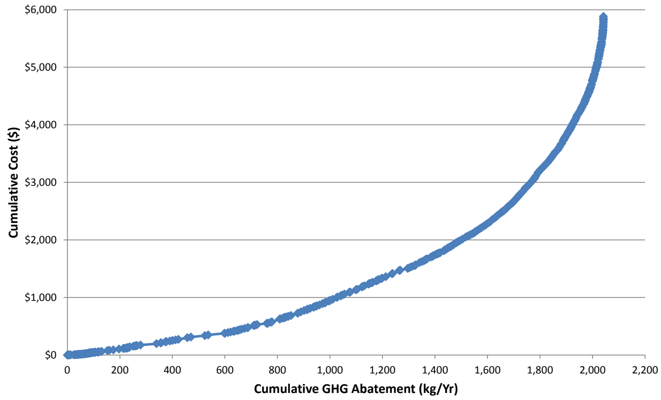


Figure 35 shows the cumulative greenhouse gas abatement which can be achieved by all lighting and appliance measures across the stock of OGA study houses, up to an including a certain payback point, segmented into the different lighting and appliance upgrade measures. The greenhouse savings have been normalised, so that they show the average greenhouse gas abatement per household up to a certain payback point. Similar graphs which show cumulative gas, electricity and total energy savings are provided in Appendix A7.

The graphs show that the more cost-effective upgrade measures provide most of their greenhouse (and therefore energy) saving benefit at relatively low paybacks (10 years or less). This includes low flow shower rose, lighting, heating, water heating, and refrigerator upgrades. The less cost effective measures, such as television, dishwasher, heat pump clothes dryer and cooling upgrades, generate most of their savings at paybacks greater than 15 years. The relative contribution of the measures to the overall savings which can be achieved is more equal than for the building shell upgrades. The largest contributions come from the heating, lighting, water heating, refrigerator and television upgrades, and are of a similar level.

The analysis of the OGA study houses suggests that average annual greenhouse savings of around 2,042 kg (or around 2.0 Tonnes) per annum – corresponding to annual energy savings of around 13,200 MJ/yr – could be achieved in the average existing (pre-2005) house if all relevant lighting and appliance upgrades are applied. Much of this savings potential can be delivered at relatively low paybacks: 37% of the savings potential can be achieved from implementing measures with paybacks up to and including 5 years; 71% from implementing measures with paybacks up to 10 years; and, 81% from implementing measures with paybacks up to 15 years.

Figure 36 shows the cumulative greenhouse abatement which can be achieved for a certain level of total (or cumulative) investment in a package of lighting and appliance upgrade measures in the stock average house (excludes double glazing). This suggests that for an investment of $1,000 average greenhouse savings of around 1,030 kg/yr would be expected, while for an investment of $2,000 average greenhouse savings of 1,500 kg/yr would be expected, and for an investment of $4,000 average greenhouse savings of 1,920 kg/yr would be expected.

47 HTR = heater; CLR = cooler; LTG = lighting; LF-SR = low flow shower rose; CW = clothes washer; DW = dishwasher; WH – HEG = high efficiency gas water heater; RF = refrigerator; TV = television; CD-HP = heat pump electric clothes dryer.

Overall analysis of house energy efficiency upgrades

The OGA study has involved the modelling of over 800 individual building shell, lighting and appliance upgrades for the 60 houses involved in the study. For some of the measures we have assessed a number of upgrade options which target the same energy service:

- Drapes & Pelmets and Double-Glazing. As noted in Chapter 3 these were modelled as separate upgrades, and the results have been included separately in both Chapters 3 and 4;
- Replacing an existing gas or electric water heater with either a high efficiency gas water heater, or a gas-boosted solar water heater. Upgrade to the high efficiency gas water heater was found to be the most cost effective option and only the results for this upgrade are provided in Chapter 4. Details relating to the gas-boosted solar water heater upgrade are provided in Appendix A4;
- Replacing an existing conventional electric clothes dryer with either a 'high efficiency' conventional clothes dryer or with a heat pump clothes dryer. The savings from upgrading to a higher efficiency conventional clothes dryer are quite small, so in Chapter 4 we present only the results for the heat pump clothes dryer. Details relating to the other upgrade are provided in Appendix A4.

A comparison of the average impact of all the upgrade measures modelled across the stock of 60 houses and ranked in order of increasing stock average payback is provided in Table 30. The OGA study analysis suggests that average annual energy savings of around 35,800 MJ/yr could be achieve across the stock of existing (pre-2005) houses if all relevant building shell, lighting and appliance upgrades which we have modelled were undertaken, reducing annual greenhouse emissions by around 3.4 tonnes per annum and resulting in energy bill savings of around $990 per annum based on current energy prices. The total cost of all upgrades is $15,274 if drapes and pelmets are used rather than double glazing, and $25,383 if double glazing is used rather than drapes and pelmets.

Cumulative greenhouse abatement curves for the building shell upgrades, segmented into the different individual upgrade measures, are shown in Figures 31 and 32, and for the lighting and appliance upgrades in Figure 35. Figure 37 is a cumulative greenhouse abatement curve for all of the energy efficiency upgrade measures (excluding double-glazing), segmented into just the building shell and lighting and appliance measures. It is evident from this that the lighting and appliance upgrades provide the majority of the greenhouse savings overall and also provide the majority of the savings at the lower payback points. Similar graphs which show cumulative gas, electricity and total energy savings are provided in Appendix A7.

TABLE 30: IMPACT OF ALL UPGRADE MEASURES, ACROSS THE STOCK OF 60 HOUSES

		Av. Energy Saving (MJ/Yr)						
Across stock	**% Houses Applied To**	**Gas**	**Elec**	**Total**	**Av. GHG Saving (Kg/Yr)**	**Av. Saving ($/Yr)**	**Av. Cost ($)**	**Av. Payback (Yrs)**
LF Shower Rose	56.7%	1,333	69	**1,402**	95	$57.9	$48.8	0.8
Ceiling Insulation (easy)	11.7%	958	32	**990**	64	$19.3	$78.6	4.1
Lighting	93.3%	-	1,202	**1,202**	365	$93.5	$535.8	5.7
Draught Sealing	98.3%	7,809	221	**8,030**	496	$153.9	$1,019.8	6.6
Clothes Washer	55.0%	135	16	**152**	12	$24.9	$190.9	7.7
Water Heater – High Eff. Gas	58.3%	460	1,004	**1,463**	330	$58.2	$477.3	8.2
Ceiling Insulation (difficult)	33.3%	1,630	68	**1,698**	111	$33.8	$278.2	8.2
Heating	80.0%	6,239	215	**6,454**	411	$125.9	$1,110.6	8.8
Refrigerator	86.7%	-	1,202	**1,202**	365	$93.5	$1,103.7	11.8
Reduce Sub-Floor Ventilation	21.7%	589	12	**601**	36	$11.2	$166.7	14.9
Seal Wall Cavity	50.0%	903	24	**927**	57	$17.6	$270.4	15.3
TV	95.0%	-	696	**696**	273	$54.1	$964.3	17.8
Ceiling Insulation (Top Up)	43.3%	853	22	**875**	54	$16.6	$335.3	20.2
Underfloor Insulation	40.0%	1,803	10	**1,813**	102	$32.4	$784.7	24.3
Dishwasher	43.3%	-	112	**112**	34	$10.4	$258.1	24.9
Clothes Dryer – Heat Pump	45.0%	-	353	**353**	107	$27.5	$727.7	26.5
Cooling	40.0%	-	160	**160**	49	$12.5	$464.8	37.3
Wall Insulation	95.0%	5,283	130	**5,412**	331	$102.5	$3,958.7	38.6
Drapes & Pelmets	100.0%	2,209	54	**2,263**	139	$42.9	$2,035.9	47.5
Double Glazing	100.0%	2,278	66	**2,344**	146	$45.0	$12,145	270
External Shading	31.7%	-	9	**9**	3	$0.7	$463.6	694
Total (ex Double Glazing)		**30,203**	**5,610**	**35,813**	**3,434**	**$989**	**$15,274**	**15.4**
Total (ex Drapes)		**30,273**	**5,621**	**35,894**	**3,441**	**$991**	**$25,665**	**25.6**

FIGURE 37: NORMALISED CUMULATIVE GREENHOUSE GAS ABATEMENT OF ALL MEASURES (EXCLUDING DG)

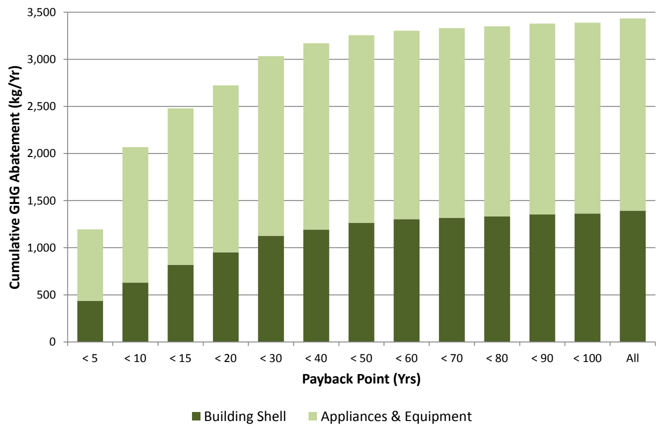
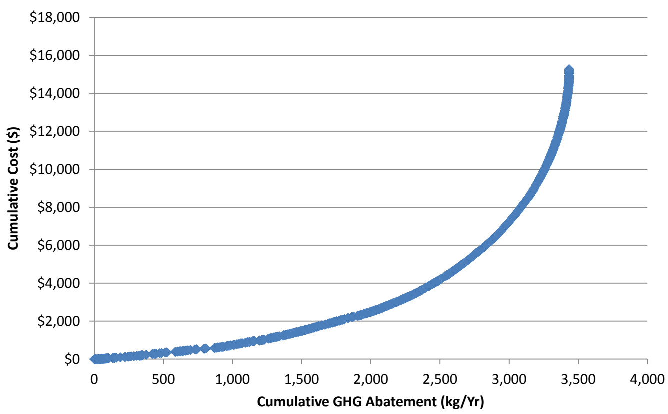


Figure 38 shows the cumulative greenhouse abatement which can be achieved for a certain level of total (or cumulative) investment in a package building shell, lighting and appliance upgrade measures in the stock average house (excludes double glazing). This suggests that for an investment of $1,000 average greenhouse savings of around 1,210 kg/yr would be expected, while for an investment of $2,000 average greenhouse savings of 1,756 kg/yr would be expected, and for an investment of $4,000 average greenhouse savings of 2,450 kg/yr would be expected. It also demonstrates (see Figures 33 and 36) that an investment in a well-targeted package of building shell, lighting and appliance upgrade measures is more cost effective than investing in either building shell upgrades or lighting and appliance upgrades alone.

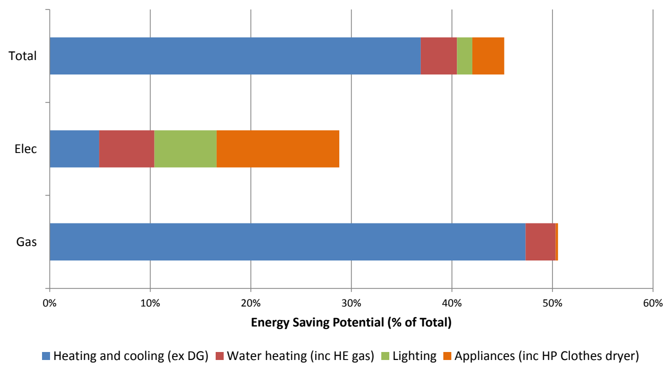
FIGURE 38: NORMALISED CUMULATIVE COST OF ALL UPGRADE MEASURES (EXCLUDING DOUBLE GLAZING) VS CUMULATIVE GREENHOUSE ABATEMENT



We have also analysed the OGA study data to provide an estimate of the energy saving potential of the energy efficiency upgrade measures assessed. Our starting point was to estimate the average gas and electricity usage of the OGA study houses – 59,759 MJ/yr for gas and 19,477 MJ/yr for electricity, or total average electricity and gas use of 79,236 MJ/yr[48]. This data was used to estimate the energy saving potential of the different measures, expressed as a percentage of the annual average gas, electricity and total energy use. The results of this analysis are summarised in Figure 39 broken down into a number of major categories:

- Heating and cooling – includes building shell (excluding double glazing), heating and cooling upgrades;
- Water heating – includes low flow shower rose and water heating (HE gas);
- Lighting; and
- Appliances – includes refrigerators, clothes washers, dishwashers, heat pump clothes dryer and television.

FIGURE 39: ESTIMATED ENERGY SAVING POTENTIAL OF OGA STUDY HOUSES



Our analysis suggests that the total energy saving potential from all the main measures assessed is 45.2% of total energy savings, 50.5% of total gas use and 28.8% of total electricity use[49]. Both the overall energy saving potential and the gas saving potential are dominated by the heating and cooling measures. In contrast, the electricity saving potential is dominated by the appliance upgrade measures, with the savings potential for lighting and water heating also being significant.

A significant amount of this energy saving potential is available for paybacks less than 20 years. Figure 40 shows the cumulative energy saving potential for all measures excluding double glazing, up to a payback of 50 years.

48 For gas consumption we used the average annual gas used derived from the houses' gas billing data. For average electricity use we used an estimate of the average annual electricity use of occupied households derived from [BREE 2013] (19,238 MJ/yr), and adjusted this for the average occupancy of the OGA study houses (2.9 people) using data on average electricity use for different occupancy levels from [DHS 2008]. This suggested the average annual use of a 2.9 person household was 1.24% higher than the average annual usage.

49 Note that if the high efficiency gas water heater upgrade is replaced by the gas boosted solar water heater upgrade our estimate of energy saving potential increases to 53.3% (total), 61.6% (gas) and 27.7% (electricity).

FIGURE 40: CUMULATIVE ENERGY SAVING POTENTIAL (EXCLUDING DOUBLE GLAZING)

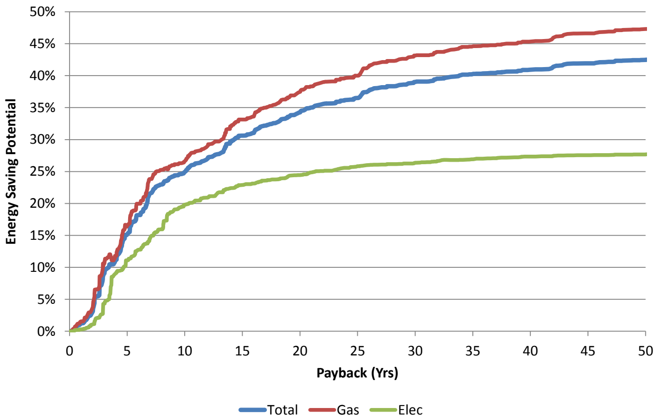
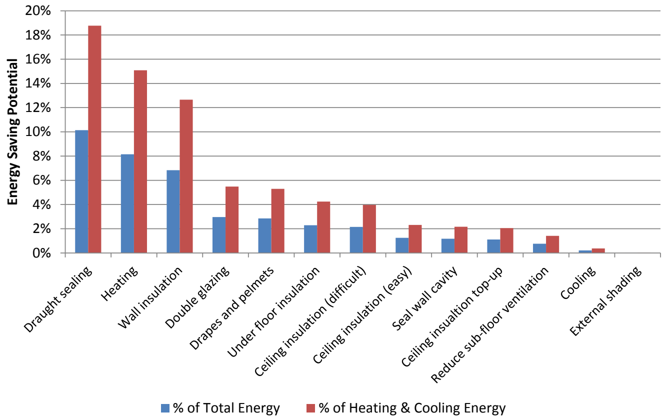


FIGURE 41: ENERGY SAVING POTENTIAL OF BUILDING SHELL UPGRADE MEASURES



A more detailed breakdown of the energy saving potential of the different upgrade measures is provided in Figures 41 (building shell, heating and cooling), 42 (water heating) and 43 (lighting and appliances). In these charts we show the savings potential relative to the total average energy use of the OGA study houses, as well as relative to the particular area of energy use which is the target of the upgrade measures – note that for the lighting and appliances this is the savings potential relative to the energy use of the particular appliance in question. For water heating we have included the energy saving potential of the gas-boosted solar upgrade, and for lighting and appliances we have included the high efficiency conventional clothes dryer upgrade option.

The overall highest savings potential is for the measures targeting heating and cooling. Taken as a group these could save around 68% of heating and cooling energy use. The basic water heating measures could save around 20% of water heating energy use, and this could be increased to around 64% if gas boosted solar water heaters were used instead of high efficiency gas. The savings potential of television upgrades (67%), refrigerator upgrades (47%) and lighting upgrades (35%) are also high.

FIGURE 42: ENERGY SAVING POTENTIAL OF WATER HEATING UPGRADE MEASURES

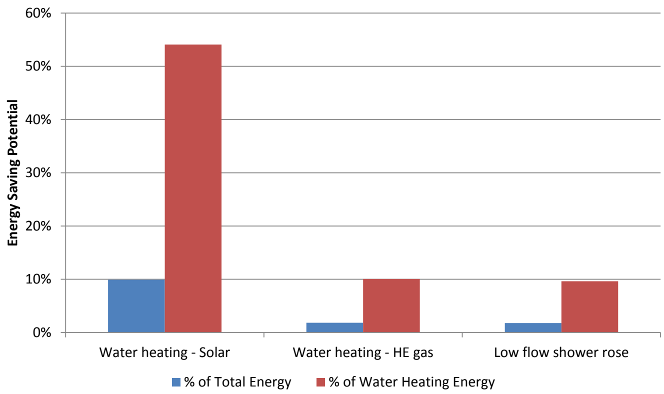
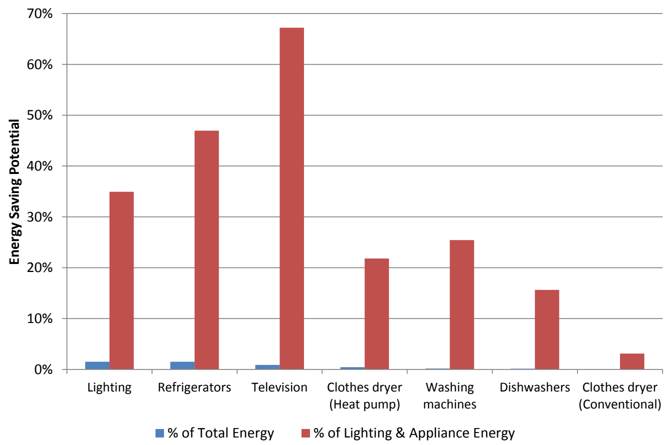


FIGURE 43: ENERGY SAVING POTENTIAL OF THE LIGHTING AND APPLIANCE UPGRADE MEASURES



5. Summary and Conclusions

Through the On-Ground Assessment study we have investigated the energy efficiency status of Victoria's existing (pre-2005) housing stock, as well as the potential for building shell, lighting and appliance upgrades to increase the energy efficiency of these houses. The study was based on 60 houses which were chosen to be reasonably representative of the existing housing stock.

The average House Energy Rating (HER) of the 60 OGA study houses was 1.81 Stars, making these houses considerably less efficient than new houses constructed today, which require a minimum 6 Star rating[50]. The average HER of the houses increased steadily over the last century, with a significant increase evident from the 1990s, corresponding to the introduction of mandatory insulation requirements for new houses in Victoria in 1991. The average HER of houses constructed prior to 1990 was 1.57 Stars and the average HER of the houses constructed between 1990 and 2005 was 3.14 Stars. In addition to the mandatory insulation requirements introduced in 1991, certain trends in the construction of houses are also likely to have contributed to the observed increase in efficiency, including the shift to concrete slab-on-ground construction for floors and the elimination of wall vents from most houses constructed since the 1990s.

One reason for the low level of energy efficiency of the existing houses studied was a high level of air leakage. The average natural air leakage rate for the OGA study houses was 1.90 air changes per hour (ACH), with houses constructed prior to 1990 having a slightly higher average natural air leakage rate (2.02 ACH) and houses constructed between 1990 and 2005 having a considerably lower natural air leakage rate (1.20 ACH). Much of this difference is likely to be related to the changing trends in house construction noted above, as well as the impact of "wear and tear" on older houses.

As well as the existing houses having quite inefficient building shells, the lighting and appliances found in the OGA study houses were considerably less energy efficient than new lighting and appliances which are available today. This was particularly the case for the lighting, heating and cooling, water heating, refrigerators and televisions.

The impact on the House Energy Rating of applying a total of 11 different building shell upgrades to the OGA study houses was modelled. Only those upgrades which were both possible and practical for the houses were considered. Through the application of all measures we estimate that the average HER of the houses could be increased from 1.81 Stars to 5.05 Stars[51], an increase of 3.24 Stars. The average HER of the pre-1990 houses was increased from 1.57 Stars to 5.00 Stars (an increase of 3.42 Stars) while the average HER of the post-1990 houses was increased from 3.14 Stars to 5.37 Stars (an increase of 2.23 Stars), only slightly higher than the pre-1990 houses. The wall insulation upgrade was the main energy efficiency measure which was responsible for bringing the HERs of the pre- and post-1990 houses much closer together.

Wall insulation (0.97 Star increase), draught sealing[52] (0.69 Stars), double glazing (0.63 Stars) and drapes and pelmets (0.58 Stars) were the building shell upgrade measures which had the biggest impact on increasing the average HER of the OGA study houses. These measures all had quite a large impact when implemented and also had a high level of applicability across the stock of OGA study houses.

50 6 Star houses have a heating and cooling load which is around 72% lower than a house with a 1.8 Star rating, for the same sized house.

51 This corresponds to a reduction in heating and cooling load of around 64%.

52 Note that this is based on reducing the air leakage rate of the houses from its initial level to 0.5 ACH. In practice it may not be possible to achieve this level of air sealing across all houses.

Ceiling insulation measures had a large impact when implemented but as they had a much lower level of applicability – most houses already have a certain level of ceiling insulation – they had a lower impact on the average HER of the houses.

The average cost of increasing the HER of the existing houses to just above 5 Stars was $11,405 if it was assumed that only drapes and pelmets were used (and not double glazing) and $24,742 if it was assumed that double glazing was used (and not drapes and pelmets). The average cost of upgrading the pre- and post-1990 houses was quite similar.

In addition to modelling the impact of building shell upgrades on the HER of the houses we undertook modelling to estimate the costs and benefits (energy saving, $ and greenhouse gas savings) from the application of a range of building shell, lighting and appliance upgrades. Across the stock of OGA study houses it was estimated that the application of all relevant building shell upgrade measures could achieve average energy savings of around 22,600 MJ/yr (dominated by gas), average energy bill savings of $430 per year, and annual greenhouse gas savings of around 1.4 Tonnes/yr. The average cost of these upgrades was $9,392 if drapes and pelmets were used and $19,501 if double glazing was used. Draught sealing, wall insulation, double glazing and drapes and pelmets provided the largest overall savings across the stock of houses. Draught sealing (6.6 year payback), and insulating an uninsulated ceiling (4.1 year and 8.2 year payback for the easy and difficult cases respectively) were the most cost-effective upgrade measures.

The application of the lighting and appliance upgrade measures to the OGA study houses was estimated to achieve average energy savings of around 13,200 MJ/yr (more evenly split between electricity and gas) , average energy (and water) bill savings of $558 per year, and annual greenhouse gas saving of around 2.0 Tonnes/yr. While the average energy savings are lower than achieved for the building shell upgrades, the average bill saving is higher due to the higher cost of electricity compared to gas. The average cost of these upgrades was $5,882, making the lighting and appliance upgrades more cost effective overall than the building shell upgrades. The largest average savings were provided by the heating, low flow shower rose, water heating, lighting and refrigerator upgrades. Low flow shower rose (0.8 year payback), lighting (5.7 year payback), clothes washer (7.7 year payback), water heating (8.2 year payback) and heating (8.8 year payback) upgrades were the most cost effective upgrade measures.

Overall we estimate that by applying all energy efficiency upgrade measures modelled in the OGA study houses it would be possible to achieve average energy savings of around 35,800 MJ/yr (split approximately 84% - 16% between electricity and gas) for an average bill saving of around $990 per year, and average greenhouse gas savings of around 3.4 Tonnes/yr. The average cost of all the upgrades was $15,274 if drapes and pelmets were used and $25,383 if double glazing was used.

If all of the energy efficiency upgrade potential identified in our main analysis was applied to the existing (Pre-2005) houses that are still standing today, we estimate that this would generate total annual energy bill savings of at least $1,500 Million per year and total annual greenhouse gas abatement of at least 5,200 kT per year. Even if only the more cost-effective energy efficiency upgrades were applied to all existing houses, the energy and greenhouse savings would still be very significant. If all measures with a payback up to 10 years were applied across the existing housing stock we estimate that this would generate annual energy bill savings of at least $900 Million per year and total annual greenhouse gas abatement of at least 3,100 kT per year.

Our analysis found that there was a very wide diversity in the energy savings (and consequently paybacks) which could be achieved for any given energy efficiency upgrade measure. Much of this diversity is due to the level of energy service which was being provided in a particular house (related to the number of occupants, size of the house and appliance settings) and to how different appliances are used. This high level of diversity means that while the average results presented in this report can be used as a guide for the most cost-effective energy efficiency upgrade options, careful assessment is required for each individual household to identify the appropriate and most cost effective upgrade options.

Based on our analysis of the OGA study houses we estimate that across the stock of existing Victorian houses there is the potential to save around 45.2% of total electricity and gas use, or around 50.5% of total gas use and 28.8% of total electricity use[53] from the implementation of the measures which we have modelled. Much of this energy saving potential – around 26% of the 45.2% - could be achieve from implementing upgrade measures with paybacks of less than 10 years.

While the results of our study are based on modelling for the 60 selected houses, we believe that they give a good indication of the energy saving potential and the economics of energy efficiency upgrades across the wider stock of existing (pre-2005) Victorian houses. If anything, the characteristics of the houses included in our study[54] suggest that slightly higher savings may be possible. Also, as we have not modelled impacts on any secondary heating and cooling found in the houses, the energy savings which can be achieved from the building shell upgrades are likely to be slightly higher than we have estimated.

The energy efficiency upgrade measures which we have assessed as part of this study do not cover all possible measures, which suggests that larger overall energy savings could be achieved. The OGA study has focussed exclusively on "hardware" measures, and significant additional savings could be possible through better energy use practices, requiring behaviour change. A recent US estimate[55] suggests that even modest behaviour change could result in electricity savings of up to 20%. In Victoria, the installation of In-Home Displays (IHDs) is currently being subsidised through the Energy Saver Incentive scheme on the basis that these will facilitate electricity savings through behaviour change. It was estimated [DPI 2011] that the IHDs could result in average electricity savings of 6.6% over a five year period.

In addition to any changes which might be possible through behaviour change, there are a range of "hardware" measures which we have not modelled which could yield additional energy savings:

- The installation of rooftop photovoltaic (PV) panels to generate electricity on-site, and other on-site generation options, could result in a significant reduction in mains electricity consumption within houses as well as generating income from surplus electricity exported to the grid. While this is not an energy efficiency measure as such, and does not save electricity, the electricity generated on-site off-sets some of the households' mains electricity consumption. In Melbourne a 1 to 2 kW PV panel installation which off-set 50% of the electricity used in the average home could reduce household electricity consumption by around a further 12% to 24% as well as exporting electricity to the grid
- The replacement of old existing ductwork used with gas ducted heating systems could generate significant additional heating savings in some older houses. A study by Graham Palmer [Palmer 2008] found that the average losses from gas heating ductwork which was more than 15 years old could be decreased from 39% to 19% if the old ductwork was replaced with good quality new ductwork. This equates to an additional heating saving of around 25% in the houses in which this measure is possible[56];
- The installation of Standby Power Controllers (SPCs) can reduce energy which would otherwise be consumed as standby power[57] for a range of common household electrical and electronic appliances. Studies undertaken for the national Equipment Energy Efficiency (E3) program estimate that standby power use is responsible for around 10% of residential electricity consumption. While some standby power use can be reduced through behaviour change – switching off appliances at the power point when not in use – SPCs attached to nests of home entertainment equipment and computer equipment can automatically reduce standby power use when a controlling device (a television or computer) is switched off;
- In the OGA study we have looked at the potential for ceiling insulation top-ups to save energy when ceilings are poorly insulated. However, even in houses which have an adequate level of insulation, some insulation can become dislodged over time (insulation batts) or blown around (loose fill insulations) so that coverage in some areas becomes quite poor. In houses which have halogen (or other) downlights it is not uncommon for either a whole insulation batt or half a batt to be removed to provide the mandatory safety clearance which is required. This can create a "Swiss cheese" effect which considerably reduces the effect of the insulation[58]. Insulating downlight covers are now available which can be used in conjunction with some light fittings and lamps, and allow the ceiling insulation to be installed much closer to the light fitting thereby improving insulation coverage. This measure is best undertaken in conjunction

53 This potential increases to 53% of total energy, 61.6% of gas and 27.7% of electricity if water heaters are assumed to be upgraded to gas-boosted solar water heaters rather than high efficiency gas water heaters.

54 The OGA study houses had a relatively high level of houses without air conditioning and a relatively high level of front load clothes washers compared to the state average.

55 "Giving US energy efficiency a jolt", David Frankel and Humayan Tai, Insights and Publications, McKinsey & Company, December 2013.

56 This measure was not modelled as part of the OGA study as it requires on-site testing to measure the heat losses from the existing ductwork. Through its Residential Energy Efficiency Retrofit Trials Sustainability Victoria is undertaking further work to investigate the energy savings which can be achieved through this measure.

57 Standby power is the electricity used by electrical and electronic appliances when they are switched on at the power point but not performing their main function. Standby Power Controllers (SPCs) monitor the use of a main appliance (television or computer) and switch off other peripheral devices when the main appliance is switched off or goes into a "sleep" mode, reducing standby power consumption. Advanced SPCs monitor use of a television and switch off peripherals when their control algorithms assess that the television is no longer being actively watched. These have the potential to save energy which would otherwise be wasted when the television is in "on mode" but is not being used.

58 For example, in a 10m2 room insulated with R3.0 insulation the insulation gaps left around the downlights could reduce the effective R-vale to R1.36 (if there were 3 downlights) and R1.13 (if there were 4 downlights).

with replacing existing downlights with a suitable LED lamp, and would generate additional heating and cooling energy savings;

- While we have considered the impact of the use of double-glazing, special window films are available which can improve the thermal performance of windows in summer or winter, or both. The use of such films will, in many, cases cross over with savings which might be possible through the use of external shading or double-glazing, but in some circumstance might yield additional savings;
- A range of solar air heating devices are available which can heat air using the sun's energy and duct this into the house to provide supplementary heating[59]. Some systems use panels mounted on a roof which are similar to solar water heating panels, while others use the roof space as the source of heated air. The solar air heating systems have the potential to reduce winter heating energy use. Their best application is likely to be in houses without north facing windows and where it is difficult to undertake retrofit measures such as ceiling or wall insulation;
- So-called "grey water" heat recovery systems are now available. These use a heat exchanger to recover heat from the warm water which goes down the shower drain and use it to preheat the cold water entering the water heater. Some systems claim to be able to recover 60% of the heat in the shower water, reducing water heating costs[60];
- Voltage optimisation devices connected to a house's electrical switchboard may be able to achieve further electricity savings. The specified single-phase voltage in Australia is 230 Volts (minus 6% or plus 10%; 216 to 253 Volts). In practice the voltage often sits above 230 Volts. Voltage optimisation devices can regulate the voltage to the lower end of the acceptable range (generally around 220 Volts), and this can result in energy savings in some voltage dependent appliances[61]. Trials undertaken in the UK in 50 houses found average electricity savings of 5.2% to 6.3% [EA Tech 2011], although a recent review of these devices [DPI 2012] suggested that this level of savings might not be possible in Victoria.

Also, it is important to keep in mind that the analysis presented in this report is based on a snapshot in time. The housing stock is dynamic and changes from year to year. While the building shells of the houses are likely to change quite slowly, the stock of lighting and appliances changes much more rapidly. Given this, it is likely that some of the energy efficiency upgrade potential identified in this report has already been taken up, and that under business-as-usual more of the energy efficiency potential will be progressively taken up over time due to a combination of: general improvement in the energy efficiency of lighting and appliances as time goes on[62]; government regulations relating to minimum energy performance standards (MEPS) for appliances and energy efficiency regulations which apply to home renovations; subsidies for the installation of energy efficient products available through schemes such as the Energy Saver Incentive; and increasing consumer preference for higher efficiency lighting and appliances in response to increasing energy prices.

It is important to note that our cost-benefit analysis is based on the commercial costs of undertaking the energy efficiency upgrades, and does not include any government incentives which can reduce the costs of some upgrade measures. Where upgrades can be undertaken more cheaply as a DIY project or where government incentives are available[63] both the costs and the paybacks will be reduced. In some cases the costs of the upgrades are decreasing and the economics of the upgrades is likely to improve over time. This is the case for LED lighting, televisions and heat pump clothes dryers. There may also be some areas where further market development and increased competition could result in lower upgrade costs, for example, pump in cavity wall insulation.

The savings documented in this report are based only on the energy (and in some cases water) bill savings which result directly from the upgrades studied. We have not included any value associated with the greenhouse gas savings resulting from the upgrades, or comfort or health improvements which could result from the building shell upgrades. Currently, there is not widespread agreement regarding how to include the value of the greenhouse abatement in such analysis, and as yet there is no evidence base which would allow the comfort and health benefits for households in Victoria to be included. While some of these benefits might accrue directly to the households, they will be shared with governments and society more generally.

Energy efficiency upgrades which improve the energy efficiency of the building shell will result in improved occupant comfort in both summer and winter and could have significant health benefits, especially for low income households. Studies evaluating the costs and benefits of large-scale insulation programs undertaken in New Zealand[64] suggest that the associated health benefits could be at least one and a half times the value of the energy bill savings. There have been no similar studies in Australia to date.

59 Little independent data is currently available on the performance of these systems in the Victorian climate. Sustainability Victoria will be trialling the use of solar air heating panels as part of its Residential Energy Efficiency Retrofit Trials.

60 See for example "Claim back 60% of energy lost from hot water" Infolink, 18 December, 2012.

61 For example electrical equipment which includes an electrical resistor will have a lower power consumption at a lower voltage, although this will not translate into savings in all cases. Lighting such as incandescent or halogen lighting is voltage dependent and will achieve savings at a lower voltage, although appliances (for example electric ovens or heaters) which are controlled by a thermostat are unlikely to achieve savings at lower voltage. Electric motors and some fluorescent lighting can achieve savings at lower voltages.

62 In particular, we would expect the efficiency and performance of LED lighting to continue to improve, and the efficiency of both televisions and refrigerators to continue to improve, partly in response to government efficiency regulations.

63 Incentives are currently available in Victoria for some draught sealing measures, underfloor insulation, double-glazing, lighting, lower flow shower roses, heating and cooling, water heating, refrigerator, television and clothes dryer upgrades.

64 Retrofitting houses with insulation: a cost-benefit analysis of a randomised community trial, Dr Ralph Chapman et al, February 2007, funded by NZ Health and Research Council and Energy Efficiency and Conservation Authority; Cost Benefit Analysis of the Warm UP New Zealand Heat Smart Program, Arthur Grimes et al, prepared for the Ministry of Economic Development, October 2012.

There are also a range of additional co-benefits which are likely to result from the application of energy efficiency upgrades, especially if there is widespread uptake across the existing Victorian housing stock:

- Energy efficiency upgrades which result in electricity savings help to put downward pressure on the price of electricity by reducing future investment in electricity generation and supply infrastructure. Further, as residential electricity consumption is concentrated morning and evening peaks in the electricity supply system the resulting electricity demand savings help to supress the wholesale price of electricity;
- There are potentially significant flow-on economic benefits from the more widespread uptake of energy efficiency. Many energy efficiency upgrades are quite labour intensive, so there is significant potential to generate local employment. Further, the energy bill savings mean that households have greater disposable income, and this can generate further benefits as it is spent and flows through the economy.

The energy (and water) bill savings are based on the energy (and water) tariffs which applied at the time the analysis was undertaken. As energy prices seem likely to continue to rise in real terms[65], the cost-effectiveness of many of the energy efficiency upgrades studied in this report are likely to improve.

Taken together, the costs and savings assumptions which have been used as the basis of the analysis presented in this report mean that we present a reasonably conservative picture of the economics of upgrading the energy efficiency of existing Victorian houses. Where households can undertake the upgrade as a DIY project or access a government financial incentive the costs will be lower. As time progresses the declining cost of the some of the upgrades, as well as a general increase in real energy prices will also help to make the upgrades more cost effective.

The On-Ground Assessment study report has presented a theoretical analysis of the energy efficiency upgrade potential of existing (pre-2005) Victorian houses grounded in data collected from actual houses. For the next phase of work on the existing housing stock Sustainability Victoria is trialling key energy efficiency upgrade measures in houses to assess the practical issue related to the implementation of the measures as well as the actual quantitative (cost, energy savings, impact on energy service) and qualitative (householder perceptions and acceptance) impacts which can be achieved in practice. The results of the Residential Energy Efficiency Retrofit Trials will be published in a forthcoming series of reports.

65 The retail price index for electricity in Melbourne increased by 88% from 2006/07 to 2013/14, and the corresponding retail price index for gas increased by 45% over this same period. The retail price of electricity is expected to remain fairly flat in the short term, while the retail price of gas is expected to continue to increase. [State of the Energy Market 2014, Australian Energy Regulator, 2014]

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Technical Note 2 – Guidance for Calculating Ceiling Penetrations (Version 1.0 – 2012), Nationwide House Energy Rating Scheme, October 2012

Palmer 2008

Field study on gas ducted heating systems in Victoria, Graham Palmer, Minor Thesis submitted to RMIT University, September 2008

YVW 2011

Yarra Valley Water Future Water: Residential Water Use Study Volume 1 – Winter 2010, Yarra Valley Water July 2011

APPENDICES

A1: Summary of OGA Study House Characteristics

House Number	Construction Characteristics	Construction Era	No. of People	Ownership Status	Floor Area (m2)	Existing HER	Main Heating	Main Cooling	% of Floor Area Heated	Existing Insulation and Air Leakage Rate
A1	› Single storey › Detached › Brick Veneer › Suspended timber floor	1970s	4	Owner occupied	175.3	1.6	Gas central	Ducted evaporative	68%	› R0.5 ceiling insulation › 1.16 ACH
A2	› Single storey › Semi-Detached › Weatherboard › Suspended timber floor	1910s	5	Owner occupied	88.7	1.6	Gas room	N/A	60%	› R2.0 ceiling insulation, except flat roof › 1.09 ACH
A3	› Single storey › Detached › Brick Veneer › Suspended timber floor	1950s	5	Private rental	139	0.5	Gas central	N/A	98%	› No ceiling insulation › 1.71 ACH
A4	› Single storey › Detached › Brick Veneer › Suspended timber floor	1970s	2	Owner occupied	97.3	1.7	Gas room	Ducted evaporative	52%	› R1.5 ceiling insulation › 2.00 ACH
A5	› Single storey › Detached › Weatherboard › Suspended timber floor	1950s	3	Private rental	83.8	0.9	Gas room	N/A	23%	› R3.0 ceiling insulation, except flat roof › 2.67 ACH
A6	› Single storey › Semi-Detached › Brick VeneerSuspended timber floor	1960s	4	Private rental	75.1	0.8	Room RAC	Room RAC	32%	› No ceiling insulation › 1.82 ACH
A7	› Single storey › Semi-Detached › Brick Cavity › Suspended timber floor / concrete slab on ground	1930s	2	Owner occupied	114.3	2.7	Gas room	N/A	19%	› R2.5 ceiling insulation, except flat roof › 1.43 ACH
A8	› Single storey › Detached › Weatherboard › Suspended timber floor	1910s	4	Owner occupied	157.5	0	Gas central	N/A	80%	› No ceiling insulation › 1.14 ACH

House Number	Construction Characteristics	Construction Era	No. of People	Ownership Status	Floor Area (m2)	Existing HER	Main Heating	Main Cooling	% of Floor Area Heated	Existing Insulation and Air Leakage Rate
A9	› Single storey › Detached › Weatherboard › Suspended timber floor	1900s	4	Owner occupied	139.2	1.1	Gas room	Room RAC	58%	› R3.0 ceiling insulation, except flat roof › 0.87 ACH
A10	› Single storey › Detached › Brick Veneer › Suspended timber floor	1950s	4	Owner occupied	124.2	1.8	Gas central	Cooling only room AC	74%	› R3.0 ceiling insulation › 1.68 ACH
A11	› Single storey › Detached › Brick Veneer › Suspended timber floor	1970s	5	Owner occupied	149.8	2.3	Gas central	Cooling only room AC	92%	› R2.5 ceiling insulation › 0.85 ACH
A12	› Single storey › Detached › Weatherboard / cement sheeting › Suspended timber floor / concrete slab on ground	1930s	4	Owner occupied	108	1.6	Gas room	N/A	42%	› R2.5 ceiling insulation › 1.4 ACH
A13	› Double storey › Detached › Brick veneer › Suspended timber floor	1960s	4	Owner occupied	226.3	1.5	Gas central	N/A	82%	› R2.0 ceiling insulation › 1.65 ACH
A14	› Single storey › Detached › Weatherboard › Suspended timber floor	1940s	4	Owner occupied	123.4	1.8	Gas room	Cooling only room AC	27%	› R2.5 ceiling insulation › 1.35 ACH
A15	› Single storey › Detached › Brick cavity / brick veneer › Suspended timber floor / concrete slab on ground	1930s	1	Owner occupied	134.4	1.4	Gas room	Room RAC	42%	› No ceiling insulation in pitched roof › R2.5 ceiling insulation in flat roof › 0.98 ACH
B1	› Single storey › Detached › Brick veneer › Suspended timber floor	1980s	2	Owner occupied	128	0.8	Gas central	Ducted evaporative	92%	› R3.0 ceiling insulation › No floor or wall insulation › 4.29 ACH

House Number	Construction Characteristics	Construction Era	No. of People	Ownership Status	Floor Area (m2)	Existing HER	Main Heating	Main Cooling	% of Floor Area Heated	Existing Insulation and Air Leakage Rate
B2	› Single storey › Detached › Brick veneer › Suspended timber floor	1960s with 2000s extension	2	Owner occupied	106	2.4	Gas central	N/A	91%	› R2.0 ceiling insulation › R1.5 wall insulation in extension; No floor insulation › 2.03 ACH
B3	› Single storey › Detached › Brick veneer › Suspended timber floor	1960s with 2000s extension	4	Owner occupied	150	1.5	Gas central	Room RAC	99%	› R1.5 ceiling insulation in main house, R4.0 in extension › No wall insulation in main house, R2.0 in extension › No floor insulation › 2.71 ACH
B4	› Single storey › Detached › Brick veneer › Suspended timber floor in main house / concrete slab on ground in extension	1970s with 1990s extension	4	Owner occupied	120	1.4	Gas central	Cooling only room AC	62%	› R1.0 ceiling insulation › RFL wall insulation in extension only › No floor insulation › 3.91 ACH
B5	› Single storey › Detached › Brick veneer › Concrete slab on ground	1990s	4	Owner occupied	202	3.1	Gas central	Room RAC	78%	› R.2 ceiling insulation › RFL wall insulation › No floor insulation › 0.94 ACH
B6	› Three storey › Detached › Brick veneer with some weatherboard and brick cavity › Suspended timer floor in main house, concrete slab on ground in basement	1980s	5	Owner occupied	238	1.1	Gas central	Room RAC	60%	› R2.5 ceiling insulation › No wall insulation › No floor insulation › 2.67 ACH
B7	› Two storey › Semi-Detached › Brick veneer › Concrete slab on ground	2000s	3	Owner occupied	107	3.8	Gas room	N/A	45%	› R0.6 ceiling insulation › RFL wall insulation › No floor insulation › 1.12 ACH

House Number	Construction Characteristics	Construction Era	No. of People	Ownership Status	Floor Area (m2)	Existing HER	Main Heating	Main Cooling	% of Floor Area Heated	Existing Insulation and Air Leakage Rate
B8	› Two storey › Detached › Brick veneer with some weatherboard › Suspended timber floor	1990s	3	Owner occupied	173	2.5	Gas central	Ducted evaporative	88%	› R2.5 ceiling insulation › R1.5 wall insulation › No floor insulation › 1.91 ACH
B9	› Single storey › Detached › Brick veneer › Suspended timber floor	1980s	1	Owner occupied	183	1.8	Gas central	Ducted evaporative	59%	› R1.5 ceiling insulation › No wall insulation › No floor insulation › 1.59 ACH
B10	› Single storey › Detached › Brick veneer › Suspended timber floor	1950s	1	Owner occupied	74	1.8	Gas room	Ducted evaporative	39%	› R3.5 ceiling insulation › No wall insulation › No floor insulation › 4.41 ACH
B11	› Single storey › Detached › Weatherboard › Suspended timber floor	1950s with 2000s extension	3	Owner occupied	160	1.6	Gas central	Room RAC	51%	› R1.5 to R2.5 ceiling insulation › R1.5 wall insulation in extension › No floor insulation › 2.15 ACH
B12	› Single storey › Detached › Brick veneer › Concrete slab on ground	2000s	2	Owner occupied	155	3.1	Gas central	Ducted evaporative	58%	› R2.0 ceiling insulation › No wall insulation › No floor insulation › 1.1 ACH
B13	› Single storey › Detached › Brick cavity › Suspended timber floor	1920s	4	Owner occupied	169	1.9	Gas central (hydronic)	Room RAC	96%	› R4.0 ceiling insulation › No wall insulation › No floor insulation › 2.49 ACH

House Number	Construction Characteristics	Construction Era	No. of People	Ownership Status	Floor Area (m2)	Existing HER	Main Heating	Main Cooling	% of Floor Area Heated	Existing Insulation and Air Leakage Rate
B14	› Single storey › Detached › Brick veneer › Suspended timber floor	1950s	2	Owner occupied	84	1.4	Room RAC	Room RAC	31%	› R2.5 ceiling insulation › No wall insulation › No floor insulation › 3.48 ACH
B15	› Single storey › Detached › Brick veneer › Suspended timber floor	1980s	2	Owner occupied	105	2.3	Gas central	Room RAC	64%	› R2.0 ceiling insulation › No wall insulation › No floor insulation › 1.77 ACH
B16	› Two storey › Semi-Detached › Brick cavity › Concrete slab on ground	1980s	2	Owner occupied	79	1.8	Electric panel heater	Cooling only room AC	45%	› No ceiling insulation › No wall insulation › No floor insulation › 1.63 ACH
B17	› Single storey › Detached › Brick veneer with some weatherboard and brick cavity › Concrete slab on ground	1960s with 1980s extension	4	Owner occupied	151	0	Gas room	Cooling only room AC	90%	› No ceiling insulation › No wall insulation › No floor insulation › 2.29 ACH
B18	› Single storey › Detached › Brick veneer › Suspended timber floor	1960s	2	Owner occupied	102	1.5	Gas central	Ducted evaporative	98%	› R3.5 ceiling insulation › No wall insulation › No floor insulation › 2.50 ACH
B19	› Single storey Detached Brick veneer Concrete slab on ground	1980s	2	Owner occupied	104	2.6	Gas room	N/A	51%	› R3.5 ceiling insulation › No wall insulation › No floor insulation › 1.54 ACH
B20	› Single storey › Detachef › Weatherboard › Suspended timber floor / concrete slab on ground in some areas	1950s	1	Owner occupied	70	1.9	Gas central	N/A	92%	› R2.5 ceiling insulation › No wall insulation › No floor insulation › 2.17 ACH

House Number	Construction Characteristics	Construction Era	No. of People	Ownership Status	Floor Area (m2)	Existing HER	Main Heating	Main Cooling	% of Floor Area Heated	Existing Insulation and Air Leakage Rate
B21	› Single storey › Detached › Brick veneer › Concrete slab on ground	1990s	4	Owner occupied	264	3.2	Gas central	N/A	57%	› R1.5 ceiling insulation › RFL wall insulation › No floor insulation › 0.62 ACH
B22	› Single storey › Detached › Weatherboard › Suspended timber floor	1930s	2	Owner occupied	89	1	Gas room	N/A	92%	› No ceiling insulation › No wall insulation › No floor insulation › 0.95 ACH
B23	› Single storey › Detached › Brick veneer › Suspended timber floor	1950s	4	Owner occupied	194	1.7	Gas central	N/A	35%	› R2.0 ceiling insulation › No wall insulation › No floor insulation › 1.64 ACH
B24	› Single storey › Detached › Weatherboard › Suspended timber floor / concrete slab on ground in rear extension	1980s	1	Owner occupied	93	1.2	Gas room	N/A	43%	› R2.0 ceiling insulation in attic section › No wall insulation › No floor insulation › 2.37 ACH
B25	› Single storey › Detached › Weatherboard › Suspended timber floor	1990s	4	Owner occupied	94	2.4	Gas room	N/A	49%	› R2.0 ceiling insulation › R2.0 wall insulation › No floor insulation › 1.87 ACH
B26	› Single storey › Detached › Weatherboard › Suspended timber floor	1960s	2	Owner occupied	70	1.7	Gas room	N/A	26%	› R1.5 ceiling insulation › No wall insulation › No floor insulation › 3.71 ACH

House Number	Construction Characteristics	Construction Era	No. of People	Ownership Status	Floor Area (m2)	Existing HER	Main Heating	Main Cooling	% of Floor Area Heated	Existing Insulation and Air Leakage Rate
B27	› Single storey › Detached › Brick veneer › Concrete slab on ground	1990s	2	Owner occupied	215	4	Gas room	Room RAC	29%	› R2.0 ceiling insulation › R1.5 wall insulation › No floor insulation › 0.64 ACH
B28	› Single storey › Detached › Brick veneer › Concrete slab on ground	1980s	3	Private rental	82	2.5	Gas room	N/A	78%	› R2.0 ceiling insulation › No wall insulation › No floor insulation › 1.96 ACH
B29	› Single storey › Detached › Brick veneer › Suspended timber floor	1980s	5	Owner occupied	97	1.2	Gas room	Cooling only room AC	52%	› R2.0 ceiling insulation › No wall insulation › No floor insulation › 3.89 ACH
B30	› Single storey › Detached › Brick cavity with some brick veneer and fibre cement sheeting › Concrete slab on ground / suspended timber floor	1900s with 1930s & 1990s extensions	3		195	0	Gas room	Room RAC	24%	› R2.5 ceiling insulation in extension › No wall insulation › No floor insulation › 2.02 ACH
C1	› Single storey › Detached › Weatherboard › Suspended timber floor	1910s with 1990s extension	2	Owner occupied	213	1.1	Gas central	N/A	71%	› R1.5 ceiling insulation in main house, R2.5 in extension › No wall insulation in main house, R1.5 in extension › No floor insulation › 1.89ACH
C2	› Single storey › Detached › Brick veneer › Suspended timber floor	1960s	2	Owner occupied	105	1.8	Gas central	N/A	99%	› R1.5 ceiling insulation › No wall insulation › No floor insulation › 1.88ACH

House Number	Construction Characteristics	Construction Era	No. of People	Ownership Status	Floor Area (m2)	Existing HER	Main Heating	Main Cooling	% of Floor Area Heated	Existing Insulation and Air Leakage Rate
C3	› Double storey › Detached › Brick veneer › Suspended timber floor	1970s with 1980s extension	3	Owner occupied	275	2.1	Gas central	Cooling only room air conditioner	73%	› Ceiling insulation: mix of RFL and R1.5 & RFL and R2.0 throughout house › RFL wall insulation in main house, RFL and R1.5 in extension › No floor insulation › 1.66ACH
C4	› Single storey › Detached › Brick veneer › Concrete slab on ground	1990s	4	Owner occupied	86	3.1	Gas central	Ducted evaporative	98%	› R1.5 ceiling insulation › RFL wall insulation › No floor insulation › 1.39ACH
C5	› Double storey › Semi-Detached › Brick veer with some cement sheeting › Concrete slab on ground	2000 - 2005	2	Owner occupied	172	3.1	Gas room	N/A	36%	› R4.0 ceiling insulation › RFL in brick veneer walls and R1.4 in framed walls › No floor insulation › 1.15ACH
C6	› Single storey › Detached › Weatherboard › Suspended timber floor	1950s with 2010 extension	4	Owner occupied	105	0.7	Gas central	Room RAC	75%	› Ceiling insulation: R1.0 in main house & R3.0 in extension › Wall insulation: None in main house & R2.5 in extension › No floor insulation › 2.07ACH
C7	› Single storey › Detached › Weatherboard › Suspended timber floor	1950s	4	Owner occupied	79	1.7	Gas room	N/A	89%	› R5 ceiling insulation › No wall insulation › No floor insulation › 2.05ACH

House Number	Construction Characteristics	Construction Era	No. of People	Ownership Status	Floor Area (m2)	Existing HER	Main Heating	Main Cooling	% of Floor Area Heated	Existing Insulation and Air Leakage Rate
C8	› Single storey › Semi-Detached › Brick veneer › Concrete slab on ground	1980s	1	Owner occupied	99	1.1	Gas room	Cooling only room air conditioner	49%	› No ceiling insulation › No wall insulation › No floor insulation › 2.64ACH
C9	› Single storey › Detached › Brick cavity › Suspended timber floor	1940s with 1980s extension	2	Owner occupied	105	1.4	Gas room	Room RAC	64%	› Ceiling insulation: R1.5 in main house, none in extension › No wall insulation › No floor insulation › 2.12ACH
C10	› Single storey › Semi-Detached › Brick Veneer › Suspended timber floor	1960s	1	Owner occupied	60.6	2.4	Room RAC	Room RAC	58%	› R1.5 ceiling insulation › No wall insulation › No floor insulation › 1.94ACH
C11	› Single storey › Detached › Brick cavity with some concrete block and framed walls in extension › Suspended timber floor	1940s with 2008 extension	3	Owner occupied	215	2.4	Gas central	N/A	97%	› Ceiling insulation: R1.5 in main house, R2.5 in extension › Wall insulation: None in main house and R2.0 in extension › No floor insulation › 1.10ACH
C12	› Single storey › Detached › Weatherboard › Suspended timber floor	1950s with 1980s extension	1	Owner occupied	127	1.7	Electric panel heater	N/A	22%	› Ceiling: R3.5 in main house, none in extension › No wall insulation › No floor insulation › 1.04ACH
C13	› Single storey › Detached › Brick veneer › Suspended timber floor	1980s	2	Owner occupied	113	2.4	Gas central	Cooling only room air conditioner	83%	› R2.5 ceiling insulation › No wall insulation › No floor insulation › 1.20ACH

House Number	Construction Characteristics	Construction Era	No. of People	Ownership Status	Floor Area (m2)	Existing HER	Main Heating	Main Cooling	% of Floor Area Heated	Existing Insulation and Air Leakage Rate
C14	› Single storey › Detached › Brick veneer › Suspended timber floor	1960s with 2009 extension	4	Owner occupied	124	2.7	Room RAC	Room RAC	57%	› R3.5 ceiling insulation › Wall insulation: None in main house, R1.5 in extension › Floor insulation: None in main house, R1.5 in extension › 1.41ACH
C15	› Single storey › Detached › Brick veneer › Suspended timber floor	1950s with 1980s extension	3	Owner occupied	121.7	2.2	Gas central	N/A	99%	› R4.0 in main house, none in the extension › No wall insulation › No floor insulation › 1.19ACH
Av.			**2.9**		**133.2**	**1.81**			**63.3%**	

A2: Details of Building Shell Upgrades Modelled for Houses

House No.		1. Ceiling Insulation (easy)	2. Draught sealing	3. Seal Wall Cavity	4. Reduce Sub-Floor Ventilation	5. Underfloor insulation	6. Wall insulation	7. Ceiling insulation (difficult)	8. Ceiling insulation top-up	9. Double glazing	9a. Drapes & Pelmets	10. External Shading
A1	Applied	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes
	Details		Reduced from 1.16 to 0.5 ACH	68.7 m length of wall cavity blocked		175.4 m^2 of R1.5 installed	112.4 m^2 of R3.5 installed		175.4 m^2 of R3 installed	32.0 m^2 of Double Glazing installed	30.4 m^2 of drapes & 14.5 m of pelmets installed	22.8 m^2 of canvas awnings installed
	Cost		$1,090	$727		$3,042	$3,904		$1,526	$18,554	$4,109	$3,520
A2	Applied	No	Yes	No	Yes	No	Yes	Yes	Yes	Yes	Yes	No
	Details		Reduced from 1.09 to 0.5 ACH		10.7 m perimeter of subfloor enclosed		79.8 m^2 of R2.5 installed	22.1 m^2 of R2.5 installed	59.4 m^2 of R1.5 installed	9.8 m^2 of Double Glazing installed	7.2 m^2 of drapes & 7.0 m of pelmets installed	
	Cost		$635		$283		$3,644	$667	$369	$5,704	$1,165	
A3	Applied	Yes	Yes	Yes	No	No	Yes	No	No	Yes	Yes	No
	Details	90.0 m^2 of R3.5 installed	Reduced from 1.71 to 0.5 ACH	54.3 m length of wall cavity blocked			144.2 m^2 of R3.5 installed			25.2 m^2 of Double Glazing installed	21.8 m^2 of drapes & 12.6 m of pelmets installed	
	Cost	$864	$1,098	$575			$4,938			$14,636	$3,067	
A4	Applied	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes
	Details		Reduced from 2 to 0.5 ACH	45.9 m length of wall cavity blocked		97.3 m^2 of R1.5 installed	77.6 m^2 of R3.5 installed		97.3 m^2 of R2.0 installed	17.0 m^2 of Double Glazing installed	7.1 m of pelmets installed	11.2 m^2 of canvas awnings installed
	Cost		$1,050	$486		$1,688	$2,771		$671	$9,880	$370	$1,736
A5	Applied	No	Yes	No	Yes	No	Yes	Yes	No	Yes	Yes	No
	Details		Reduced from 2.67 to 0.5 ACH		12.3 m perimeter of subfloor enclosed		99.3 m^2 of R2.5 installed	24.7 m^2 of R2.5 installed		2.4 m^2 of Double Glazing installed	2.4 m^2 of drapes & 1.5 m of pelmets installed	
	Cost		$578		$323		$4,470	$691		$1,399	$344	

House No.		1. Ceiling Insulation (easy)	2. Draught sealing	3. Seal Wall Cavity	4. Reduce Sub-Floor Ventilation	5. Underfloor insulation	6. Wall insulation	7. Ceiling insulation (difficult)	8. Ceiling insulation top-up	9. Double glazing	9a. Drapes & Pelmets	10. External Shading
A6	Applied	Yes	Yes	Yes	No	No	Yes	No	No	Yes	Yes	No
	Details	75.2 m^2 of R3.5 installed	Reduced from 1.82 to 0.5 ACH	36.3 m of wall cavity sealed			83.7 m^2 of R3.5 installed			3.0 m^2 of Double Glazing installed	2.96 m^2 of drapes installed	
	Cost	$722	$456	$384			$2,969			$1,718	$327	
A7	Measure applied	No	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	No
	Details		Reduced from 1.43 to 0.5 ACH	52.6 m length of wall cavity blocked			83.4 m^2 of R1.5 installed	7.6 m^2 of R2.5 installed		3.5 m^2 of Double Glazing installed	3.5 m^2 of drapes & 2.0 m of pelmets installed	
	Cost		$630	$557			$2,959	$404		$2,046	$492	
A8	Measure applied	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No
	Details	132.4 m^2 of R3.5 installed	Reduced from 1.14 to 0.5 ACH		30.8 m perimeter of subfloor enclosed	157.6 m^2 of R1.5 installed	176.8 m^2 of R2.5 installed	25.1 m^2 of R2.5 installed		16.9 m^2 of Double Glazing installed	13.3 m^2 of drapes & 5.6 m of pelmets installed	
	Cost	$1,271	$776		$814	$2,734	$7,763	$695		$9,825	$1,761	
A9	Measure applied	No	Yes	No	Yes	No	Yes	Yes	No	Yes	Yes	Yes
	Details		Reduced from 0.87 to 0.5 ACH		9.7 m perimeter of subfloor enclosed		150.1 m^2 of R2.5 installed	25.7 m^2 of R2.5 installed		17.4 m^2 of Double Glazing installed	14.2 m^2 of drapes & 5.1 m of pelmets installed	6.9 m^2 of canvas awnings installed
	Cost		$426		$255		$6,629	$699		$10,073	$1,833	$1,072
A10	Measure applied	No	Yes	Yes	No	No	Yes	No	No	Yes	Yes	Yes
	Details		Reduced from 1.68 to 0.5 ACH	49.3 m length of wall cavity blocked			105.6 m^2 of R3.5 installed			24.6 m^2 of Double Glazing installed	19.7 m^2 of drapes installed	3.4 m^2 of canvas awnings installed
	Cost		$458	$522			$3,682			$14,289	$2,180	$521

House No.		1. Ceiling Insulation (easy)	2. Draught sealing	3. Seal Wall Cavity	4. Reduce Sub-Floor Ventilation	5. Underfloor insulation	6. Wall insulation	7. Ceiling insulation (difficult)	8. Ceiling insulation top-up	9. Double glazing	9a. Drapes & Pelmets	10. External Shading
A11	Measure applied	No	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	No
	Details		Reduced from 0.85 to 0.5 ACH	63 m length of wall cavity blocked		149.8 m² of R1.5 installed	119.0 m² of R3.5 installed			18.0 m² of Double Glazing installed	23.6 m² of drapes & 6.0 m of pelmets installed	
	Cost		$505	$667		$2,600	$4,118			$10,445	$2,927	
A12	Measure applied	No	Yes	No	No	No	Yes	No	No	Yes	Yes	No
	Details		Reduced from 1.4 to 0.5 ACH				104.4 m² of R2.5 installed			8.6 m² of Double Glazing installed	4.1 m² of drapes installed	
	Cost		$620				$4,686			$4,988	$456	
A13	Measure applied	No	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes	No
	Details		Reduced from 1.65 to 0.5 ACH	59.2 m length of wall cavity blocked			219.7 m² of R3.5 installed		124.4 m² of R1.5 installed	33.4 m² of Double Glazing installed	31.9 m² of drapes & 21.9 m of pelmets installed	
	Cost		$795	$627			$8,740		$722	$19,347	$4,669	
A14	Measure applied	No	Yes	No	Yes	No	Yes	Yes	No	Yes	Yes	No
	Details		Reduced from 1.35 to 0.5 ACH		12.5 m perimeter of subfloor enclosed		113.1 m² of R2.5 installed	16.4 m² of R2.5 installed		6.0 m² of Double Glazing installed	6.0 m² of drapes installed	
	Cost		$404		$330		$5,056	$483		$3,461	$659	
A15	Measure applied	Yes	Yes	Yes	No	No	Yes	No	No	Yes	Yes	Yes
	Details	90.3 m² of R3.5 installed	Reduced from 0.98 to 0.5 ACH	41.9 m length of wall cavity blocked			168.0 m² of R1.5 installed			23.0 m² of Double Glazing installed	15.5 m² of drapes & 6.7 m of pelmets installed	17.5 m² of canvas awnings installed
	Cost	$867	$747	$444			$6,297			$13,338	$2,069	$2,702

House No.		1. Ceiling Insulation (easy)	2. Draught sealing	3. Seal Wall Cavity	4. Reduce Sub-Floor Ventilation	5. Underfloor insulation	6. Wall insulation	7. Ceiling insulation (difficult)	8. Ceiling insulation top-up	9. Double glazing	9a. Drapes & Pelmets	10. External Shading
B1	Measure applied	No	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes
	Details		Reduced from 4.29 to 0.5 ACH	57.9 m of wall cavity blocked		132.6 m^2 of R1.5 installed	98.5 m^2 of R3.5 installed	43.0 m^2 of R2.5 installed		39.8 m^2 of Double Glazing installed	31.0 m^2 of drapes & 16.2 m of pelmets installed	16.4 m^2 of canvas awnings installed
	Cost		$1,285	$613		$2,300	$3,452	$854		$23,072	$4,265	$2,528
B2	Measure applied	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	No
	Details		Reduced from 2.03 to 0.5 ACH	48.5 m of wall cavity blocked		106.3 m^2 of R1.5 installed	55.7 m^2 of R3.5 installed		106.3 m^2 of R2.5 installed	25.3 m^2 of Double Glazing installed	12.1 m^2 of drapes & 7.8 m of pelmets installed	
	Cost		$1,310	$514		$1,845	$2,061		$660	$14,668	$1,739	
B3	Measure applied	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes
	Details		Reduced from 2.71 to 0.5 ACH	64.8 m of wall cavity blocked		150.0 m^2 of R1.5 installed	67.2 m^2 of R3.5 installed		87.5 m^2 of R2.0 installed	39.9 m^2 of Double Glazing installed	15.7 m^2 of drapes & 14.8 m of pelmets installed	4.0 m^2 of canvas awnings installed
	Cost		$1,655	$686		$2,603	$2,433		$604	$23,127	$2,507	$611
B4	Measure applied	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes
	Details		Reduced from 3.91 to 0.5 ACH	57.8 m of wall cavity blocked		93.4 m^2 of R1.5 installed	99.1 m^2 of R3.5 installed		119.8 m^2 of R2.5 installed	22.6 m^2 of Double Glazing installed	20.1 m^2 of drapes & 5.4 m of pelmets installed	3.8 m^2 of canvas awnings installed
	Cost		$1,630	$613		$1,621	$3,472		$934	$13,085	$2,505	$583
B5	Measure applied	No	Yes	No	No	No	Yes	No	No	Yes	Yes	Yes
	Details		Reduced from 0.94 to 0.5 ACH				131.1 m^2 of R1.5 installed, 34.9 m^2 of R2.5 installed			39.2 m^2 of Double Glazing installed	14.1 m^2 of drapes & 10.8m of pelmets installed	4.3 m^2 of canvas awnings installed
	Cost		$1,150				$6,475			$22,763	$2,115	$667

House No.		1. Ceiling Insulation (easy)	2. Draught sealing	3. Seal Wall Cavity	4. Reduce Sub-Floor Ventilation	5. Underfloor insulation	6. Wall insulation	7. Ceiling insulation (difficult)	8. Ceiling insulation top-up	9. Double glazing	9a. Drapes & Pelmets	10. External Shading
B6	Measure applied	No	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes
	Details		Reduced from 2.67 to 0.5 ACH	46.1 m of wall cavity sealed		70.2 m^2 of R1.5 installed	42.3 m^2 of R1.5 installed, 34.9 m^2 of R2.5 installed, 131.5 m^2 of R3.5 installed	16.8 m^2 of R2.5 installed		43.7 m^2 of Double Glazing installed	40.0 m^2 of drapes & 16.1 m of pelmets installed	22.2 m^2 of canvas awnings installed
	Cost		$1,455	$488		$1,218	$8,016	$486		$25,352	$5,263	$3,428
B7	Measure applied	No	Yes	No	No	No	Yes	No	Yes	Yes	Yes	No
	Details		Reduced from 1.12 to 0.5 ACH				124.1 m^2 of R1.5 installed		107.3 m^2 of R2.5 installed	11.2 m^2 of Double Glazing installed	11.2 m^2 of drapes & 8.3 m of pelmets installed	
	Cost		$776				$5,153		$837	$6,519	$1,675	
B8	Measure applied	Yes	Yes	Yes	No	Yes	No	No	No	Yes	Yes	No
	Details	14.0 m^2 of R3.5 installed	Reduced from 1.91 to 0.5 ACH	46.1 m length of wall cavity blocked		132.5 m^2 of R1.5 installed				38.3 m^2 of Double Glazing installed	14.4 m of pelmets installed	
	Cost	$135	$1,380	$488		$2,298				$22,200	$751	
B9	Measure applied	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	No
	Details		Reduced from 1.59 to 0.5 ACH	56.2 m length of wall cavity blocked		128.2 m^2 of R1.5 installed	6.5 m^2 of R2.5 & 77.8 m^2 of R3.5 installed		128.2 m^2 of R2.0 installed	41.9 m^2 of Double Glazing installed	35.8 m^2 of drapes & 19.7 m of pelmets installed	
	Cost		$1,450	$595		$2,225	$2,990		$885	$24,325	$4,988	
B10	Measure applied	No	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes
	Details		Reduced from 4.41 to 0.5 ACH	36.2 m length of wall cavity blocked		73.7 m^2 of R1.5 installed	7.5 m^2 of R2.5 & 63.4 m^2 of R3.5 installed			7.7 m^2 of Double Glazing installed	6.8 m^2 of drapes & 4.5 m of pelmets installed	3.7 m^2 of canvas awnings installed
	Cost		$1,280	$384		$1,279	$2,556			$4,489	$980	$570

House No.		1. Ceiling Insulation (easy)	2. Draught sealing	3. Seal Wall Cavity	4. Reduce Sub-Floor Ventilation	5. Underfloor insulation	6. Wall insulation	7. Ceiling insulation (difficult)	8. Ceiling insulation top-up	9. Double glazing	9a. Drapes & Pelmets	10. External Shading
B11	Measure applied	No	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	No
	Details		Reduced from 2.15 to 0.5 ACH		65.4 m perimeter of subfloor enclosed	160.1 m² of R1.5 installed	77.4 m² of R2.5 & 15.2 m² of R3.5 installed		79.9 m² of R1.5 & 34.3 m² of R2.5 installed	18.5 m² of Double Glazing installed	17.5 m² of drapes & 8.7 m of pelmets installed	
	Cost		$1,440		$1,727	$2,778	$4,186		$764	$10,742	$2,391	
B12	Measure applied	No	Yes	No	No	No	Yes	No	Yes	Yes	Yes	Yes
	Details		Reduced from 1.1 to 0.5 ACH				105.8 m² of R1.5 installed		155.3 m² of R1.5 installed	15.6 m² of Double Glazing installed	13.0 m² of drapes & 5.1 m of pelmets installed	11.8 m² of canvas awnings installed
	Cost		$1,035				$3,681		$964	$9,025	$1,698	$1,818
B13	Measure applied	No	Yes	Yes	No	No	Yes	No	No	Yes	Yes	Yes
	Details		Reduced from 2.49 to 0.5 ACH	58.5 m length of wall cavity blocked			144.0 m² of R1.5 installed			33. m² of Double Glazing installed	28.1 m² of drapes & 16.2 m of pelmets installed	9.7 m² of canvas awnings installed
	Cost		$1,495	$619			$4,930			$19,146	$3,950	$1,500
B14	Measure applied	No	Yes	Yes	No	No	Yes	No	No	Yes	Yes	Yes
	Details		Reduced from 3.48 to 0.5 ACH	42.1 m length of wall cavity blocked			96.1 m² of R3.5 installed			5.0 m² of Double Glazing installed	5.0 m² of drapes & 2.4 m of pelmets installed	5.3 m² of canvas awnings installed
	Cost		$795	$446			$3,372			$2,923	$682	$815
B15	Measure applied	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	Yes
	Details		Reduced from 1.77 to 0.5 ACH	54.8 m length of wall cavity blocked		82.0 m² of R1.5 installed	66.4 m² of R3.5 installed		82.0 m² of R1.5 installed	19.3 m² of Double Glazing installed	16.4 m² of drapes & 8.1 m of pelmets installed	2.2 m² of canvas awnings installed
	Cost		$653	$581		$1,422	$2,408		$509	$11,171	$2,232	$333

House No.		1. Ceiling Insulation (easy)	2. Draught sealing	3. Seal Wall Cavity	4. Reduce Sub-Floor Ventilation	5. Underfloor insulation	6. Wall insulation	7. Ceiling insulation (difficult)	8. Ceiling insulation top-up	9. Double glazing	9a. Drapes & Pelmets	10. External Shading
B16	Measure applied	No	Yes	No	No	No	Yes	Yes	No	Yes	Yes	Yes
	Details		Reduced from 1.63 to 0.5 ACH				69.7 m^2 of R1.5 installed	42.0 m^2 of R2.5 installed		14.9 m^2 of Double Glazing installed	14.6 m^2 of drapes & 7.2 m of pelmets installed	4.0 m^2 of canvas awnings installed
	Cost		$926				$2,863	$846		$8,665	$1,986	$611
B17	Measure applied	No	Yes	No	Yes	No	Yes	Yes	No	Yes	Yes	Yes
	Details		Reduced from 2.29 to 0.5 ACH		26.8 m perimeter of subfloor enclosed		19.6 m^2 of R1.5 & 22.4 m^2 of R2.5 & 78.7 m^2 of R3.5 installed	162.8 m^2 of R2.5 installed		40.8 m^2 of Double Glazing installed	37.4 m^2 of drapes & 16.0 m of pelmets installed	16.4 m^2 of canvas awnings installed
	Cost		$1,300		$706		$4,593	$2,128		$23,677	$4,968	$2,534
B18	Measure applied	No	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	No
	Details		Reduced from 2.5 to 0.5 ACH	47.3 m length of wall cavity blocked		101.8 m^2 of R1.5 installed	97.4 m^2 of R3.5 installed			26.6 m^2 of Double Glazing installed	18.3 m^2 of drapes & 12.1 m of pelmets installed	
	Cost		$1,111	$501		$1,767	$3,415			$15,428	$2,655	
B19	Measure applied	No	Yes	No	No	No	Yes	No	No	Yes	Yes	No
	Details		Reduced from 1.54 to 0.5 ACH				80.5 m^2 of R3.5 installed			10.6 m^2 of Double Glazing installed	7.6 m^2 of drapes & 4.2 m of pelmets installed	
	Cost		$1,272				$3,267			$6,160	$1,061	
B20	Measure applied	No	Yes	No	No	Yes	Yes	Yes	No	Yes	Yes	No
	Details		Reduced from 2.17 to 0.5 ACH			69.9 m^2 of R1.5 installed	82.8 m^2 of R2.5 installed	5.5 m^2 of R2.5 installed		9.3 m^2 of Double Glazing installed	8.5 m^2 of drapes & 7.4 m of pelmets installed	
	Cost		$659			$1,212	$3,770	$385		$5,411	$1,327	

House No.		1. Ceiling Insulation (easy)	2. Draught sealing	3. Seal Wall Cavity	4. Reduce Sub-Floor Ventilation	5. Underfloor insulation	6. Wall insulation	7. Ceiling insulation (difficult)	8. Ceiling insulation top-up	9. Double glazing	9a. Drapes & Pelmets	10. External Shading
B21	Measure applied	No	Yes	No	No	No	Yes	No	Yes	Yes	Yes	No
	Details		Reduced from 0.62 to 0.5 ACH				126.7 m^2 of R1.5 installed		263.8 m^2 of R2.0 installed	35.2 m^2 of Double Glazing installed	21.2 m^2 of drapes & 14.1 m of pelmets installed	
	Cost		$1,197				$4,369		$1,820	$20,393	$3,082	
B22	Measure applied	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No
	Details	81.46 m^2 of R3.5 installed	Reduced from 0.95 to 0.5 ACH		40.2 m perimeter of subfloor enclosed	88.6 m^2 of R1.5 installed	105.1 m^2 of R2.5 installed	7.01 m^2 of R2.5 installed		11.4 m^2 of Double Glazing installed	11.4 m^2 of drapes & 7.0 m of pelmets installed	
	Cost	$782	$668		$1,060	$1,536	$4,717	$399		$6,632	$1,629	
B23	Measure applied	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	No
	Details		Reduced from 1.64 to 0.5 ACH	75.4 m length of wall cavity blocked		193.8 m^2 of R1.5 installed	157.7 m^2 of R3.5 installed		193.8 m^2 of R1.5 installed	9.4 m^2 of Double Glazing installed	5.0 m^2 of drapes & 2.5 m of pelmets installed	
	Cost		$1,471	$799		$3,363	$5,375		$1,204	$5,449	$681	
B24	Measure applied	No	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	No
	Details		Reduced from 2.37 to 0.5 ACH				122.3 m^2 of R2.5 installed	20.6 m^2 of R2.5 installed	72.3 m^2 of R1.5 installed	5.5 m^2 of Double Glazing installed	4.4 m^2 of drapes & 2.6 m of pelmets installed	
	Cost		$591				$5,448	$654	$449	$3,207	$626	
B25	Measure applied	No	Yes	No	Yes	Yes	No	No	No	Yes	Yes	No
	Details		Reduced from 1.87 to 0.5 ACH		41.4 perimeter of subfloor enclosed	94.4 m^2 of R1.5 installed				11.2 m^2 of Double Glazing installed	8.7 m^2 of drapes & 6.9 m of pelmets installed	
	Cost		$761		$1,092	$1,637				$6,496	$1,321	

House No.		1. Ceiling Insulation (easy)	2. Draught sealing	3. Seal Wall Cavity	4. Reduce Sub-Floor Ventilation	5. Underfloor insulation	6. Wall insulation	7. Ceiling insulation (difficult)	8. Ceiling insulation top-up	9. Double glazing	9a. Drapes & Pelmets	10. External Shading
B26	Measure applied	No	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	No
	Details		Reduced from 3.71 to 0.5 ACH		36 m perimeter of subfloor enclosed		61.3 m^2 of R2.5 installed		70.5 m^2 of R2.0 installed	6.5 m^2 of Double Glazing installed	6.5 m^2 of drapes & 3.6m of pelmets installed	
	Cost		$927		$950		$2,855		$486	$3,758	$904	
B27	Measure applied	No	Yes	No	No	No	No	No	Yes	Yes	Yes	Yes
	Details		Reduced from 0.64 to 0.5 ACH						179.8 m^2 of R1.5 installed	14.6 m^2 of Double Glazing installed	14.6 m^2 of drapes & 7.2 m of pelmets installed	5.4 m^2 of canvas awnings installed
	Cost		$1,212						$1,117	$8,456	$1,986	$833
B28	Measure applied	No	Yes	No	No	No	Yes	No	Yes	Yes	Yes	No
	Details		Reduced from 1.96 to 0.5 ACH				73.8 m^2 of R3.5 installed		82.0 m^2 of R1.5 installed	14.9 m^2 of Double Glazing installed	13.5 m^2 of drapes & 9.0 m of pelmets installed	
	Cost		$849				$2,647		$509	$8,665	$1,961	
B29	Measure applied	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Details	7.6 m^2 of R3.5 installed	Reduced from 3.89 to 0.5 ACH	46.4 m length of wall cavity blocked		66.4 m^2 of R1.5 installed	86.0 m^2 of R3.5 installed	9.1 m^2 of R2.5 installed	89.7 m^2 of R1.5 installed	20.2 m^2 of Double Glazing installed	3.8 m^2 of drapes & 9.86 m of pelmets installed	2.1 m^2 of canvas awnings installed
	Cost	$73	$1,260	$492		$1,152	$3,044	$417	$557	$11,743	$934	$324
B30	Measure applied	No	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	Yes
	Details		Reduced from 2.02 to 0.5 ACH	24.3 m of wall cavity sealed			182.1 m^2 of R1.5 & 1.4 m^2 of R2.5 & 11.8 m^2 of R3.5 installed	65.2 m^2 of R2.5 & 82.2 m^2 of R3.5 installed		6.6 m^2 of Double Glazing installed	6.6 m^2 of drapes & 2.4 m of pelmets installed	21.7 m^2 of canvas awnings installed
	Cost		$929	$421			$6,598	$1,990		$3,805	$852	$3,352

House No.		1. Ceiling Insulation (easy)	2. Draught sealing	3. Seal Wall Cavity	4. Reduce Sub-Floor Ventilation	5. Underfloor insulation	6. Wall insulation	7. Ceiling insulation (difficult)	8. Ceiling insulation top-up	9. Double glazing	9a. Drapes & Pelmets	10. External Shading
C1	Measure applied	No	Yes	No	Yes	No	Yes	No	Yes	Yes	Yes	No
	Details		Reduced from 1.70 to 0.5 ACH		26.7 m perimeter of subfloor enclosed		160.6 m^2 of R2.5 installed		182.5 m^2 of R2.0 installed	32.6 m^2 of Double Glazing installed	26.4 m^2 of drapes & 12.7 m of pelmets installed	
	Cost		$1,276		$704		$7,075		$1,259	$18,914	$3,576	
C2	Measure applied	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	Yes	No
	Details		Reduced from 2.21 to 0.5 ACH	48.3 m length of wall cavity blocked		105.1 m^2 of R1.5 installed	90.6 m^2 of R3.5 installed		105.1 m^2 of R2.0 installed	36.2 m^2 of Double Glazing installed	4.0 m^2 of drapes & 16.3 m of pelmets installed	
	Cost		$1,083	$512		$1,823	$3,194		$725	$21,013	$1,289	
C3	Measure applied	No	Yes	No	No	Yes	Yes	No	Yes	Yes	Yes	Yes
	Details		Reduced from ACH to 0.5 ACH			144.2 m^2 of R1.5 installed	157.8 m^2 of R1.5 installed		17.5 m^2 of R2.0 installed	62.6 m^2 of Double Glazing installed	11.4 m^2 of drapes & 18.64m of pelmets installed	16.7 m^2 of canvas awnings installed
	Cost		$1,104			$2,501	$6,167		$121	$36,314	$2,230	$2,577
C4	Measure applied	No	Yes	No	No	No	Yes	No	Yes	Yes	Yes	Yes
	Details		Reduced from 1.62 to 0.5 ACH				84.2 m^2 of R1.5 installed		85.6 m^2 of R1.5 installed	24.7 m^2 of Double Glazing installed	15.3 m^2 of drapes & 11.7m of pelmets installed	24.7 m^2 of canvas awnings installed
	Cost		$994				$3,827		$532	$14,323	$2,301	$3,811
C5	Measure applied	No	Yes	No	No	No	Yes	No	No	Yes	Yes	No
	Details		Reduced from 1.26 to 0.5 ACH				103.9 m^2 of R1.5 installed			15.0 m^2 of Double Glazing installed	12.8 m^2 of drapes & 3.6 m of pelmets installed	
	Cost		$1,575				$4,145			$8,694	$1,604	

House No.		1. Ceiling Insulation (easy)	2. Draught sealing	3. Seal Wall Cavity	4. Reduce Sub-Floor Ventilation	5. Underfloor insulation	6. Wall insulation	7. Ceiling insulation (difficult)	8. Ceiling insulation top-up	9. Double glazing	9a. Drapes & Pelmets	10. External Shading
C6	Measure applied	No	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
	Details		Reduced from 1.92 to 0.5 ACH		43.7 m perimeter of subfloor enclosed	105.5 m^2 of R1.5 installed	89.8 m^2 of R2.5 installed	88.8 m^2 of R2.5 installed		25.1 m^2 of Double Glazing installed	13.6 m^2 of drapes & 13.8 m of pelmets installed	7.3 m^2 of canvas awnings installed
	Cost		$1,046		$1,152	$1,830	$4,068	$1,465		$14,575	$2,226	$1,130
C7	Measure applied	No	Yes	No	Yes	Yes	Yes	No	No	Yes	Yes	No
	Details		Reduced from 2.27 to 0.5 ACH		22.9 m perimeter of subfloor enclosed	79.4 m^2 of R1.5 installed	75.4 m^2 of R2.5 installed			15.9 m^2 of Double Glazing installed	14.2 m^2 of drapes & 9.2 m of pelmets installed	
	Cost		$873		$604	$1,377	$3,455			$9,210	$2,046	
C8	Measure applied	No	Yes	No	No	No	Yes	Yes	No	Yes	Yes	Yes
	Details		Reduced from ACH to 0.5 ACH				41.8 m^2 of R3.5 installed	94.8 m^2 of R2.5 installed		16.2 m^2 of Double Glazing installed	10.6 m^2 of drapes & 5.0 m of pelmets installed	7.8 m^2 of canvas awnings installed
	Cost		$702				$2,028	$1,520		$9,367	$1,432	$1,199
C9	Measure applied	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes
	Details		Reduced from 2.37 to 0.5 ACH	33.4 m length of wall cavity blocked			68.1 m^2 of R1.5 installed, 33.6 m^2 of R3.5 installed	24.7 m^2 of R2.5 installed	95.4 m^2 of R2.0 installed	17.2 m^2 of Double Glazing installed	15.4 m^2 of drapes & 5.4 m of pelmets installed	1.2 m^2 of canvas awnings installed
	Cost		$2,090	$354			$3,555	$691	$658	$9,953	$1,987	$179
C10	Measure applied	No	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes	Yes
	Details		Reduced from 2.05 to 0.5 ACH	34.7 m length of wall cavity blocked			23.7 m^2 of R3.5 installed		66.6 m^2 of R2.0 installed	9.6 m^2 of Double Glazing installed	1.6 m of pelmets installed	5.9 m^2 of canvas awnings installed
	Cost		$940	$367			$1,021		$459	$5,568	$83	$911

House No.		1. Ceiling Insulation (easy)	2. Draught sealing	3. Seal Wall Cavity	4. Reduce Sub-Floor Ventilation	5. Underfloor insulation	6. Wall insulation	7. Ceiling insulation (difficult)	8. Ceiling insulation top-up	9. Double glazing	9a. Drapes & Pelmets	10. External Shading
C11	Measure applied	No	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes	No
	Details		Reduced from 1.12 to 0.5 ACH	43.7 m length of wall cavity blocked			107.6 m^2 of R1.5 installed		105.8 m^2 of R2.0 installed	41.1 m^2 of Double Glazing installed	39.0 m^2 of drapes & 32.6 m of pelmets installed	
	Cost		$2,078	$463			$3,748		$730	$23,834	$6,006	
C12	Measure applied	No	Yes	No	No	No	Yes	Yes	No	Yes	Yes	No
	Details		Reduced from 1.11 to 0.5 ACH				104.1 m^2 of R2.5 installed	17.9 m^2 of R2.5 installed		5.9 m^2 of Double Glazing installed	5.9 m^2 of drapes & 4.2 m of pelmets installed	
	Cost		$849				$4,675	$496		$3,422	$871	
C13	Measure applied	No	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes
	Details		Reduced from 1.32 to 0.5 ACH	52.0 m length of wall cavity blocked		113.1 m^2 of R1.5 installed	91.7 m^2 of R3.5 installed			26.4 m^2 of Double Glazing installed	25.6 m^2 of drapes & 14.1 m of pelmets installed	19.1 m^2 of canvas awnings installed
	Cost		$844	$551		$1,962	$3,229			$15,312	$3,564	$2,948
C14	Measure applied	No	Yes	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes
	Details		Reduced from 1.27 to 0.5 ACH	54.5 m length of wall cavity blocked		114.9 m^2 of R1.5 installed	79.2 m^2 of R3.5 installed			15.6 m^2 of Double Glazing installed	15.0 m^2 of drapes & 7.1 m of pelmets installed	11.3 m^2 of canvas awnings installed
	Cost		$890	$577		$1,994	$2,823			$9,048	$2,027	$1,744
C15	Measure applied	No	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	No
	Details		Reduced from 1.32 to 0.5 ACH	55.8 m length of wall cavity blocked			107.4 m^2 of R3.5 installed	28.3 m^2 of R2.5 installed		32.6 m^2 of Double Glazing installed	2.9 m^2 of drapes & 8.6 m of pelmets installed	
	Cost		$1,360	$591			$3,742	$723		$18,909	$773	

A3: Detailed Analysis of Building Shell Upgrades

Introduction

The different building shell upgrade options which were modelled for this study are listed in Table 21 (Chapter 3). Only those options which were relevant and practically possible for each house were modelled. The details of the building shell upgrades which were modelled for each of the OGA study houses are provided in Appendix A2.

An overview of the analysis methodology is provided in Chapters 3 and 4. The cost of each building shell upgrade was estimated based on the nature and extent of the upgrades required and cost data provided by MEFL (See Appendix A5 for building shell upgrade cost assumptions). The building shell upgrades were applied progressively in the order shown in Table 21 and the impact of the upgrades on the base heating and cooling loads for each house was modelled using FirstRate5. The estimated conversion efficiency of either the existing, or new, heating and cooling equipment was then used to estimate actual energy saving achieved from the upgrade.

Note that where gas heating is present it generally consumes both gas and electricity (mainly for the air circulation fan). In this case the building shell upgrades result in a saving of both gas and electricity. For this study it was assumed that the electricity consumption of a gas ducted heater was 2% of the gas consumption, and the electricity consumption of a gas room heater was 1% of the gas consumption.

In Chapter 3 we summarised the aggregated results for all of the building shell upgrades which were modelled. In this section we present the detailed results for each of the building shell upgrades. This highlights the diversity in results which are achieved for the different upgrades, and also provides an insight into the underlying reasons for this diversity.

Ceiling insulation (easy)

This measure involved modelling the installation of ceiling insulation where the roof space is easily accessible and there is currently no ceiling insulation. Only 7 (11.7%) of the OGA study houses were found to have uninsulated ceilings which would benefit from the installation of insulation, and this is in line with the results published in ABS statistics[66]. The installation of R3.5 insulation on the ceiling was modelled for these houses.

The insulation of uninsulated ceilings might be expected to have the overall biggest impact on improving a houses' thermal efficiency, and to also generate the largest energy saving of the building shell upgrade measures. However, it was rare for the OGA study houses to have a completely uninsulated ceiling, and generally only some sections of the ceiling required insulation. This meant that the energy saving impact was less than anticipated.

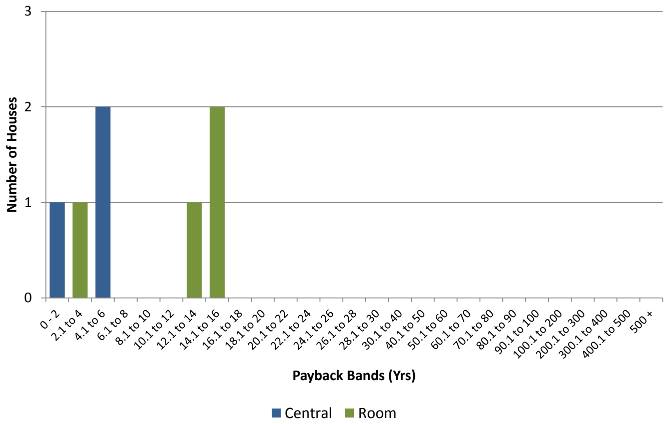
66 ABS data [ABS 2011 b] for 2011 shows that 76.5% of households indicated they had insulation, 7.8% indicated they had no insulation, and 15.6% didn't know; 97.2% of households that were insulated indicated that this was located in the roof/ceiling. If the "don't know" responses are allocated based on the relative weighting of the "Yes" and "No" responses, this suggests that 11.7% of Victorian houses have no ceiling insulation.

TABLE A1: MODELLED IMPACT CEILING INSULATION (EASY) UPGRADE

		Energy Saving (MJ/Yr)						
House No.	Heating Type	Gas	Elec	Total	GHG Saving (kg/Yr)	Cost ($)	Saving ($/Yr)	Payback (Yrs)
A3	Gas central	27,370	547	**27,917**	1,681	$863.7	$521.5	1.7
B22	Gas room	11,136	111	**11,247**	650	$782.0	$203.5	3.8
B8	Gas central	1,742	34	**1,775**	107	$134.8	$33.1	4.1
A8	Gas central	14,684	294	**14,978**	902	$1,271.3	$279.8	4.5
A6	RAC	0	694	**694**	211	$726.1	$54.0	13.4
A15	Gas room	2,373	231	**2,604**	201	$866.9	$59.5	14.6
B29	Gas room	169	26	**195**	68	$73.4	$4.9	15.1
Av. – Across Stock		**958**	**32**	**990**	**64**	**$78.6**	**$19.3**	**4.1**
Av. - When Implemented		**8,210**	**277**	**8,487**	**546**	**$673.4**	**$165.2**	**4.1**
Av. - Central Heating		14,599	292	14,890	896	$756.6	$278.2	2.7
Av. - Room Heating		3,419	266	3,685	283	$611.0	$80.5	7.6

The initial House Energy Rating modelling found an average increase of 0.84 stars in the houses to which this measure was applied, or an average impact across the stock of houses of 0.10 stars. The modelled energy saving impact of the ceiling insulation (easy) upgrade for the individual houses is shown in Table A1. The average impact across the stock of 60 houses, as well as the average impact for the houses in which this measure was modelled, and the average impact for the houses with central heating and room heating are shown. The impact across the stock is relatively low because the measure was found to be applicable to only around 1 out of 10 houses. The impact of the measure when implemented is also lower than expected. This is because in most cases the houses already had partially insulated ceilings and only some sections of the ceiling would benefit from the addition of insulation.

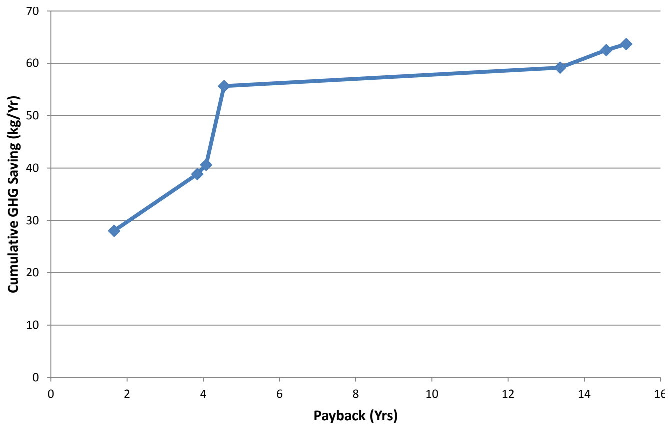
FIGURE A1: DISTRIBUTION OF PAYBACKS FOR CEILING INSULATION (EASY) UPGRADE



The stock average payback for the measure was 4.1 years, and the median of the individual paybacks was 4.5 years, making this the most cost-effective building shell upgrade and one of the most cost-effective upgrades overall. As expected, the energy savings for those houses with a central heating system were much larger than for those houses with only room heating, and the payback period correspondingly lower. Figure A1 shows the distribution of the paybacks for the individual houses, broken down by the type of heating system. Figure A2 provides the cumulative greenhouse abatement curve for the measure. Around 87% of the total savings are provided for a payback of less than 10 years, with most of this corresponding to the centrally heated houses.

Ceiling insulation could be undertaken as a DIY project, reducing the cost to the householder, although great care needs to be taken due to the safety issues involved in working at heights in confined spaces where electrical wiring is present, and adequate safety clearances must be left around hot equipment such as downlights and ceiling exhaust fans. Based on the current retail price of glasswool insulation batts[67] if undertaken as a DIY project the average cost when implemented would be reduced to $421 and the paybacks would be reduced to only 2.5 years.

FIGURE A2: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE FOR CEILING INSULATION (EASY) UPGRADE



67 In November 2015 the average retail price for a pack of R3.5 glasswool batts was around $6.00 per square metre of area covered.

Draught sealing

As part of the OGA study air pressurisation (blower door) tests were undertaken by Air Barrier Technologies to measure the air leakage rate of the houses. The measured natural air leakage rate for each of the houses, expressed in Air Changes per Hour (ACH)[68], is provided in Appendix A1. The average natural air leakage rate for the stock of 60 houses was 1.9 ACH, although quite a wide range of air leakage rates were measured (see Figure 3, Chapter 2 for a distribution of the air leakage rates).

The blower door tests were also used by Air Barrier Technologies to identify the main sources of air leakage in the houses, and to identify and cost a comprehensive package of air sealing measures which could be used to reduce the natural air leakage rate of the houses from their initial measured value to 0.5 ACH. Common sources of air leakage identified in the houses include wall vents, external doors, windows, unsealed exhaust fans, ducted evaporative coolers with no or ineffective dampers, skirting boards, open fireplaces, and manholes.

For this study we modelled the impact of a package of comprehensive draught sealing measures which reduced the air leakage rate from the measured rate to 0.5 ACH for each house. The impact of the draught sealing was modelled in FirstRate5 by simulating the pre- and post-upgrade air leakage rate using ceiling exhaust fans.

In practice, some caution needs to be used when applying comprehensive draught sealing to houses:

- The natural air leakage rate of houses helps to remove water vapour (and other internal air contaminants) from the room air. In houses which have high internal moisture loads – for example from unflued gas heating (or other unflued heaters), indoor plants, heated fish tanks, and poorly ventilated cooking and bathroom areas – a high level of draught sealing might lead to condensation problems and mould growth during winter, especially where the ceiling, walls and windows don't have adequate thermal insulation. Adequate controlled ventilation (eg operable windows or exhaust fans) should be provided for all cooking, bathroom and laundry areas to expel warm-moist air when these areas are being used. In other areas which have high moisture loads, provision should also be made for controlled ventilation – ideally this would be closed when the heating is operating but would allow fresh air to enter the house at other times. The installation of insulation also helps to control internal condensation;
- Special care needs to be taken in houses which have gas heating, especially houses which have unflued gas heating[69], houses which have gas room, space or decorative heaters which are installed into chimneys, and houses which have flued gas heaters with an open flue. All unflued gas heaters require a certain amount of fixed ventilation to expel the products of combustion from the home. In some cases, where gas heaters are installed in a chimney and the chimney deteriorates, or open flued heaters where the flue has deteriorated, the products of the combustion (including carbon monoxide) can enter the room air – carbon monoxide is a poisonous and odourless gas, and this can be fatal. It is recommended to have gas heating appliances serviced regularly and to also have carbon monoxide levels checked at this time[70].

In all houses it is important to have controlled ventilation – operable windows, vents, exhaust fans or hoods – which allow adequate ventilation to be provided where and when it is required. Heat recovery ventilation systems are also available. In winter, these draw in fresh air from outside and pass the air through a heat exchanger before it is blown inside the home. An equivalent volume of warm room air is expelled through the heat exchanger where it warms the incoming fresh air. These systems allow higher ventilation rates with reduced heat losses, but operate on electricity. The use of these systems has not been modelled for this study.

68 The air leakage rate measured at a pressure differential of 50 Pascals was divided by the volume of the house (m3) to calculate the air leakage rate expressed as Air Changes per Hour (ACH@50) – this represents the number of times the total volume of air in the house changes in one hour at a 50 Pascals pressure differential. The ACH@50 result was divided by 20 to estimate the air change rate (ACH) at atmospheric pressure.

69 These heaters do not have a flue and expel the products of combustion – mainly water vapour, carbon dioxide and nitrogen oxides – into the room air.

70 For further information refer to Energy Safe Victoria's website: http://www.esv.vic.gov.au/For-Consumers/Gas-and-electrical-safety-in-the-home/Gas-safety-in-the-home

TABLE A2: MODELLED IMPACT OF THE COMPREHENSIVE DRAUGHT SEALING

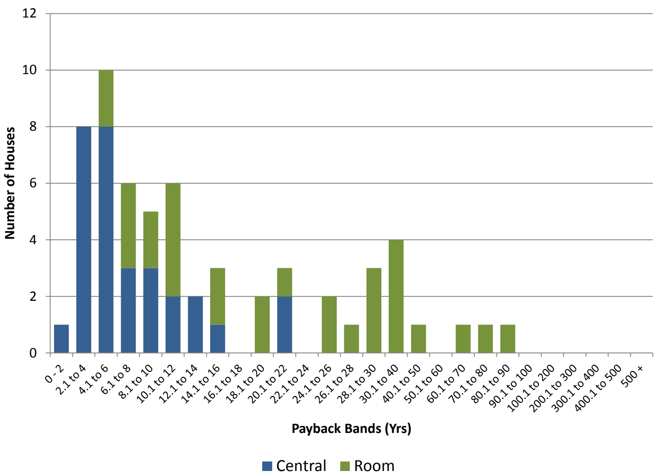
		Energy Saving (MJ/Yr)						
House No.	Heating Type	Gas	Elec	Total Energy	GHG Saving (kg/Yr)	Cost ($)	Saving ($/Yr)	Payback (Yrs)
C3	Gas central	26,317	1,121	27,437	1,797	$1,104.3	$547.7	2.0
B1	Gas central	32,726	681	33,407	2,018	$1,285.0	$625.7	2.1
A13	Gas central	19,266	385	19,651	1,183	$795.0	$367.1	2.2
C1	Gas central	25,809	516	26,325	1,585	$1,276.0	$491.8	2.6
B8	Gas central	25,337	511	25,849	1,557	$1,380.0	$483.2	2.9
B13	Gas central	27,089	554	27,643	1,502	$1,495.0	$517.1	2.9
A10	Gas central	7,406	115	7,521	445	$458.0	$138.5	3.3
A3	Gas central	16,677	334	17,011	1,024	$1,098.0	$317.8	3.5
C2	Gas central	14,401	288	14,689	884	$1,083.0	$274.4	3.9
B4	Gas central	19,178	436	19,614	1,194	$1,630.0	$369.5	4.4
B11	Gas central	16,947	339	17,286	1,041	$1,440.0	$322.9	4.5
B18	Gas central	12,707	285	12,991	790	$1,111.0	$244.5	4.5
C11	Gas central	23,475	469	23,944	1,442	$2,077.5	$447.3	4.6
B6	Gas central	14,812	346	15,157	925	$1,455.0	$286.1	5.1
B10	Gas room	13,307	129	13,436	775	$1,280.0	$242.9	5.3
B17	Gas room	12,659	273	12,932	783	$1,300.0	$242.8	5.4
C6	Gas central	10,068	224	10,292	625	$1,046.0	$193.6	5.4
A11	Gas central	4,503	120	4,623	286	$505.0	$88.1	5.7
C13	Gas central	7,253	244	7,497	475	$844.0	$145.9	5.8
B9	Gas central	12,271	249	12,520	755	$1,450.0	$234.1	6.2
B3	Gas central	12,237	340	12,577	780	$1,655.0	$240.6	6.9
C7	Gas room	6,937	69	7,006	405	$872.5	$126.8	6.9
B20	Gas central	4,759	95	4,854	292	$659.0	$90.7	7.3
B16	Electric panel heater	0	1,606	1,606	488	$926.0	$124.9	7.4
A4	Gas room	7,579	98	7,677	449	$1,050.0	$140.2	7.5
A1	Gas central	6,891	152	7,043	427	$1,090.0	$132.4	8.2
B24	Gas room	3,830	38	3,869	224	$591.0	$70.0	8.4
B28	Gas room	5,101	51	5,152	298	$849.0	$93.2	9.1
C4	Gas central	5,335	144	5,479	339	$994.0	$104.6	9.5

House No.	Heating Type	Energy Saving (MJ/Yr) Gas	Elec	Total Energy	GHG Saving (kg/Yr)	Cost ($)	Saving ($/Yr)	Payback (Yrs)
B2	Gas central	6,854	137	6,991	421	$1,310.0	$130.6	10.0
A8	Gas central	4,032	81	4,112	248	$776.0	$76.8	10.1
A9	Gas room	2,305	22	2,327	134	$426.0	$42.0	10.1
A5	Gas room	2,898	29	2,927	169	$578.0	$53.0	10.9
B26	Gas room	4,437	44	4,481	259	$927.0	$81.1	11.4
A12	Gas room	2,948	29	2,977	172	$620.0	$53.9	11.5
C15	Gas central	5,963	119	6,082	366	$1,359.5	$113.6	12.0
B21	Gas central	4,669	93	4,762	287	$1,197.0	$89.0	13.5
B15	Gas central	2,490	62	2,552	142	$653.0	$48.4	13.5
B5	Gas central	4,171	88	4,259	258	$1,150.0	$79.8	14.4
C12	Electric panel heater	0	745	745	226	$848.5	$58.0	14.6
B29	Gas room	4,227	78	4,304	257	$1,260.0	$80.0	15.7
C9	Gas room	6,178	82	6,260	367	$2,089.5	$114.5	18.3
C10	Room RAC	0	619	619	188	$940.0	$48.2	19.5
B30	Gas room	3,376	-167	3,209	136	$929.0	$46.1	20.1
B23	Gas central	3,694	74	3,768	227	$1,471.0	$70.4	20.9
B12	Gas central	2,491	50	2,542	153	$1,035.0	$47.5	21.8
A6	Room RAC	0	238	238	72	$456.0	$18.5	24.6
B22	Gas room	1,451	15	1,465	85	$668.0	$26.5	25.2
A14	Gas room	881	0	880	49	$404.0	$15.4	26.3
B25	Gas room	1,468	15	1,483	86	$761.0	$26.8	28.4
A2	Gas room	1,224	12	1,237	71	$635.0	$22.4	28.4
B14	Room RAC	0	340	340	103	$795.0	$26.5	30.0
A15	Gas room	1,280	17	1,297	76	$747.0	$23.7	31.5
B27	Gas room	2,012	40	2,052	123	$1,212.0	$38.3	31.6
B19	Gas room	2,006	20	2,026	117	$1,272.0	$36.7	34.7
B7	Gas room	898	9	907	52	$776.0	$16.4	47.3
C5	Gas room	1,312	13	1,326	77	$1,575.0	$24.0	65.7
C14	Room RAC	0	148	148	45	$890.0	$11.5	77.4

House No.	Heating Type	Energy Saving (MJ/Yr) Gas	Elec	Total Energy	GHG Saving (kg/Yr)	Cost ($)	Saving ($/Yr)	Payback (Yrs)
A7	Gas room	416	4	420	24	$630.0	$7.6	82.9
Av. – Across Stock		**7,809**	**221**	**8,030**	**496**	**$1,019.8**	**$153.9**	**6.6**
Av. - When Implemented		**7,942**	**225**	**8,167**	**505**	**$1,037.1**	**$156.5**	**6.6**
Av. - Central Heating		12,661	288	12,949	782	$1,162.7	$244.0	4.8
Av. - Room Heating		3,060	159	3,219	218	$907.2	$65.9	13.8

Comprehensive draught sealing was found to be applicable to the majority (59 or 98.3%) of the OGA study houses. The initial House Energy Rating modelling found and average increase of 0.69 stars in the houses to which this measure was applied, and an average impact across the stock of houses of 0.69 stars. The modelled energy saving impact of the comprehensive air sealing upgrade measure for the individual houses is shown in Table A2. The average impact across the stock of 60 houses, as well as the average impact for the houses in which this measure was modelled, and the average impact for the houses with central heating and room heating are shown. The average impact across the stock is similar to the average impact in the houses in which this measure was implemented, and this is because it was found to be applicable to the majority of houses.

FIGURE A3: DISTRIBUTION OF PAYBACKS FOR COMPREHENSIVE DRAUGHT SEALING

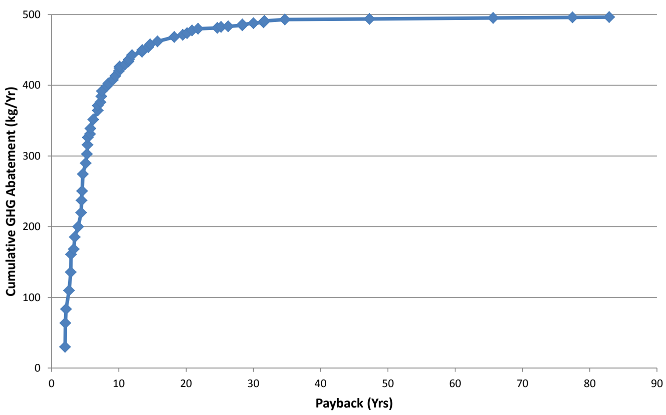


The stock average payback for the measure was 6.6 years, the second lowest of all of the building shell upgrade measures, and the median of the individual paybacks was 10.0 years. As expected, the energy savings for those houses with a central heating system were much larger than for those houses with only room heating, and the payback period correspondingly lower. Figure A3 shows the distribution of the paybacks for the individual houses, broken down by the type of heating system. Figure A4 provides the cumulative greenhouse abatement curve for the measure. Around 55% of the total savings are achieved for a payback of less than 5 years and around 85% of the savings are achieved for a payback of less than 10 years, with most of this corresponding to the centrally heated houses.

It is important to note that the cost estimates for the air sealing are based on commercial rates. It would be possible for much of this air sealing work to be undertaken as a DIY project by the households, substantially reducing the cost. Based on the comprehensive retrofit trials that Sustainability Victoria has undertaken as part of the Residential Energy Efficiency Retrofit Trials we estimate that the labour cost accounts for around 57% of the overall cost of commercial draught sealing upgrades. If undertaken as a DIY project we estimate that the average cost would be reduced to $446 in houses where draught sealing is undertaken and the average payback would be reduced to 2.8 years.

A range of simple draught sealing measures are eligible for a subsidy under Victoria's Energy Saver Incentive scheme, including draught sealing external doors, weather stripping windows, sealing wall vents and the chimneys of open fireplaces, and installing dampers on ceiling exhaust fans. These subsidies substantially reduce the costs of draught sealing existing houses.

FIGURE A4: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE FOR COMPREHENSIVE DRAUGHT SEALING



Sealing the wall cavity

This measure can be applied to houses which have a suspended timber floor where the wall cavity connects the sub-floor space and the attic (or roof space), creating a pathway for air to flow. For the OGA study modelling it was assumed that the wall cavity was sealed off at the top of the wall by the installation of a batten to stop air flow through the wall cavity. If the sub-floor space is easily accessible it may be possible and cheaper to seal the wall cavity by installing expanding foam at the base of the wall; however, this may not allow any water that penetrates the bricks to drain through weep holes.

Sealing the wall cavity will produce the greatest energy saving benefits where:

- The air leakage rate of the sub-floor space is highest, e.g. where the sub-floor space is not well enclosed;
- Where there is little resistance to heat flow through the floor, for example where the house has a bare timber floor.

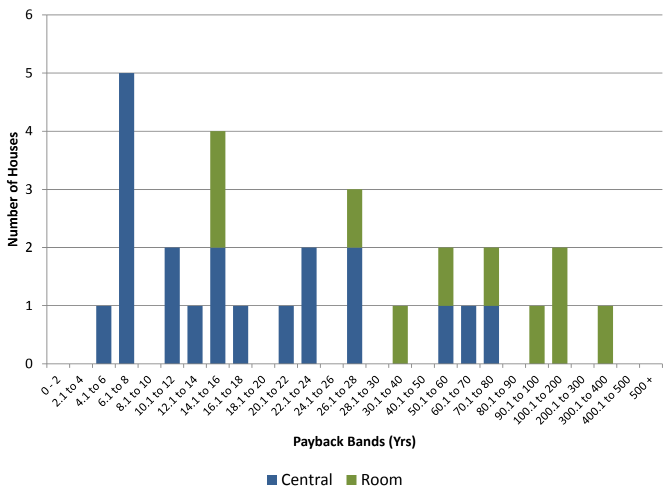
TABLE A3: MODELLED IMPACT OF THE CAVITY WALL SEALING UPGRADE

		Energy Saving (MJ/Yr)						
House No.	Heating Type	Gas	Elec	Total	GHG Saving (kg/Yr)	Cost ($)	Saving ($/Yr)	Payback (Yrs)
C11	Gas central	5,208	104	5,312	320	$462.9	$99.2	4.7
A11	Gas central	5,403	118	5,521	335	$667.4	$103.7	6.4
B13	Gas central	4,954	101	5,054	275	$619.3	$94.5	6.6
A1	Gas central	5,430	128	5,557	339	$727.2	$104.9	6.9
B8	Gas central	3,453	70	3,524	212	$488.0	$65.9	7.4
A3	Gas central	3,836	77	3,913	236	$575.4	$73.1	7.9
A10	Gas central	2,455	66	2,521	156	$522.2	$48.1	10.9
C13	Gas central	2,632	45	2,678	159	$550.6	$49.6	11.1
C15	Gas central	2,258	45	2,303	139	$590.6	$43.0	13.7
B10	Gas room	1,489	15	1,505	87	$383.7	$27.3	14.1
C2	Gas central	1,892	38	1,930	116	$512.0	$36.1	14.2
A4	Gas room	1,836	20	1,856	108	$486.0	$33.7	14.4
B1	Gas central	2,038	34	2,072	123	$613.0	$38.3	16.0
B18	Gas central	1,539	37	1,576	96	$500.8	$29.8	16.8
A13	Gas central	1,537	31	1,568	94	$627.1	$29.3	21.4
B2	Gas central	1,217	24	1,241	75	$514.1	$23.2	22.2
B4	Gas central	1,391	28	1,419	85	$612.6	$26.5	23.1
B9	Gas central	1,190	25	1,215	73	$595.3	$22.7	26.2
B3	Gas central	1,312	37	1,349	84	$686.2	$25.8	26.6
C9	Gas room	695	11	707	42	$354.2	$13.1	27.1
C10	RAC	0	138	138	42	$367.3	$10.8	34.1
B29	Gas room	476	19	494	32	$491.5	$9.8	50.3
B23	Gas central	711	14	725	44	$798.9	$13.6	58.9

		Energy Saving (MJ/Yr)						
House No.	Heating Type	Gas	Elec	Total	GHG Saving (kg/Yr)	Cost ($)	Saving ($/Yr)	Payback (Yrs)
B6	Gas central	397	6	403	24	$488.3	$7.4	66.0
B15	Gas central	411	13	424	24	$580.6	$8.2	70.7
A15	Gas room	312	3	315	18	$443.8	$5.7	77.9
C14	RAC	0	77	77	23	$577.4	$6.0	96.5
B14	RAC	0	55	55	17	$445.8	$4.3	104.6
A6	RAC	0	44	44	14	$384.4	$3.5	111.1
A7	Gas room	96	1	97	6	$557.1	$1.8	317.2
Av. – Across Stock		**903**	**24**	**927**	**57**	**$270.4**	**$17.6**	**15.3**
Av. - When Implemented		**1,806**	**48**	**1,853**	**113**	**$540.8**	**$35.3**	**15.3**
Av. - Central Heating		2,463	52	2,515	150	$586.6	$47.2	12.4
Av. - Room Heating		490	38	529	39	$449.1	$11.6	38.8

Sealing the wall cavity was found to be possible for 30 (50%) of the OGA study houses. The initial House Energy Rating modelling found and average increase of 0.16 stars in the houses to which this measure was applied, or an average impact across the stock of houses of 0.08 stars. The modelled energy saving impact of the cavity wall sealing upgrade measure for the individual houses is shown in Table A3. The average impact across the stock of 60 houses, as well as the average impact for the houses in which this measure was modelled, and the average impact for the houses with central heating and room heating are shown. The average impact across the stock is somewhat lower than the average impact in the houses in which this measure was implemented, because this measure was found to be applicable in only half of the houses.

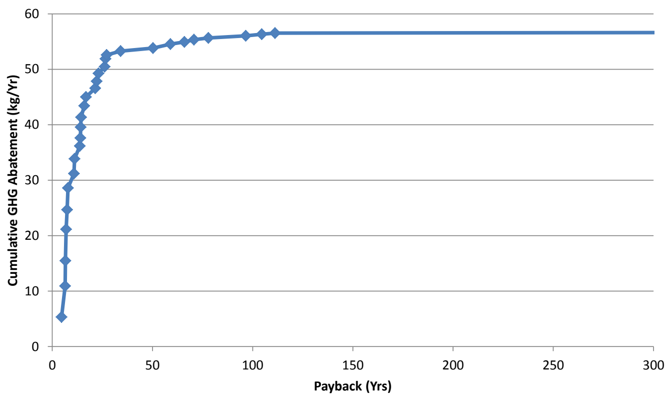
FIGURE A5: DISTRIBUTION OF PAYBACKS FOR CAVITY WALL SEALING UPGRADE



The stock average payback for the measure was 15.3 years and the median of the individual paybacks was 21.8 years. As expected, the energy savings for those houses with a central heating system were much larger than for those houses with only room heating, and the payback period correspondingly lower. Figure A5 shows the distribution of the paybacks for the individual houses, broken down by the type of heating system. Figure A6 provides the cumulative greenhouse abatement curve for the measure. Around 50% of the total savings are achieved for a payback of less than 10 years and around 80% of the savings are achieved for a payback of less than 20 years, with most of this corresponding to the centrally heated houses.

It may be possible to undertake this measure as a DIY project, reducing costs and the payback period, although given the nature of the work required it is probably best left to somebody with professional building experience.

FIGURE A6: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE FOR CAVITY WALL SEALING UPGRADE



Reduce sub-floor ventilation

This measure applies only to those houses with a suspended timber floor. Heat losses through a suspended floor are greatest when the ventilation rates under the floor are high, e.g. where there are large gaps in the walls enclosing (or surrounding) the sub-floor space or no sub-floor walls at all. Most houses in the OGA study sample with a suspended floor had a sub-floor space which was partially enclosed, and it was deemed that only 13 of the 60 houses would benefit from further sealing to reduce sub-floor ventilation. In houses with accessible sub-floor spaces it is generally more effective to insulate the floor. Indeed, reducing the sub-floor ventilation and sealing the wall cavity would usually only be considered in existing homes where the sub floor space is inaccessible and thus under-floor insulation is not possible.

TABLE A4: MODELLED IMPACT OF REDUCING SUB-FLOOR VENTILATION

		Energy Saving (MJ/Yr)						
House No.	Heating Type	Gas	Elec	Total	GHG Saving (kg/Yr)	Cost ($)	Saving ($/Yr)	Payback (Yrs)
C1	Gas central	12,847	257	13,104	789	$704.4	$244.8	2.9
A9	Gas room	2,926	61	2,988	181	$255.1	$56.0	4.6
A2	Gas room	1,426	14	1,440	83	$282.7	$26.1	10.8
A8	Gas central	3,556	71	3,627	218	$813.9	$67.8	12.0
C7	Gas room	1,984	20	2,004	116	$603.9	$36.3	16.7
A14	Gas room	656	96	752	65	$329.9	$18.9	17.4
A5	Gas room	991	10	1,001	58	$323.4	$18.1	17.9
C6	Gas central	3,057	52	3,109	185	$1,152.1	$57.5	20.0
B11	Gas central	4,184	84	4,268	257	$1,726.6	$79.7	21.7
B22	Gas room	1,187	12	1,199	69	$1,059.8	$21.7	48.9
B25	Gas room	1,096	11	1,107	64	$1,091.7	$20.0	54.5
B17	Gas room	724	-3	721	39	$705.9	$12.4	56.9
B26	Gas room	731	7	738	43	$950.0	$13.4	71.1
Av. – Across Stock		**589**	**12**	**601**	**36**	**$166.7**	**$11.2**	**14.9**
Av. - When Implemented		**2,720**	**53**	**2,774**	**167**	**$769.2**	**$51.7**	**14.9**
Av. - Central Heating		5,911	116	6,027	362	$1,099.3	$112.5	9.8
Av. - Room Heating		1,302	25	1,328	80	$622.5	$24.8	25.1

Reducing the sub-floor ventilation was found to be possible for 13 (21.7%) of the OGA study houses. The initial House Energy Rating modelling found and average increase of 0.26 stars in the houses to which this measure was applied, or an average impact across the stock of houses of 0.06 stars. The modelled energy saving impact of the reducing sub-floor ventilation measure for the individual houses is shown in Table A4. The average impact across the stock of 60 houses, as well as the average impact for the houses in which this measure was modelled, and the average impact for the houses with central heating and room heating are shown.

The average impact across the stock is much lower than the average impact in the houses in which this measure was implemented, because this measure was found to be applicable in only around 1 out of 5 houses.

FIGURE A7: DISTRIBUTION OF PAYBACKS FOR REDUCING SUB-FLOOR VENTILATION

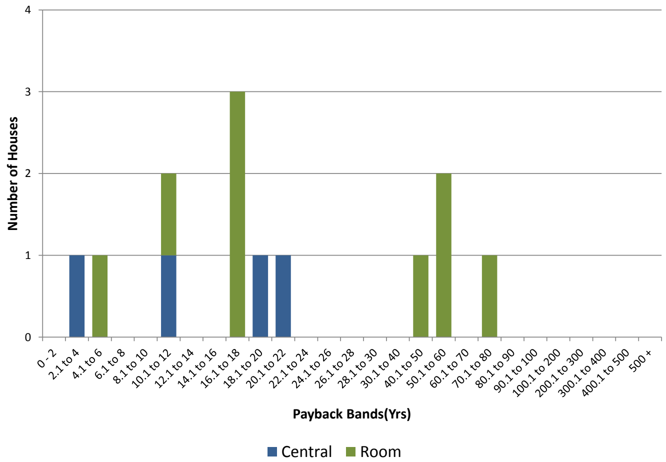
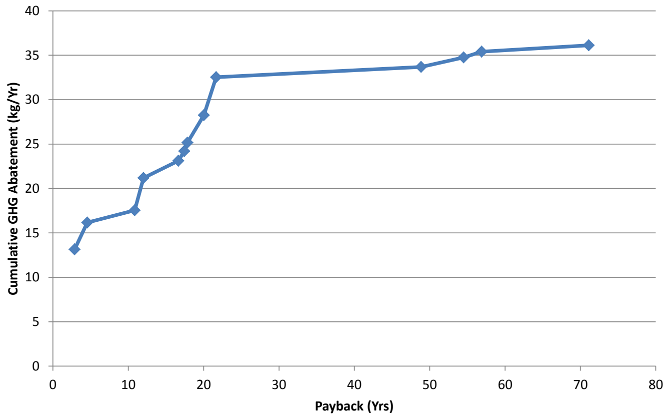


FIGURE A8: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE FOR REDUCING SUB-FLOOR VENTILATION



The stock average payback for the measure was 14.9 years and the median of the individual paybacks was 17.9 years. As expected, the energy savings for those houses with a central heating system were much larger than for those houses with only room heating, and the payback period correspondingly lower. Figure A7 shows the distribution of the paybacks for the individual houses, broken down by the type of heating system. Figure A8 provides the cumulative greenhouse abatement curve for the measure. Around 48% of the total savings are achieved for a payback of less than 10 years and around 80% of the savings are achieved for a payback of less than 20 years, with most of this corresponding to the houses with room heating.

It would be possible to implement this measure as a DIY project, thereby reducing costs and the payback period. We do not have a detailed breakdown of the labour and materials costs for this measure. However, assuming that it is similar to draught sealing and that labour costs account for around 50% to 60% of the total commercial costs, we estimate that the payback could be reduced to around 6.0 to 7.4 years if undertaken as a DIY project.

Underfloor insulation

The installation of R1.5 batt-type insulation was modelled for those houses with an uninsulated suspended timber floor and an accessible under-floor space. Underfloor insulation is likely to be most effective where:

- The sub-floor space is unenclosed or highly ventilated, as in these cases heat losses through the floor will be highest in winter;
- Houses are centrally heated so insulation benefits most rooms;
- Heating is used fairly frequently.

Under-floor insulation should be used with some caution. While it will give both comfort and energy saving benefits in winter, it often leads to some reduction in thermal comfort during the summer months as the underfloor space acts to help cool the house during the night time. The installation of underfloor insulation will reduce this cooling effect. It is important that underfloor insulation is used as part of a comprehensive approach which includes insulation to the ceiling (and ideally walls), good external shading, and the use of adequate ventilation via windows (or other controlled ventilation) during night time hours.

TABLE A5: MODELLED IMPACT OF INSTALLING UNDERFLOOR INSULATION

		Energy Saving (MJ/Yr)						
House No.	Heating Type	Gas	Elec	Total	GHG Saving (kg/Yr)	Cost ($)	Saving ($/Yr)	Payback (Yrs)
B10	Gas room	6,847	59	6,906	397	$1,279.0	$124.4	10.3
B8	Gas central	10,211	191	10,402	623	$2,298.4	$193.5	11.9
B4	Gas central	7,453	56	7,509	429	$1,621.0	$134.8	12.0
A4	Gas room	7,394	55	7,449	426	$1,687.8	$133.7	12.6
C3	Gas central	10,439	88	10,527	564	$2,501.2	$189.5	13.2
B11	Gas central	10,180	204	10,384	625	$2,778.3	$194.0	14.3
C13	Gas central	7,911	-59	7,852	420	$1,962.1	$133.9	14.7
C6	Gas central	5,525	9	5,534	308	$1,830.3	$97.4	18.8
B1	Gas central	6,140	111	6,252	374	$2,300.4	$116.1	19.8
B9	Gas central	5,316	102	5,418	325	$2,224.8	$101.0	22.0
C2	Gas central	3,749	75	3,824	230	$1,822.6	$71.4	25.5
B6	Gas central	2,292	26	2,319	135	$1,218.0	$42.2	28.9
A1	Gas central	5,167	66	5,232	306	$3,042.3	$95.5	31.8
A11	Gas central	6,331	-414	5,917	225	$2,599.6	$78.6	33.1
B20	Gas central	1,741	35	1,776	107	$1,212.2	$33.2	36.5
B18	Gas central	2,461	-8	2,454	134	$1,766.9	$42.5	41.6
B22	Gas room	1,808	18	1,826	106	$1,536.3	$33.0	46.5
C7	Gas room	1,094	11	1,105	64	$1,377.1	$20.0	68.9
B2	Gas central	1,255	25	1,280	77	$1,844.8	$23.9	77.2
B29	Gas room	624	32	656	44	$1,152.0	$13.4	85.0
B3	Gas central	1,886	-89	1,797	77	$2,603.2	$26.1	99.8
B15	Gas central	727	-15	712	36	$1,421.8	$11.6	122.7
B25	Gas room	571	6	577	33	$1,637.1	$11.7	139.6
B23	Gas central	1,042	21	1,063	64	$3,363.1	$19.9	169.3

House No.	Heating Type	Energy Saving (MJ/Yr) Gas	Elec	Total	GHG Saving (kg/Yr)	Cost ($)	Saving ($/Yr)	Payback (Yrs)
Av. – Across Stock		**1,803**	**10**	**1,813**	**102**	**$784.7**	**$32.4**	**24.3**
Av. - When Implemented		**4,507**	**25**	**4,532**	**255**	**$1,961.7**	**$80.9**	**24.3**
Av. - Central Heating		4,990	24	5,014	281	2,133.9	$89.2	23.9
Av. - Room Heating		3,056	30	3,087	178	$1,444.9	$56.0	25.8

Installing under-floor insulation was found to be possible for 24 (40.0%) of the OGA study houses. The initial House Energy Rating modelling found an average increase of 0.34 stars in the houses to which this measure was applied, or an average impact across the stock of houses of 0.15 stars. The modelled energy saving impact of the under-floor insulation measure for the individual houses is shown in Table A5. The average impact across the stock of 60 houses, as well as the average impact for the houses in which this measure was modelled, and the average impact for the houses with central heating and room heating are shown. The average impact across the stock is lower than the average impact in the houses in which this measure was implemented, because this measure was found to be applicable in only around 2 out of 5 houses.

The stock average payback for the measure was 24.3 years and the median of the individual paybacks was 30.4 years. The energy savings for those houses with a central heating system were larger than for those houses with only room heating, and the payback period lower. Figure A9 shows the distribution of the paybacks for the individual houses, broken down by the type of heating system. Figure A10 provides the cumulative greenhouse abatement curve for the measure. Around 6.5% of the total savings are achieved for a payback of less than 10 years, and around 68% of the savings are achieved for a payback of less than 20 years, with most of this corresponding to the centrally heated houses.

Underfloor insulation could be undertaken as a DIY project, reducing the cost to the householder, although great care needs to be taken due to the safety issues involved in working in confined spaces where electrical wiring, gas and water pipes may be present. Based on the current retail price of glasswool underfloor insulation rolls[71] if undertaken as a DIY project the average cost when implemented would be reduced to around $905 and the paybacks would be reduced to 11.2 years.

Underfloor insulation is eligible for a subsidy through Victoria's Energy Saver Incentive scheme, although this currently requires insulation with a minimum winter R-value of R2.5 to be installed, and while the energy savings would be larger this is more expensive than the R1.5 insulation on which our costings are based. Under the Energy Saver Incentive the products are installed at commercial rates, less the subsidy which results from the energy efficiency certificates which are created.

FIGURE A9: DISTRIBUTION OF PAYBACKS FOR INSTALLING UNDERFLOOR INSULATION

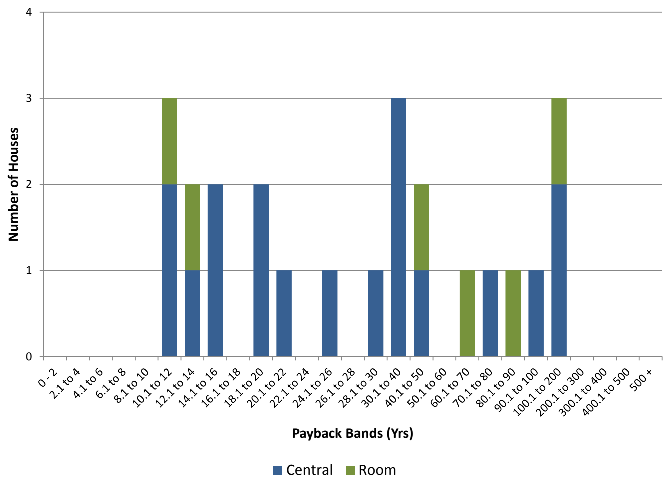
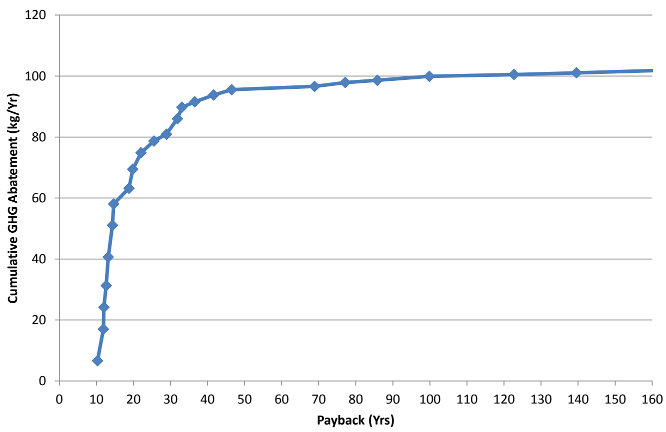


FIGURE A10: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE FOR INSTALLING UNDERFLOOR INSULATION



71 In November 2015 the typical retail price for a roll of R1.7 glasswool underfloor insulation was $7.08 per square metre of area covered. We have increased this to $8.00 per square meter to account for the additional materials required to hold the insulation in place.

Cavity wall insulation

While mandatory insulation regulations required the use of a certain minimum level of wall insulation in houses with brick-veneer and weatherboard construction between 1991 and 2005, there were no requirements for wall insulation to be installed into newly constructed houses prior to this, and many pre-1991 Victorian houses have no wall insulation. When existing houses are renovated the existing internal wall linings can be removed[72], creating the opportunity to install batt-type insulation before wall linings are replaced. However, this is not possible for many existing houses.

Special insulation products are available which can be pumped into the wall cavity of existing houses. The main pump-in cavity wall insulation products currently available on the Victorian market are hydrophobic[73] granulated rockwool and foam insulation. The insulation can be installed in a variety of ways, depending on the wall and roof construction: from above by removing sections of the roof above the wall cavity (easiest for tiled roofs); by removing bricks or drilling through the mortar between bricks for brick veneer or cavity brick walls; by removing boards or drilling through the boards for weatherboard walls; or by drilling through the internal wall linings. Bricks are replaced or holes filled after the installation of the insulation, usually with minimum visual impact.

The installation of wall insulation can significantly reduce heat losses through the walls in winter and also heat gains through the walls in summer. In addition to saving energy this improves the thermal comfort of houses in both summer and winter.

72 Upstairs extensions to existing houses often require some internal wall linings to be removed so that structural bracing can be installed in ground floor walls. This reduces the cost of retrofitting wall insulation to these walls.

73 It is important that the insulation products are hydrophobic, or water repelling, so that they will not wick water across the wall cavity when installed.

It will also keep the interior of the external walls warmer in winter, significantly reducing any condensation or mould problems associated with the walls [HEAT 2010].

Before insulation is installed the house's wiring must be checked by an electrician to ensure that it will still comply with electrical safety regulations after any insulation electrical wiring located in the walls is covered with insulation. In some cases this may require modifications to the electrical wiring [HEAT 2010].

TABLE A6: TYPICAL R-VALUES ACHIEVED BY CAVITY WALL INSULATION

Wall Type	Uninsulated R-vale	Insulated R-value
Cavity (double) brick	R0.5	R1.5
Brick veneer	R0.4	R3.4
Weatherboard	R0.5	R2.5

For the OGA study we modelled the installation of hydrophobic granulated rockwool in those houses with uninsulated cavity walls[74]. The insulation level achieved depends on the width of the cavity. Typical insulation values which can be achieved for different wall construction types are shown in Table A6 above [HEAT 2010].

74 Other options are available, including removing the external cladding for weatherboard houses or removing the internal wall linings for both weatherboard and brick-veneer houses and installing insulation batts, however both of these methods are more invasive that pump-in cavity wall insulation. Weatherboard houses could have the external cladding removed and replaced with a rendered EPS foam board, and houses with solid concrete walls can also have a rendered EPS foam board fixed to the outside of the wall.

TABLE A7: MODELLED IMPACT OF INSTALLING CAVITY WALL INSULATION

		Energy Saving (MJ/Yr)						
House No.	Heating Type	Gas	Elec	Total	GHG Saving (kg/Yr)	Cost ($)	Saving ($/Yr)	Payback (Yrs)
C11	Gas central	14,657	293	14,950	900	$3,748.0	$279.3	13.4
A3	Gas central	19,035	381	19,416	1,169	$4,937.5	$362.7	13.6
A11	Gas central	15,487	316	15,803	953	$4,118.3	$295.6	13.9
C1	Gas central	23,040	461	23,501	1,415	$7,074.5	$439.0	16.1
B18	Gas central	9,699	240	9,939	610	$3,414.6	$188.4	18.1
B2	Gas central	5,713	114	5,828	351	$2,061.2	$108.9	18.9
B11	Gas central	11,446	229	11,675	703	$4,186.2	$218.1	19.2
A4	Gas room	7,596	103	7,698	451	$2,771.1	$140.9	19.7
B1	Gas central	8,925	204	9,129	556	$3,451.5	$172.1	20.1
C6	Gas central	9,689	277	9,966	620	$4,067.9	$191.1	21.3

		Energy Saving (MJ/Yr)						
House No.	Heating Type	Gas	Elec	Total	GHG Saving (kg/Yr)	Cost ($)	Saving ($/Yr)	Payback (Yrs)
A10	Gas central	8,338	172	8,510	514	$3,681.9	$159.3	23.1
C13	Gas central	6,804	235	7,038	448	$3,229.2	$137.3	23.5
B9	Gas central	6,338	134	6,472	391	$2,990.4	$121.3	24.7
A1	Gas central	7,921	204	8,125	500	$3,903.6	$154.5	25.3
A13	Gas central	18,030	361	18,390	1,107	$8,739.5	$343.6	25.4
B13	Gas central (hydronic)	9,944	203	10,147	612	$4,930.5	$189.8	26.0
B4	Gas central	6,729	176	6,904	426	$3,471.8	$131.4	26.4
B28	Gas room	5,345	53	5,399	312	$2,646.9	$97.7	27.1
C2	Gas central	6,083	122	6,205	374	$3,193.8	$115.9	27.6
B20	Gas central	6,912	138	7,050	424	$3,770.4	$131.7	28.6
B22	Gas room	8,776	88	8,864	512	$4,717.0	$160.4	29.4
C7	Gas room	6,320	63	6,384	369	$3,454.9	$115.5	29.9
B17	Gas room	7,483	184	7,667	470	$4,593.4	$145.2	31.6
B10	Gas room	3,714	50	3,763	221	$2,555.6	$68.9	37.1
C15	Gas central	5,046	101	5,146	310	$3,741.9	$96.1	38.9
A2	Gas room	5,072	51	5,123	296	$3,643.7	$92.7	39.3
A12	Gas room	6,123	61	6,184	340	$4,685.6	$111.9	41.9
B6	Gas central	9,862	237	10,099	618	$8,015.9	$191.0	42.0
A9	Gas room	7,347	364	7,711	517	$6,629.3	$156.9	42.3
B3	Gas central	2,765	93	2,858	181	$2,432.7	$55.6	43.7
A8	Gas central	7,904	158	8,062	485	$7,763.1	$150.6	51.5
B19	Gas room	3,435	34	3,469	200	$3,267.4	$62.8	52.0
B26	Gas room	2,393	24	2,417	140	$2,855.1	$43.7	65.3
B21	Gas central	3,247	65	3,312	199	$4,369.1	$61.9	70.6
C3	Gas central	3,834	122	3,956	249	$6,167.2	$76.6	80.5
C9	Gas room	2,344	38	2,382	141	$3,554.5	$44.0	80.8
B29	Gas room	1,689	78	1,766	117	$3,043.9	$35.6	85.5
B15	Gas central	1,336	51	1,387	89	$2,407.9	$27.3	88.1
A5	Gas room	2,755	28	2,782	161	$4,469.6	$50.4	88.8

		Energy Saving (MJ/Yr)						
House No.	**Heating Type**	**Gas**	**Elec**	**Total**	**GHG Saving (kg/Yr)**	**Cost ($)**	**Saving ($/Yr)**	**Payback (Yrs)**
C10	Room RAC	0	146	146	44	$1,021.2	$11.3	90.2
B5	Gas central	3,432	77	3,509	213	$6,475.1	$66.0	98.1
B12	Gas central	1,917	40	1,957	118	$3,681.2	$36.6	100.5
B24	Gas room	2,408	24	2,432	141	$5,448.1	$44.0	123.8
B23	Gas central	2,219	44	2,264	136	$5,375.4	$42.3	127.1
A14	Gas room	1,391	134	1,525	118	$5,055.7	$34.7	145.6
C5	Gas room	1,432	14	1,447	84	$4,144.8	$26.2	158.3
A15	Gas room	1,969	52	2,021	125	$6,297.4	$38.5	163.5
C4	Gas central	1,124	27	1,151	70	$3,827.4	$21.7	176.0
A6	Room RAC	0	211	211	64	$2,968.9	$16.4	180.6
B16	Electric panel heater	0	200	200	61	$2,862.6	$15.6	183.7
B7	Gas room	1,175	12	1,186	69	$5,153.5	$21.5	240.0
C12	Electric panel heater	0	245	245	74	$4,674.6	$19.0	245.7
C14	Room RAC	0	119	119	36	$2,823.3	$9.3	305.2
B14	Room RAC	0	125	125	38	$3,372.3	$9.7	347.0
C8	Gas room	379	-12	367	17	$2,027.6	$5.7	357.7
A7	Gas room	165	2	167	10	$2,959.1	$3.0	980.6
B30	Gas room	168	16	184	14	$6,598.4	$4.2	1,587.7
Av. – Across Stock		**5,283**	**130**	**5,412**	**331**	**$3,958.7**	**$102.5**	**38.6**
Av. - When Implemented		**5,561**	**136**	**5,697**	**349**	**$4,167.1**	**$107.9**	**38.6**
Av. - Central Heating		8,189	182	8,371	508	$4,456.1	$157.4	28.3
Av. - Room Heating		2,839	89	2,928	184	$3,867.7	$56.6	68.3

Pump-in wall insulation was found to be applicable to 57 (95.0%) of the OGA study houses. The initial House Energy Rating modelling found and average increase of 1.02 stars in the houses to which this measure was applied, or an average impact across the stock of houses of 0.97 stars. The modelled energy saving impact of the wall insulation measure for the individual houses is shown in Table A7. The average impact across the stock of 60 houses, as well as the average impact for the houses in which this measure was modelled, and the average impact for the houses with central heating and room heating are shown. The average impact across the stock is around the same as the average impact in the houses in which this measure was implemented, because this measure was found to be applicable to the majority of the existing houses.

The stock average payback for the measure was 38.6 years and the median of the individual paybacks was 42.3 years. The energy savings for those houses with a central heating system were much larger than for those houses with only room heating, and the payback period correspondingly lower.

At an average cost of slightly over $4,000 per house, the installation of cavity wall insulation is considerably more expensive than the installation of ceiling insulation. One reason for this seems to be the fairly undeveloped state of the cavity wall insulation industry in Victoria, and in Australia more generally. Only a small number of companies currently provide this service in Victoria, and installation rates are believed to be quite low. An increased volume of work and increased competition might lead to lower costs, and make this measure more cost effective. As the majority of houses constructed prior to 1991 have uninsulated walls[75], there is considerable potential for energy savings across the Victorian housing stock if this measure was taken up more widely.

Figure A11 shows the distribution of the paybacks for the individual houses, broken down by the type of heating system. Figure A12 provides the cumulative greenhouse abatement curve for the measure. In all cases the payback was found to be above 13 years. Around 35% of the total savings are achieved for a payback of less than 20 years, and around 69% of the savings are achieved for a payback of less than 30 years, with most of this corresponding to the centrally heated houses. The paybacks for the houses with room heating were all above 19 years.

FIGURE A11: DISTRIBUTION OF PAYBACKS FOR INSTALLING CAVITY WALL INSULATION

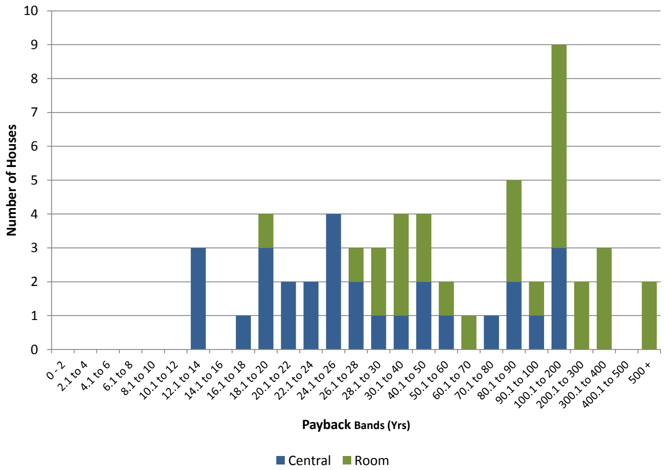
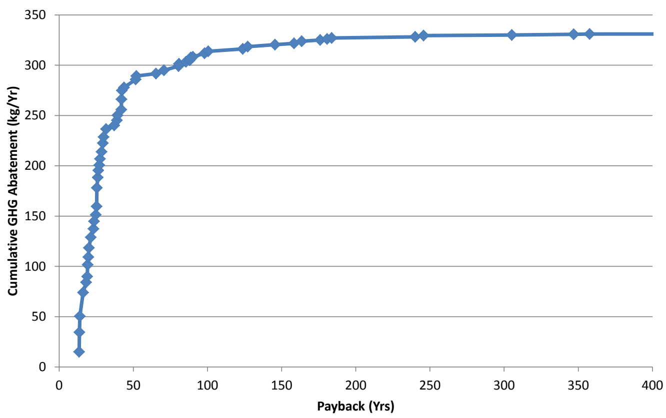


FIGURE A12: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE FOR CAVITY WALL INSULATION



75 ABS data [ABS 2011b] suggests that around 31% of all Victorian houses in 2011 had wall insulation – most of this is likely to be due to houses constructed since 1991.

Ceiling insulation (Difficult)

This measure involved the installation of ceiling insulation onto an un-insulated ceiling where installation was not straightforward. This generally covered the insulation of flat roofs or cathedral ceilings, which is more difficult and expensive than insulating an attic roof space because the roof sheet (metal or tiles) must be removed to install the insulation. In addition to this, there may be limited space available to install the insulation, meaning that a lower R-value is installed compared to an attic roof.

TABLE A8: MODELLED IMPACT OF INSTALLING CEILING INSULATION (DIFFICULT)

		Energy Saving (MJ/Yr)						
House No.	Heating Type	Gas	Elec	Total	GHG Saving (kg/Yr)	Cost ($)	Saving ($/Yr)	Payback (Yrs)
B17	Gas room	40,349	1,399	41,748	2,658	$2,128.1	$815.0	2.6
C6	Gas central	17,934	571	18,505	1,166	$1,465.5	$358.2	4.1
B1	Gas central	10,765	231	10,996	666	$854.2	$206.4	4.1
A9	Gas room	7,482	343	7,825	518	$699.4	$157.6	4.4
C15	Gas central	3,830	77	3,906	235	$722.5	$73.0	9.9
B6	Gas central	1,855	46	1,901	117	$486.2	$36.0	13.5
B30	Gas room	3,290	877	4,167	448	$1,990.4	$125.8	15.8
C9	Gas room	2,226	26	2,252	131	$690.9	$41.0	16.9
B29	Gas room	1,243	34	1,277	79	$417.2	$24.4	17.1
A8	Gas central	2,073	41	2,115	127	$694.7	$39.5	17.6
A2	Gas room	2,000	20	2,020	117	$667.5	$36.6	18.3
C8	Gas room	2,728	205	2,932	213	$1,519.5	$63.7	23.9
A5	Gas room	1,257	13	1,269	73	$691.0	$23.0	30.1
B22	Gas room	367	4	371	21	$399.0	$6.7	59.4
B16	Electric panel heater	0	135	135	41	$846.0	$10.5	80.8
A14	Gas room	206	11	217	15	$482.5	$4.5	107.7
C12	Electric panel heater	0	53	53	16	$495.6	$4.1	120.6
B24	Gas room	130	1	132	8	$653.7	$2.4	274.3
B20	Gas central	58	1	60	4	$384.9	$1.1	346.1
A7	Gas room	18	0	18	1	$403.5	$0.3	1244.6
Av. – Across Stock		**1,630**	**68**	**1,698**	**111**	**$278.2**	**$33.8**	**8.2**
Av. – When Implemented		**4,891**	**204**	**5,095**	**333**	**$834.6**	**$101.5**	**8.2**
Av. - Central Heating		6,086	161	6,247	386	$768.0	$119.0	6.5
Av. - Room Heating		4,378	223	4,601	310	$863.2	$94.0	9.2

The ceiling insulation (difficult) measure was found to be applicable to 20 (33.3%) of the OGA study houses. The initial House Energy Rating modelling found and average increase of 1.14 stars in the houses to which this measure was applied, or an average impact across the stock of houses of 0.38 stars. The modelled energy saving impact of the ceiling insulation (difficult) measure for the individual houses is shown in Table A8. The average impact across the stock of 60 houses, as well as the average impact for the houses in which this measure was modelled, and the average impact for the houses with central heating and room heating are shown. The average impact across the stock is lower than the average impact in the houses in which this measure was implemented, because this measure was found to be applicable in only around one-third of the houses.

The stock average payback for the measure was 8.2 years and the median of the individual paybacks was 17.9 years. The average energy savings for those houses with a central heating system were larger than for those houses with only room heating[76], and the payback period lower. Figure A13 shows the distribution of the paybacks for the individual houses, broken down by the type of heating system. Figure A14 provides the cumulative greenhouse abatement curve for the measure. Around 79% of the total savings are achieved for a payback of less than 10 years, and around 94% of the savings are achieved for a payback of less than 20 years, with most of this corresponding to the centrally heated houses.

While it might be possible to undertake this measure as a DIY project, the more complicated nature of the work – which requires the removal of the roof cladding – means that it is probably best left to a professional insulation installer or builder.

FIGURE A13: DISTRIBUTION OF PAYBACKS FOR CEILING INSULATION (DIFFICULT)

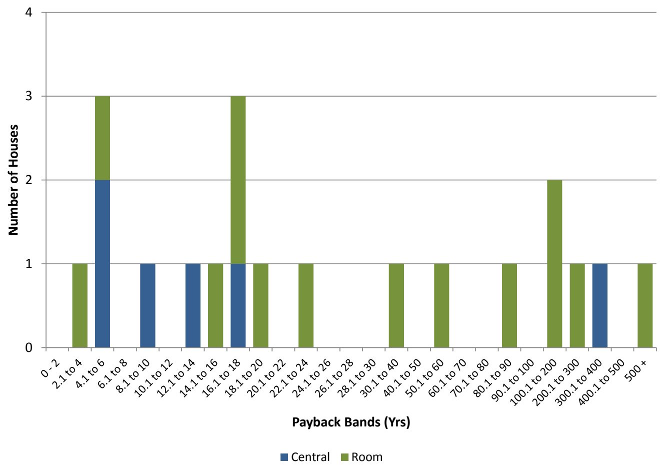
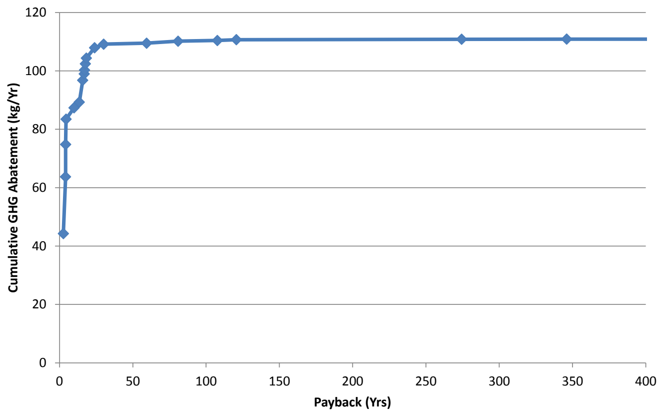


FIGURE A14: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE FOR CEILING INSULATION (DIFFICULT)



76 For this measure the largest energy saving and lowest payback was actually achieved house B17 which had gas room heating. However, this house had two gas room heaters and a high annual gas usage for heating (around 82,000 MJ/Yr).

Ceiling insulation (top-up)

Ceiling insulation top-ups with R3.5 insulation were modelled for those houses which initially had a relatively low level of insulation (R2.0 or less) and where the roof space was easily accessible. For the modelling it was necessary to assume a uniform initial R-value for the insulation (i.e. R1.0, R2.0, etc). In practice it is likely that where a ceiling is poorly insulated the R-value of the insulation could vary across the ceiling. This might be the case were older loose-fill cellulose fibre insulation has compacted or been blown around, or where downlights have been installed or other electrical work undertaken in the roof space and the existing insulation dislodged[77]. This may mean that in practice the savings which can be achieved from ceiling insulation top-ups are greater than suggested by the modelling undertaken for the OGA study.

77 Where 12 volt halogen downlights, or other downlights, are installed certain mandatory minimum safety clearances must be maintained around the light fitting. It is common practice for either a whole insulation batt or half a batt to be removed to create this clearance, and this will significantly degrade the performance of the insulation.

TABLE A9: MODELLED IMPACT OF CEILING INSULATION TOP-UP

		Energy Saving (MJ/Yr)						
House No.	Heating Type	Gas	Elec	Total	GHG Saving (kg/Yr)	Cost ($)	Saving ($/Yr)	Payback (Yrs)
C11	Gas central	5,667	113	5,780	348	$730.0	$108.0	6.8
A1	Gas central	11,463	311	11,775	729	$1,525.5	$224.8	6.8
B4	Gas central	4,643	129	4,773	296	$934.1	$91.3	10.2
B11	Gas central	3,204	64	3,268	197	$763.6	$61.0	12.5
C3	Gas central	451	9	460	28	$121.0	$8.6	14.1
C2	Gas central	2,471	49	2,520	152	$724.8	$47.1	15.4
A4	Gas room	2,134	45	2,178	132	$671.2	$40.8	16.4
C1	Gas central	3,736	75	3,811	229	$1,259.0	$71.2	17.7
B9	Gas central	2,501	51	2,552	154	$884.8	$47.7	18.5
B2	Gas central	1,521	30	1,551	93	$660.3	$29.0	22.8
B27	Gas room	2,356	62	2,417	149	$1,116.6	$46.0	24.3
B21	Gas central	3,206	64	3,270	197	$1,820.2	$61.1	29.8
B3	Gas central	1,001	33	1,033	65	$603.7	$20.0	30.1
B28	Gas room	839	8	847	49	$509.0	$15.3	33.2
A13	Gas central	1,214	24	1,238	75	$772.4	$23.1	33.4
B26	Gas room	667	7	674	39	$486.2	$12.2	39.9
C4	Gas central	549	29	578	39	$531.8	$11.9	44.8
C10	Reverse-cycle room air conditioner	0	130	130	39	$459.2	$10.1	45.5
C9	Gas room	685	17	701	43	$658.5	$13.3	49.6
B12	Gas central	961	20	981	59	$964.3	$18.4	52.4
A2	Gas room	355	4	358	21	$369.1	$6.5	56.9
B23	Gas central	708	14	722	43	$1,203.7	$13.5	89.2
B15	Gas central	287	8	295	18	$508.9	$5.7	89.7
B24	Gas room	232	2	234	14	$448.7	$4.8	94.3

		Energy Saving (MJ/Yr)						
House No.	Heating Type	Gas	Elec	Total	GHG Saving (kg/Yr)	Cost ($)	Saving ($/Yr)	Payback (Yrs)
B29	Gas room	258	1	259	15	$557.1	$4.6	121.3
B7	Gas room	102	1	103	6	$836.7	$1.9	447.0
Av. – Across Stock		**853**	**22**	**875**	**54**	**$335.3**	**$16.6**	**20.2**
Av. - When Implemented		**1,970**	**50**	**2,020**	**124**	**$773.9**	**$38.4**	**20.2**
Av. - Central Heating		2,724	64	2,788	170	$875.5	$52.7	16.6
Av. - Room Heating		763	28	790	51	$611.2	$15.5	39.3

The ceiling insulation top-up measure was found to be applicable to 26 (43.3%) of the OGA study houses, although as with the ceiling insulation (easy) measure the insulation top-up was not necessarily applied to all areas of the ceiling. Many older houses have had newer extensions and additions, and the newer areas of the ceiling might be well insulated while the older areas are poorly insulated. The initial House Energy Rating modelling found and average increase of 0.39 stars in the houses to which this measure was applied, or an average impact across the stock of houses of 0.17 stars. The modelled energy saving impact of the ceiling insulation top-up measure for the individual houses is shown in Table A9. The average impact across the stock of 60 houses, as well as the average impact for the houses in which this measure was modelled, and the average impact for the houses with central heating and room heating are shown. The average impact across the stock is lower than the average impact in the houses in which this measure was implemented, because this measure was found to be applicable in around 2 out of 5 houses.

The stock average payback for the measure was 20.2 years – as expected this was significantly longer than the payback for insulating and uninsulated ceiling – as once a ceiling is insulated with at least R2.0 insulation, the saving achieved from additional insulation is quite modest. The median of the individual paybacks was 31.7 years. The energy savings for those houses with a central heating system were larger than for those houses with only room heating, and the payback period lower. Figure A15 shows the distribution of the paybacks for the individual houses, broken down by the type of heating system. Figure A16 provides the cumulative greenhouse abatement curve for the measure. In all cases, the payback for the ceiling insulation top-up measure was found to be greater than 6 years. Around one-third of the total savings are achieved for a payback of less than 10 years, around 70% for a payback of less than 20 years, and around 85% for a payback of less than 30 years, with most of this corresponding to the centrally heated houses.

Ceiling insulation top-ups could be undertaken as a DIY project, reducing the cost to the householder, although great care needs to be taken due to the safety issues involved in working at heights in confined spaces where electrical wiring is present, and adequate safety clearances must be left around hot equipment such as downlights and ceiling exhaust fans. Based on the current retail price of glasswool insulation batts[78] if undertaken as a DIY project the average cost when implemented would be reduced to $484 and the paybacks would be reduced to only 12.6 years.

FIGURE A15: DISTRIBUTION OF PAYBACKS FOR CEILING INSULATION TOP-UP

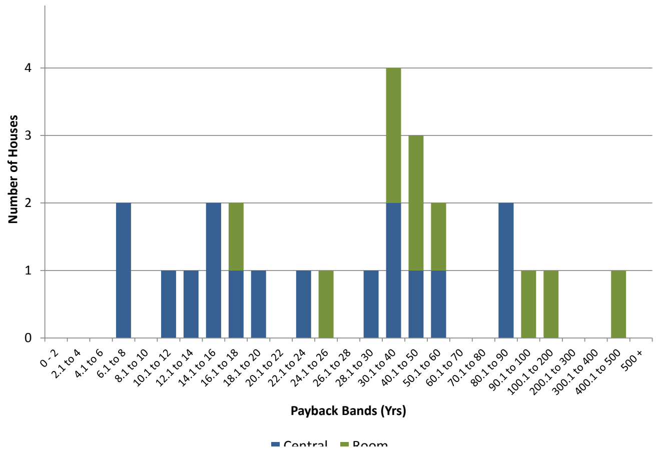
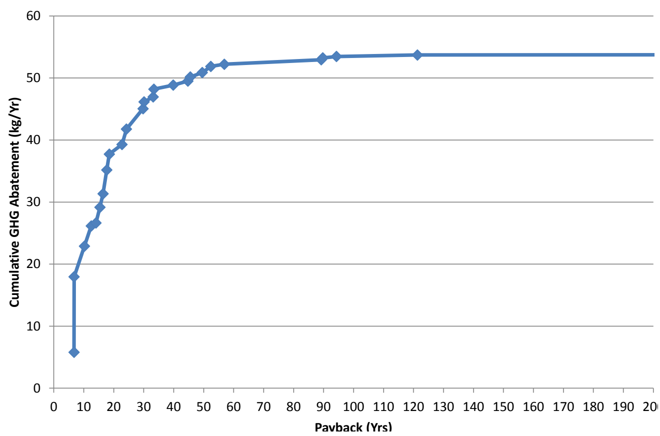


FIGURE A16: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE FOR CEILING INSULATION TOP-UP



78 In November 2015 the average retail price for a pack of R3.5 glasswool batts was around $6.00 per square metre of area covered.

Double-Glazing

For the OGA study we modelled the replacement of existing single-glazed windows with new double-glazed windows. This is the most expensive option for significantly improving the overall thermal performance of the windows in an existing house, and cheaper options are available. Secondary glazing systems are available which allow either an extra pane of glass or Perspex to be installed in the existing window frame in conjunction with the existing pane of glass to create a double glazing effect, at around 50% to 60% lower cost than new double-glazing. The lowest cost option is to install special heat shrink films on the existing window frame to create a still air gap between the existing pane of glass and the film. This can either be installed commercially or as a DIY project at a significantly lower cost – in this case we estimate a basic materials cost of around \$10 per m^2 and a commercial installation cost of around \$50 per m^2 [79]. While this gives a much lower installation cost, it may not be applicable to all windows in the house, and is likely to have a shorter lifetime than either secondary glazing or full double glazing.

In the case of both secondary glazing and heat shrink window films, the thermal performance of the windows is likely to be lower than for new double-glazed windows as the existing window frames will be used and it may not be possible to achieve an optimal clearance between the two panes of 'glazing'.

79 Cost estimates are from Sustainability Victoria's window film retrofit trial undertaken during 2013.

TABLE A10: MODELLED IMPACT OF DOUBLE-GLAZED WINDOW RETROFIT

		Energy Saving (MJ/Yr)						
House No.	Heating Type	Gas	Elec	Total	Saving (kg/Yr)	Cost ($)	Saving ($/Yr)	Payback (Yrs)
B10	Gas room	3,083	27	3,110	179	$4,489.2	$56.1	80.1
A5	Gas room	605	6	611	35	$1,399.2	$11.1	126.6
B27	Gas room	3,443	60	3,503	209	$8,456.4	$64.9	130.3
A4	Gas room	3,484	53	3,537	209	$9,880.0	$65.1	151.8
C3	Gas central	10,863	480	11,343	747	$36,313.8	$227.4	159.7
A10	Gas central	4,410	121	4,531	281	$14,289.1	$86.6	165.0
C5	Gas room	2,869	29	2,897	167	$8,694.2	$52.4	165.8
B18	Gas central	4,528	107	4,635	283	$15,428.0	$87.6	176.2
A13	Gas central	5,699	114	5,813	350	$19,346.9	$108.6	178.1
C1	Gas central	5,343	107	5,450	328	$18,913.8	$101.8	185.8
C6	Gas central	4,165	69	4,234	252	$14,575.4	$78.3	186.2
B7	Gas room	1,904	19	1,923	111	$6,519.2	$34.8	187.3
A11	Gas central	2,537	127	2,664	179	$10,445.2	$54.3	192.5
A2	Gas room	1,612	16	1,628	94	$5,703.8	$29.5	193.6
C11	Gas central	6,329	127	6,455	389	$23,833.5	$120.6	197.6
B26	Gas room	1,031	10	1,041	60	$3,758.4	$18.8	199.5
B4	Gas central	3,327	62	3,389	203	$13,084.8	$63.0	207.6
B19	Gas room	1,576	16	1,591	92	$6,159.6	$28.8	213.9
B28	Gas room	2,215	22	2,238	129	$8,665.2	$40.5	214.0
A12	Gas room	1,267	13	1,280	74	$4,988.2	$23.2	215.4
B8	Gas central	5,224	108	5,332	322	$22,199.5	$99.8	222.5

		Energy Saving (MJ/Yr)						
House No.	Heating Type	Gas	Elec	Total	Saving (kg/Yr)	Cost ($)	Saving ($/Yr)	Payback (Yrs)
B21	Gas central	4,688	94	4,782	288	$20,392.8	$89.3	228.3
A14	Gas room	430	95	525	53	$3,460.7	$14.9	232.6
C13	Gas central	3,077	134	3,211	211	$15,312.0	$64.3	238.3
A1	Gas central	3,918	102	4,021	248	$18,554.2	$76.5	242.4
B2	Gas central	3,090	62	3,151	190	$14,668.2	$58.9	249.1
B30	Gas room	528	75	603	52	$3,805.4	$15.1	252.3
B11	Gas central	2,229	45	2,274	137	$10,741.6	$42.5	252.9
C2	Gas central	4,348	87	4,435	267	$21,013.4	$82.9	253.6
C7	Gas room	1,830	18	1,848	107	$9,210.4	$33.4	275.4
A3	Gas central	2,753	55	2,808	169	$14,636.1	$52.5	279.0
B13	Gas central (hydronic)	3,217	67	3,284	198	$19,145.8	$61.5	311.3
B9	Gas central	3,948	85	4,032	244	$24,325.2	$75.7	321.4
B1	Gas central	3,722	78	3,800	230	$23,072.4	$71.2	324.1
C12	Electric panel heater	0	132	132	40	$3,422.0	$10.3	333.4
B6	Gas central	3,893	99	3,992	245	$25,351.8	$75.8	334.3
B12	Gas central	1,394	30	1,424	86	$9,024.8	$26.8	337.3
A9	Gas room	1,501	37	1,538	94	$10,073.3	$29.2	345.4
B20	Gas central	763	15	778	47	$5,411.4	$14.5	372.4
B22	Gas room	867	9	876	51	$6,631.7	$15.9	418.4
B17	Gas room	2,695	88	2,782	176	$23,676.8	$54.0	438.6
A8	Gas central	1,111	22	1,133	68	$9,824.9	$21.2	464.0
C9	Gas room	1,123	11	1,134	66	$9,952.8	$20.5	484.9
C4	Gas central	1,246	48	1,294	84	$14,323.1	$25.5	560.7
B16	Electric panel heater	0	194	194	59	$8,665.2	$15.1	575.4
A15	Gas room	847	88	934	73	$13,338.0	$21.6	616.6
C10	Room RAC	0	116	116	35	$5,568.0	$9.0	619.0
B3	Gas central	1,808	70	1,877	121	$23,126.9	$37.1	624.2
B15	Gas central	891	30	920	58	$11,170.8	$17.9	624.4
B25	Gas room	554	6	560	32	$6,496.0	$10.1	641.0

		Energy Saving (MJ/Yr)						
House No.	Heating Type	Gas	Elec	Total	Saving (kg/Yr)	Cost ($)	Saving ($/Yr)	Payback (Yrs)
B5	Gas central	1,625	43	1,668	103	$22,762.7	$31.8	716.6
C15	Gas central	1,366	27	1,394	84	$18,909.2	$26.0	726.3
B14	Room RAC	0	45	45	14	$2,923.2	$3.5	836.6
B29	Gas room	711	16	727	44	$11,742.7	$13.7	859.8
B24	Gas room	191	2	193	11	$3,207.4	$3.5	916.9
B23	Gas central	296	6	302	18	$5,448.5	$5.6	965.3
A6	Room RAC	0	21	21	6	$1,717.8	$1.6	1053.7
C8	Gas room	442	11	453	28	$9,367.0	$8.6	1093.3
A7	Gas room	91	1	92	5	$2,046.2	$1.7	1224.6
C14	Room RAC	0	94	94	28	$9,048.0	$7.3	1241.4
Av. – Across Stock		**2,278**	**66**	**2,344**	**146**	**$12,145.2**	**$45.0**	**270.0**
Av. - When Implemented		**2,278**	**66**	**2,344**	**146**	**$12,145.2**	**$45.0**	**270.0**
Av. - Central Heating		3,394	87	3,481	214	$17,188.2	$66.2	259.7
Av. - Room Heating		1,163	44	1,208	78	$7,102.2	$23.8	298.4

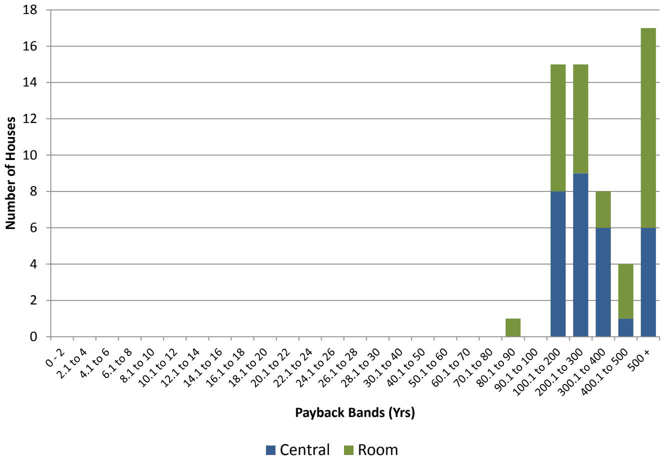
The double-glazing window retrofit was modelled for all 60 of the OGA study houses. The initial House Energy Rating modelling found and average increase of 0.63 stars, both in the houses to which this measure was applied and across the stock of houses. The modelled energy saving impact of the double-glazing retrofit for the individual houses is shown in Table A10. The average impact across the stock of 60 houses, as well as the average impact for the houses in which this measure was modelled, and the average impact for the houses with central heating and room heating are shown.

The stock average payback for the measure was 270 years, reflecting the high cost of replacing existing windows with new double-glazed windows. Much of this additional cost is for the labour to remove the existing windows and to install the double-glazed windows. This suggests a stock average payback of around 135 to 162 years if secondary glazing was used rather than new double glazing, and a payback of around 28 years if a heat shrink window film product was installed commercially (less if installed as a DIY project).

It may also be that the modelling tools used to estimate the energy savings achieved from the installation of double-glazing are under-estimating the extent of the energy saving achieved. Bare single-glazed windows have fairly high conducted heat losses in winter when heating is operating (and conducted heat gains in summer when cooling is operating), and also reduce occupant comfort as heat is radiated from the body to the cold window surfaces in winter (and radiated to the body from hot window surfaces in summer). The addition of the extra pane of 'glazing' reduces this effect and increases occupant comfort, as the internal pane of glass is warmer in winter and cooler in summer. This may mean that occupants feel comfortable at a lower thermostat setting on the heating in winter and a higher thermostat setting on the cooling in summer, reducing energy consumption further than suggested by the modelling.

It is also important to note that the paybacks for installing double-glazing are significantly lower when existing single-glazed windows have deteriorated and must be replaced, are being replaced anyway as part of a renovation or refurbishment, or are new windows installed in an addition or new house. In this case there is no additional removal and installation cost, and the cost differential only relates to the windows themselves.

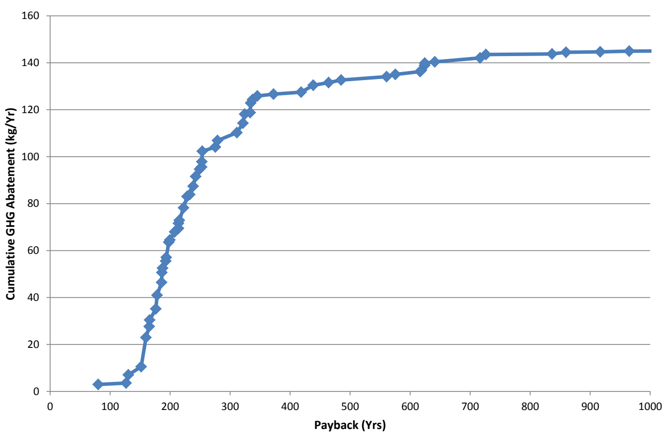
FIGURE A17: DISTRIBUTION OF PAYBACKS FOR DOUBLE-GLAZED WINDOW RETROFIT



The median of the individual paybacks was 277 years. The energy savings for those houses with a central heating system were larger than for those houses with only room heating, and the payback period lower. Figure A17 shows the distribution of the paybacks for the individual houses, broken down by the type of heating system. Figure A18 provides the cumulative greenhouse abatement curve for the measure. In all cases, the payback for the double-glazed window retrofit measure was found to be greater than 80 years. Around 7% of the total savings are achieved for a payback of less than 150 years, and around 65% of the savings are achieved for a payback of less than 200 years.

The replacement of an existing window with a new double glazed window, or the installation of secondary glazing or a heat shrink window film are eligible to receive a subsidy through the Victorian Energy Saver Incentive scheme. This would reduce the cost of these upgrades to some extent, although they are likely to still have fairly long payback periods.

FIGURE A18: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE FOR DOUBLE-GLAZED WINDOW RETROFIT



Drapes and pelmets

The installation of a thick, close-fitting drape housed in a boxed pelmet was modelled for those windows in the OGA study houses which were located in heated areas and which did not have adequate protection. If properly installed, drapes and pelmets can achieve a similar effect to double-glazing when they are closed as well as providing some internal shading during summer months. The main difference is that the effect of double-glazing is constant, while the effect of drapes and pelmets relies on them being used effectively by house occupants.

The installation of drapes and pelmets (and in some cases just the installation of pelmets to an existing drape) was found to be applicable to some extent in all 60 of the OGA study houses. The initial House Energy Rating modelling found an average increase of 0.53 stars, both in the houses to which this measure was applied and across the stock of houses. The modelled energy saving impact of the drapes and pelmets measure for the individual houses is shown in Table A11. The average impact across the stock of 60 houses, as well as the average impact for the houses in which this measure was modelled, and the average impact for the houses with central heating and room heating are shown.

TABLE A11: MODELLED IMPACT OF INSTALLING DRAPES AND PELMETS

		Energy Saving (MJ/Yr)						
House No.	Heating Type	Gas	Elec	Total	GHG Saving (kg/Yr)	Cost ($)	Saving ($/Yr)	Payback (Yrs)
A4	Gas room	3,268	36	3,304	192	$370.0	$60.0	6.2
B8	Gas central	3,471	71	3,542	214	$751.4	$66.2	11.3
B10	Gas room	4,029	40	4,068	235	$980.4	$73.6	13.3
C2	Gas central	4,155	83	4,238	255	$1,289.1	$79.2	16.3
C3	Gas central	6,929	174	7,103	436	$2,229.8	$134.8	16.5
C10	Room RAC	0	46	46	14	$83.5	$3.6	23.2
B27	Gas room	4,440	32	4,472	255	$1,986.2	$80.2	24.8
A5	Gas room	749	7	757	44	$343.7	$13.7	25.1
C5	Gas room	2,801	28	2,829	164	$1,604.0	$51.2	31.3
B19	Gas room	1,786	18	1,804	104	$1,060.9	$32.6	32.5
B4	Gas central	3,707	120	3,827	242	$2,505.3	$74.2	33.8
C1	Gas central	5,544	111	5,655	340	$3,575.5	$105.6	33.8
B26	Gas room	1,454	15	1,469	85	$903.6	$26.6	34.0
B7	Gas room	2,615	26	2,641	153	$1,674.7	$47.8	35.0
A12	Gas room	698	7	705	41	$455.7	$12.8	35.7
A10	Gas central	3,023	59	3,082	185	$2,180.4	$57.5	37.9
B18	Gas central	3,447	69	3,515	212	$2,655.0	$65.6	40.4
C6	Gas central	2,804	38	2,842	167	$2,225.6	$52.0	42.8
A13	Gas central	5,714	114	5,829	351	$4,669.0	$108.9	42.9
A1	Gas central	4,898	121	5,019	308	$4,109.2	$95.1	43.2
B11	Gas central	2,748	55	2,803	169	$2,390.8	$52.4	45.7
B21	Gas central	3,521	70	3,591	216	$3,081.9	$67.1	45.9
B30	Gas room	974	19	993	60	$851.5	$18.5	46.0

		Energy Saving (MJ/Yr)						
House No.	Heating Type	Gas	Elec	Total	GHG Saving (kg/Yr)	Cost ($)	Saving ($/Yr)	Payback (Yrs)
A2	Gas room	1,363	14	1,376	80	$1,165.4	$24.9	46.8
C11	Gas central	6,653	133	6,786	409	$6,006.1	$126.8	47.4
B12	Gas central	1,830	35	1,865	112	$1,697.7	$34.8	48.8
B2	Gas central	1,825	37	1,862	112	$1,739.1	$34.8	50.0
C13	Gas central	3,629	78	3,707	225	$3,563.5	$69.6	51.2
A14	Gas room	497	52	549	43	$659.1	$12.8	51.7
B9	Gas central	5,005	101	5,107	308	$4,987.9	$95.5	52.2
A3	Gas central	3,309	66	3,375	203	$3,066.6	$63.1	53.0
B28	Gas room	1,999	20	2,019	117	$1,960.8	$36.5	53.7
B13	Gas central (hydronic)	3,637	73	3,710	223	$3,950.3	$69.3	57.0
C12	Electric panel heater	0	196	196	60	$870.9	$15.3	57.0
B1	Gas central	3,861	80	3,940	238	$4,265.2	$73.8	57.8
C15	Gas central	674	13	687	41	$773.5	$12.8	60.2
C7	Gas room	1,755	18	1,772	102	$2,046.4	$32.1	63.8
A8	Gas central	1,432	29	1,460	88	$1,760.7	$27.3	64.5
C9	Gas room	1,612	16	1,628	94	$1,987.3	$29.5	67.4
B17	Gas room	3,921	53	3,975	233	$4,967.6	$72.8	68.3
B29	Gas room	727	8	735	43	$934.2	$13.3	70.0
B3	Gas central	1,829	45	1,874	115	$2,506.6	$35.5	70.6
B23	Gas central	467	9	477	29	$681.0	$8.9	76.5
B20	Gas central	910	18	929	56	$1,327.2	$17.3	76.5
B6	Gas central	3,398	105	3,503	220	$5,263.4	$67.6	77.8
A11	Gas central	1,869	43	1,912	117	$2,926.6	$36.1	81.1
B16	Electric panel heater	0	314	314	95	$1,986.2	$24.4	81.3
A9	Gas room	1,039	35	1,074	68	$1,832.6	$20.9	87.7
C4	Gas central	1,314	24	1,338	80	$2,300.5	$24.8	92.6
B24	Gas room	366	4	370	21	$626.1	$6.7	93.6
B25	Gas room	756	8	764	44	$1,321.0	$13.8	95.6

		Energy Saving (MJ/Yr)						
House No.	Heating Type	Gas	Elec	Total	GHG Saving (kg/Yr)	Cost ($)	Saving ($/Yr)	Payback (Yrs)
A15	Gas room	956	27	983	61	$2,069.2	$18.9	109.8
B15	Gas central	900	21	921	56	$2,232.0	$17.4	128.3
B22	Gas room	677	7	683	39	$1,629.3	$12.4	131.7
B5	Gas central	829	13	843	50	$2,114.8	$15.5	136.1
C8	Gas room	523	13	536	33	$1,431.7	$10.2	140.9
A7	Gas room	184	2	186	11	$492.0	$3.4	146.1
B14	Room RAC	0	48	48	15	$681.9	$3.7	181.9
A6	Room RAC	0	23	23	7	$327.2	$1.8	185.3
C14	Room RAC	0	116	116	35	$2,027.4	$9.0	224.9
Av. – Across Stock		**2,209**	**54**	**2,263**	**139**	**$2,035.9**	**$42.9**	**47.5**
Av. - When Implemented		**2,209**	**54**	**2,263**	**139**	**$2,035.9**	**$42.9**	**47.5**
Av. - Central Heating		3,111	67	3,178	192	$2,760.9	$59.7	46.3
Av. - Room Heating		1,306	42	1,348	85	$1,311.0	$26.1	50.2

The stock average payback for the measure was 47.5 years and the median of the individual paybacks was 52.6 years. It is important to understand that these paybacks are based on the commercial costs of installing the curtains and drapes. If the curtains and drapes were installed as part of a DIY project, both the costs and the payback period would be lower. As with the other building shell measures the energy savings for those houses with a central heating system were larger than for those houses with only room heating, and the payback period lower. Figure A19 shows the distribution of the paybacks for the individual houses, broken down by the type of heating system. Figure A20 provides the cumulative greenhouse abatement curve for the measure. Around 3% of the total savings are achieved for a payback of less than 10 years, and around 16% of the savings are achieved for a payback of less than 20 years.

FIGURE A19: DISTRIBUTION OF PAYBACKS FOR DRAPES AND PELMETS

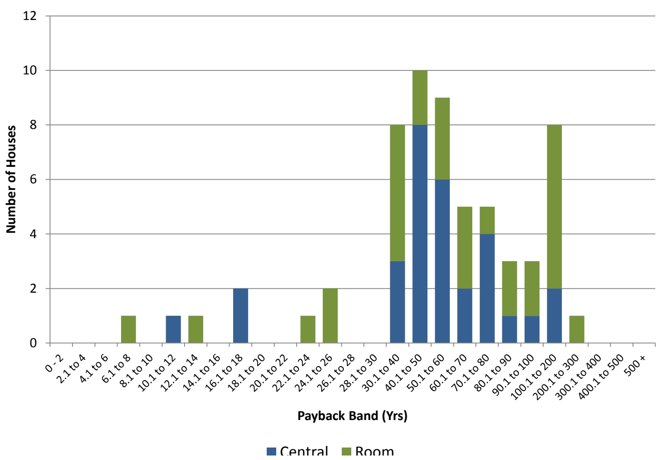
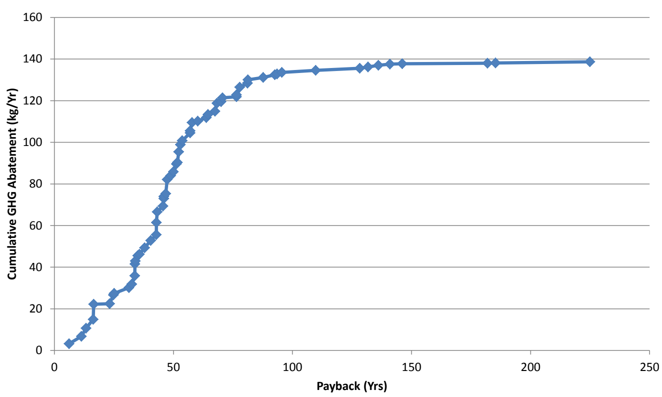


FIGURE A20: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE FOR DRAPES AND PELMETS



External shading

The installation of external awnings was modelled for those houses with inadequately shaded east, west or north facing windows for areas of the house which were cooled with either a refrigerative air conditioner or an evaporative cooler. In some cases the modelling results suggested no net reduction in cooling load or cooling energy consumption, and these houses were eliminated from the analysis. The installation costs were based on the commercial costs for installing awnings, and lower costs could be achieved if the awnings were installed as part of a DIY project.

The modelled savings for the OGA study houses were somewhat lower than expected. There may be several reasons for this:

- Many houses already had adequately shaded windows, and upgrades were only modelled for those windows in areas with cooling which were considered to be inadequately shaded – the savings would have been larger if all windows in the houses were unshaded;
- Modelling of cooling energy use was based on the reported operating times and thermostat settings of the house occupants, and may not have been reliable as cooling is used fairly infrequently in most parts of Victoria during summer and the severity of summers varies quite widely from year to year;
- The energy savings achieved for those houses with evaporative cooling are quite low, due to the inherently low energy consumption of this type of cooling;
- The FirstRate5 program may underestimate the cooling load for the houses.

The use of external shading to improve occupant comfort and reduce energy consumption will be greatest in those houses which have large, unshaded west, east or north facing windows, and in which refrigerative air conditioning is used frequently and for long hours during the summer months.

TABLE A12: MODELLED IMPACT OF INSTALLING EXTERNAL SHADING

		Energy Saving (MJ/Yr)						
House No.	Cooling Type	Gas	Elec	Total	GHG Saving (kg/Yr)	Cost ($)	Saving ($/Yr)	Payback (Yrs)
A9	Room RAC	0	173	173	53	$1,071.5	$13.4	79.7
C13	Room AC	0	56	56	17	$1,068.1	$4.3	246.5
C6	Room RAC	0	32	32	10	$1,129.8	$2.5	450.4
B27	Room RAC	0	19	19	6	$833.4	$1.5	564.7
C14	Room RAC	0	36	36	11	$1,744.0	$2.8	630.3
C3	Room AC	0	51	51	15	$2,577.5	$3.9	655.7
A15	Room RAC	0	47	47	14	$2,701.6	$3.6	741.5
A10	Room AC	0	9	9	3	$521.1	$0.7	770.5
C4	Evaporative	0	55	55	17	$3,811.4	$4.3	895.8
B10	Evaporative	0	7	7	2	$569.5	$0.5	1091.5
C10	Room RAC	0	9	9	3	$910.6	$0.7	1316.4
B15	Room RAC	0	3	3	1	$333.4	$0.2	1335.0
B5	Room RAC	0	5	5	1	$666.7	$0.4	1796.6
A4	Evaporative	0	6	6	2	$1,735.6	$0.5	3,465.9
B13	Room RAC	0	5	5	2	$1,500.2	$0.4	3672.7
B14	Room RAC	0	1	1	0	$814.9	$0.1	7057.4
B4	Room AC	0	1	1	0	$583.4	$0.1	11496.6
B12	Evaporative	0	1	1	0	$1,818.1	$0.1	17261.6
B6	Room RAC	0	0.4	0.4	0	$3,427.9	$0.0	101591.4

House No.	Cooling Type	Energy Saving (MJ/Yr) Gas	Elec	Total	GHG Saving (kg/Yr)	Cost ($)	Saving ($/Yr)	Payback (Yrs)
Av. – Across Stock		**0.0**	**8.6**	**8.6**	**2.6**	**$463.6**	**$0.7**	**694.1**
Av. - When Implemented		**0.0**	**27.1**	**27.1**	**8.2**	**$1,464.1**	**$2.1**	**694.1**
Av. - Central Cooling		0.0	17.3	17.3	5.3	$1,983.7	$1.3	1,474.1
Av. - Room Cooling		0.0	29.7	29.7	9.0	$1,325.6	$2.3	573.1

The external shading measure was found to be applicable and beneficial in 19 (31.7%) of the OGA study houses. The initial House Energy Rating modelling found an average increase of 0.01 stars, both in the houses to which this measure was applied and across the stock of houses[80]. The modelled energy saving impact of the external shading measure for the individual houses is shown in Table A12. The average impact across the stock of 60 houses, as well as the average impact for the houses in which this measure was modelled, and the average impact for the houses with central cooling (in all cases evaporative cooling) and room cooling (in all cases refrigerative air conditioning) are shown. The average impact across the stock is lower than the average impact in the houses in which this measure was implemented, because this measure was found to be applicable in one out of three houses.

The stock average payback for the measure was 694 years and the median of the individual paybacks was 1,091 years. The energy savings for those houses with a central cooling system were actually lower than for those houses with only room cooling, and the payback period higher. This is because all central cooling systems were ducted evaporative cooling, and these systems have inherently low energy consumption. Figure A21 shows the distribution of the paybacks for the individual houses, broken down by the type of heating system. Figure A22 provides the cumulative greenhouse abatement curve for the measure. In all cases, the payback for the external shading measure was found to be greater than 80 years. Around 50% of the total savings are achieved for a payback of less than 450 years.

FIGURE A21: DISTRIBUTION OF PAYBACKS FOR EXTERNAL SHADING

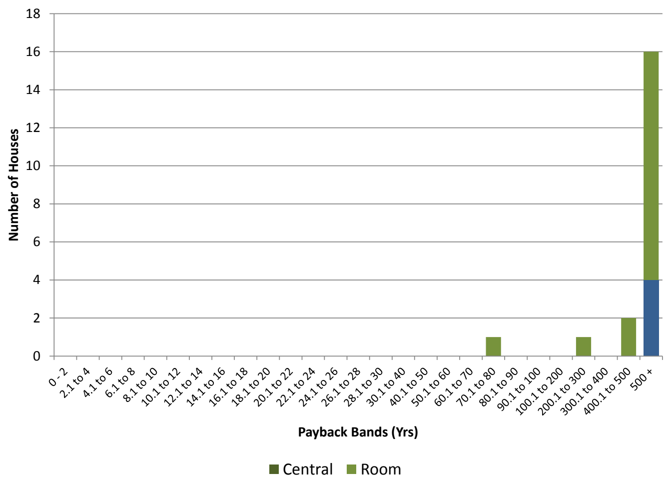
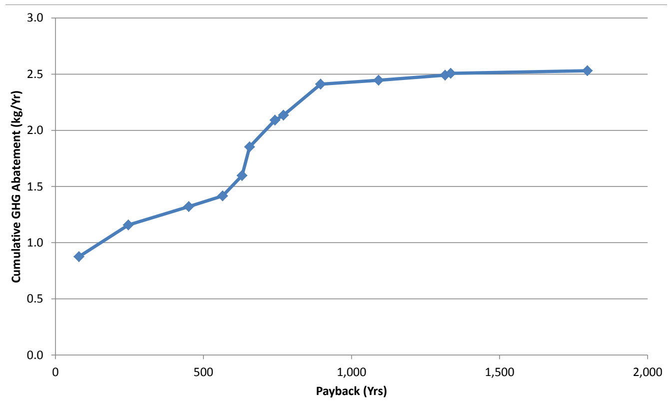


FIGURE A22: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE FOR EXTERNAL SHADING



80 Note that in the House Energy Rating modelling this measure was applied more widely across the stock of houses. For the cost benefit modelling it was only applied where needed to those rooms which had supplementary cooling.

A4: Detailed Analysis of Lighting & Appliance Upgrades

Introduction

The different lighting and appliance upgrade options which were modelled for this study are listed in Table 23 (Chapter 4). Only those options which were relevant and practically possible for each house were modelled.

An overview of the analysis methodology used is provided in Chapter 4. The cost of each upgrade was estimated based on current commercial costs of the lighting and appliances which were assumed for the upgrade, plus any additional installation costs associated with the upgrade. For this study we used the full cost of the upgrade as the starting point of the analysis, and did not discount the cost for any incentives which are currently available[81]. For the lighting and low flow shower upgrades we have used the full upgrade cost as the basis of assessing the cost-effectiveness of the measures, as these measures are often taken before the end of life of the existing products. For all other appliance upgrades we have used the adjusted capital cost[82] as the basis for assessing the cost effectiveness of the upgrades, as these appliances are usually only upgraded at the end of their useful life. Details of the cost assumptions which have been used are provided below for each upgrade type.

The methodology used to model the energy savings achieved from the upgrades varied depending on the upgrade. Details for each upgrade are provided below in the sections on specific upgrades.

In most cases the appliance and lighting energy efficiency upgrades are reasonably independent of each other, although there could be some interaction between some of the lighting and appliance upgrades, and the upgrade of heating and cooling equipment[83]. We have not considered these interactions in this analysis, and in most cases they are likely to be fairly minor. There is likely to be a stronger interaction between the water heater upgrade and the upgrade of "wet" appliances and equipment (eg low flow shower rose, washing machine and dishwasher), and for these upgrades our main analysis assumed the upgrades were applied progressively in the order shown in Table 23. Further information on the impact of the order of these upgrades on the energy savings is provided in Appendix A5.

In Chapter 3 we summarised the aggregated results for all of the lighting and appliance upgrades which were modelled. In this section we present the detailed results for each of the lighting and appliance upgrades. As with the building shell upgrades this highlights the diversity in results which are achieved for the different upgrades, and also provides an insight into the underlying reasons for this diversity.

Lighting upgrades

Lighting audits were undertaken in each of the OGA study houses to identify the type and wattage of the lighting installed. A summary of the main types of lighting installed in the houses is provided in Table 8, Chapter 2. Details on the lighting installed, broken down by lighting type and key areas of the home, are provided in Table A13 below. Inefficient incandescent and 12 volt halogen lighting was found to be most common in the living areas of the houses, comprising 58.7% of installed lamps, compared to 50.9% in non-living areas and 37.8% in external areas. This is important, as the lighting in the living areas operates for longer hours than the lighting in the non-living and external areas. The most common wattage of incandescent lamp installed was 60 Watts, accounting for around 72% of all incandescent lamps. Both compact fluorescent lamps (CFLs) and incandescent lamps, 43.9% and 30% respectively, were the most common lamp types found in the non-living areas. Fluorescent tubes (linear or circular) were most common in both the external areas of the houses and also in the living area – in this case mainly in the kitchen. External lighting was dominated by the "Other" category (mainly incandescent flood lamps), although the common incandescent lamps were still used quite widely (28%) here.

The data presented in Table A13 provides a snapshot in time. The residential lighting stock is undergoing a fairly rapid transformation, due to the mass roll-out of compact fluorescent lamps (CFLs) and now LEDs through the *Victorian Energy Saver Incentive* scheme, and because LED lamps are becoming much more widely available and cheaper.

81 This provides a fairer comparison of the overall cost-effectiveness of the upgrades. While any incentives reduce the upgrade cost to households and improve the cost-effectiveness from a household perspective, the incentives can vary significantly in availability, eligibility, and value over time.

82 See Chapter 4, page 39 for a description of how this cost is calculated.

83 Lighting and appliances generate some heat when they operate. An efficiency upgrade can lead to the lighting and appliances generating less heat, reducing the cooling load in summer and increasing the heating load in winter. The exact impact will depend very much on the timing of the use of the lighting and appliances in relation to the timing of the use of the heating and cooling equipment.

TABLE A13: AVERAGE NUMBER OF LIGHTS, BY TYPE, INSTALLED IN DIFFERENT AREAS OF THE OGA STUDY HOUSES

					Incandescent[84]						
Area of House	Metric	CFL / LED	Fluoro Tubes	Other	25W	40W	60W	75W	100W	All	12V Halogen
Living	Number	4.05	0.98	0.08	0.03	0.45	2.28	0.30	0.00	3.07	4.20
	%	32.7%	7.9%	0.7%	0.3%	3.6%	18.4%	2.4%	0.0%	24.8%	33.9%
Non-Living	Number	6.27	0.73	0.02	0.10	0.90	2.82	0.25	0.22	4.28	2.98
	%	43.9%	5.1%	0.1%	0.7%	6.3%	19.7%	1.8%	1.5%	30.0%	20.9%
External	Number	0.82	0.30	1.22	0.00	0.03	0.97	0.02	0.03	1.05	0.37
	%	21.8%	8.0%	32.4%	0.0%	0.9%	25.8%	0.4%	0.9%	28.0%	9.8%

TABLE A14: POWER SAVINGS ASSUMED FOR LAMP REPLACEMENTS

	Incandescent					Floodlight	Halogen	
	25W	40W	60W	75W	100W	150W	Down Lights	TF Loss Factor*
Low Energy Equivalent (W)	5	8	13	15	20	23	10.5	1.16
Assumed power saving per lamp (W)	20	20	29	38	52	127	45.8	1.16

* Transformer loss factor – the lamp power consumption is multiplied by the TF loss factor to obtain the total power consumption

84 The wattages for the incandescent lamps are nominal and are based on the typical wattages of the older tungsten-filament incandescent lamps. The newer "mains voltage halogen" incandescent lamps which comply with current minimum standards for incandescent lamps will have a lower wattage.

The replacement of any incandescent and 12 volt halogen lighting was modelled for the OGA study houses. It was assumed that the 12 volt halogen lamps were replaced with LED lamps. Minimum energy performance standards (MEPS) were introduced for incandescent lamps in November 2009. These standards mean that it is no longer possible to buy the older-style incandescent lamps with a tungsten-filament. It is possible to buy the "mains voltage halogen" style of incandescent lamp, which has a power consumption around 30% lower than the older style lamps. Energy savings will be achieved as the existing stock of old style incandescent lamps reach their end of life and are replaced with MEPS compliant lamps. For this study the energy savings calculations were based on replacing MEPS compliant incandescent lamps with compact fluorescent lamps. Table A14 shows the power saving which was assumed for the different lamp replacements which were modelled.

To estimate the annual energy savings from the lamp replacements it was necessary to make assumptions concerning the average daily usage of the lighting in different areas of the home:

- Living areas – 2.2 hours per day
- Non-Living areas – 1.0 hour per day
- External areas – 0.17 hours per day

These figures represent the average daily operating time across all lamps installed in that area of the house across a whole year. The lighting will operate for longer hours in winter than in summer, and will operate for longer hours in some rooms compared to others. We have taken this simplified approach as there is little data currently available on the annual operating time of lighting in Victorian (or Australian) homes[85].

85 A number of recent studies have been undertaken which will shed more light on the operating time in Victorian houses. Sustainability Victoria's Victorian Residential End-Use Metering (Vic-REMP) project collected lighting data from 24 houses, and data for lighting in the living areas of an additional 16 houses was collected as part of SV's Halogen Downlight Retrofit Trials – this latter trial found an average daily use of 2.2 hours per day to lighting in the living areas of the 16 houses studied. Full reports on this work will be published in 2016.

The assumed average costs of the lighting replacements are shown in Table A15, and are based on typical commercial costs in early 2013. No labour costs were included for the simple incandescent lamp replacements as this can be easily undertaken as a DIY project. The cost of using an electrician was included for replacing halogen downlights with LED downlights, although in many cases it is possible to replace these lamps successfully without the use of an electrician[86]. It is also relevant to note that government incentive schemes such as Victoria's Energy Saver Incentive mean that currently households can have simple incandescent lamps and 12 volt halogen downlights replaced for free, and the replacement of mains voltage halogen downlights with LED lamps is heavily subsidised.

86 Compatibility issues can arise when replacing 12 volt halogen downlight lamps with 12 volt LED lamps, including compatibility with the transformer (or electronic convertor), compatibility with the shape/size of the existing fitting, and compatibility of the electrical connectors. This may require the existing transformer/convertor to be replaced by an electrician and/or the downlight fitting to be modified or replaced. In some circumstances it may be better to replace the existing lamp and its transformer/convertor with a new LED lamp and driver, and where the existing transformer/convertor is hardwired this will require an electrician.

TABLE A15: ASSUMED COST OF LIGHTING UPGRADES

Basic CFL	Dimmable CFL	Non-Dimmable LED to replace Halogen Downlight*	Dimmable LED to replace Dimmable Halogen*	Floodlights
$5.00	$30.00	$54.95	$67.99	$27.00

* Includes average labour costs of $15 per lamp and average materials cost of $5 per lamp in addition to the cost of the lamp.

TABLE A16: MODELLED IMPACT OF THE LIGHTING UPGRADES

	Energy Saving (MJ/Yr)						
House No.	Gas	Elec	Total	GHG Saving (kg/Yr)	Bill Saving ($/Yr)	Cost ($)	Payback (Yrs)
A15	0	330	330	100	$25.6	$15.0	0.6
A2	0	100	100	30	$7.8	$10.0	1.3
C7	0	288	288	88	$22.4	$30.0	1.3
B7	0	1,024	1,024	311	$79.6	$115.0	1.4
B10	0	531	531	161	$41.3	$60.0	1.5
B12	0	582	582	177	$45.2	$75.0	1.7
A10	0	76	76	23	$5.9	$10.0	1.7
B28	0	38	38	12	$3.0	$5.0	1.7
B20	0	363	363	110	$28.3	$50.0	1.8
B1	0	1,890	1,890	574	$147.0	$271.0	1.8
B8	0	1,455	1,455	442	$113.2	$244.0	2.2
C3	0	2,993	2,993	909	$232.8	$504.0	2.2
B15	0	625	625	190	$48.6	$109.0	2.2
C9	0	700	700	213	$54.5	$123.0	2.3
C2	0	165	165	50	$12.8	$30.0	2.3
B29	0	470	470	143	$36.6	$89.0	2.4

	Energy Saving (MJ/Yr)						
House No.	Gas	Elec	Total	GHG Saving (kg/Yr)	Bill Saving ($/Yr)	Cost ($)	Payback (Yrs)
A14	0	79	79	24	$6.1	$15.0	2.4
C12	0	79	79	24	$6.1	$15.0	2.4
B24	0	347	347	105	$27.0	$75.0	2.8
A4	0	488	488	148	$37.9	$115.0	3.0
C1	0	2,695	2,695	819	$209.6	$740.9	3.5
B5	0	2,543	2,543	773	$197.8	$718.7	3.6
B23	0	273	273	83	$21.2	$80.0	3.8
B21	0	2,359	2,359	717	$183.4	$704.5	3.8
C4	0	2,194	2,194	667	$170.7	$691.4	4.1
C8	0	980	980	298	$76.2	$310.9	4.1
B27	0	1,807	1,807	549	$140.5	$583.6	4.2
B4	0	1,364	1,364	414	$106.1	$483.9	4.6
A8	0	622	622	189	$48.4	$234.9	4.9
C13	0	1,432	1,432	435	$111.4	$542.8	4.9
B2	0	109	109	33	$8.5	$42.0	5.0
A1	0	1,997	1,997	607	$155.3	$796.5	5.1
A9	0	801	801	243	$62.3	$334.7	5.4
B6	0	2,003	2,003	609	$155.8	$921.5	5.9
A12	0	715	715	217	$55.6	$334.8	6.0
B30	0	1,776	1,776	540	$138.1	$856.6	6.2
B11	0	2,430	2,430	739	$189.0	$1,184.3	6.3
B22	0	1,889	1,889	574	$146.9	$938.2	6.4
C15	0	199	199	61	$15.5	$102.0	6.6
A7	0	349	349	106	$27.1	$179.9	6.6
B17	0	2,367	2,367	719	$184.1	$1,248.3	6.8
A11	0	3,540	3,540	1,076	$275.3	$1,909.3	6.9
A13	0	4,181	4,181	1,270	$325.2	$2,297.4	7.1
B13	0	1,070	1,070	325	$83.2	$593.6	7.1
B3	0	2,985	2,985	907	$232.1	$1,701.3	7.3
C6	0	607	607	184	$47.2	$364.7	7.7
B25	0	372	372	113	$28.9	$228.9	7.9

	Energy Saving (MJ/Yr)						
House No.	Gas	Elec	Total	GHG Saving (kg/Yr)	Bill Saving ($/Yr)	Cost ($)	Payback (Yrs)
C5	0	4,708	4,708	1,431	$366.2	$2,981.4	8.1
B19	0	4,941	4,941	1,501	$384.3	$3,143.1	8.2
B16	0	913	913	278	$71.0	$606.0	8.5
B18	0	448	448	136	$34.8	$309.8	8.9
C11	0	2,671	2,671	812	$207.7	$1,883.3	9.1
B9	0	1,868	1,868	568	$145.3	$1,582.0	10.9
C14	0	169	169	51	$13.1	$168.0	12.8
B14	0	104	104	32	$8.1	$114.9	14.2
C10	0	31	31	9	$2.4	$274.8	113.5
Av. - Across Stock	**0.0**	**1,202.2**	**1,202.2**	**365.3**	**$93.5**	**$535.8**	**5.7**
Av. - When implemented	**0.0**	**1,288.0**	**1,288.0**	**391.4**	**$100.2**	**$574.1**	**5.7**

Lighting upgrades were found to be applicable for at least some of the lighting in 56 (93.3%) of the OGA study houses. The modelled energy saving impact of lighting upgrades for each of the houses is shown in Table A16. The average impact across the stock of 60 houses, as well as the average impact for the houses in which this measure was modelled is shown. The average impact across the stock is slightly lower than the average impact in the houses in which this measure was implemented, because this measure was found to be applicable in over 9 out of 10 houses

The stock average payback for the measure was 5.7 years and the median of the individual paybacks was 4.7 years. The energy savings for those houses with halogen downlights were generally larger than for those houses with simple incandescent light globes. However, as the replacement cost for the halogen downlights is higher, the paybacks are longer. As the costs of the LED lamps is starting to decrease, and as current government incentives significantly reduces the cost of replacing inefficient lamps (in fact in many cases this is now free), the actual cost to households undertaking this retrofit are likely to be significantly lower than shown and the paybacks also lower. This makes lighting retrofits one of the more cost effective retrofits which can be undertaken in Victorian houses.

Figure A23 shows the distribution of the paybacks for the individual houses. Figure A24 provides the cumulative greenhouse abatement curve for the measure. Around 9% of the total savings are achieved for a payback of less than 2 years, around 48% of the total savings are achieved for a payback of less than 6 years, and around 80% of the paybacks are achieved for a payback of less than 8 years.

FIGURE A23: DISTRIBUTION OF PAYBACKS FOR LIGHTING UPGRADES

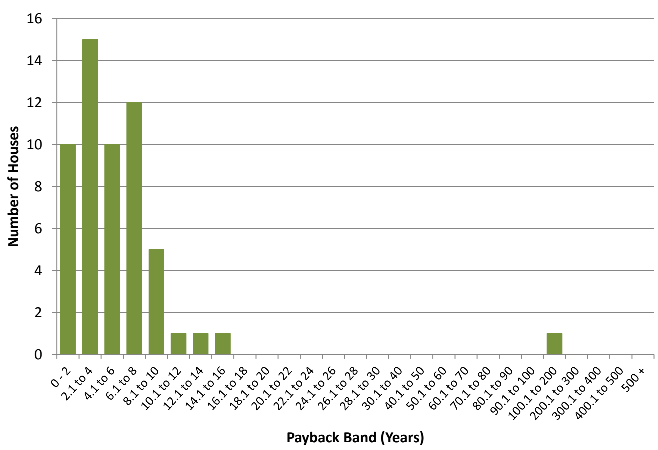
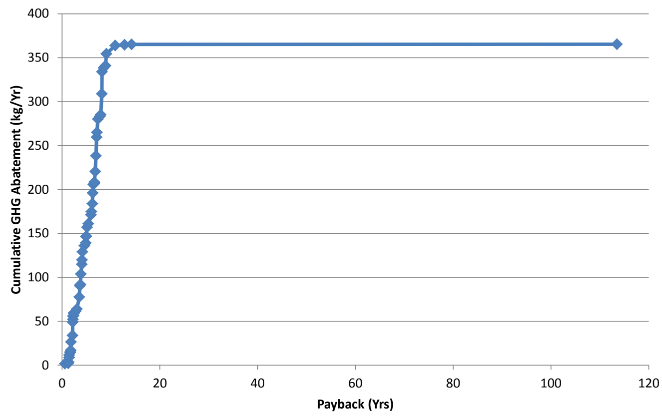


FIGURE A24: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE FOR LIGHTING UPGRADES



Heating upgrade

A summary of the main types of heating installed in the OGA study houses is provided in Table 9, Chapter 2, and Figures 7 and 8 in this chapter show the distribution of the heater ages as well as the energy efficiency (Star Rating) profile for the gas room heaters, gas central heaters and reverse-cycle air conditioners (RAC) respectively.

Data was collected for the main fixed heating system found in the OGA study houses, including the type, brand and model number, age, and where available the Energy Rating label data (where label was still affixed) and nameplate details. This data was used to estimate the energy efficiency of the heaters:

- Where the Energy Rating labels were still affixed the Star Rating was obtained directly from the label;
- Where only brand and model number were available, either current or historical lists of energy rating data were obtained and used to obtain the Star Rating;
- Where only the age of the appliance was available, the efficiency of the appliance was assumed to be the same as the average efficiency for appliances sold in the year it was purchased, based on [EES 2008].

The energy rating algorithms for gas ducted, gas room and room reverse-cycle air conditioners (RAC) were then used to estimate the conversion efficiency of these types of heater. The estimation of conversion efficiency was slightly more complicated for the gas ducted heaters. In this case, the Energy Rating depends partly on the conversion efficiency of the heater and partly on the Heat Load Reduction (HLR) factor, which is a measure of the extent to which the system can be zoned. For this study it was assumed that heaters with a rating of 3 stars or less had a HLR of 0, and that heaters with a rating of more than 3 stars had a HLR of 0.5. Ducted heating systems also suffer from heat losses in the ductwork. It was assumed that systems which were less than 5 years old had duct losses of 15%, and then for each year older than this duct losses were increased by 0.75% on the assumption that the ductwork suffers some degradation in performance over its lifetime[87] – this means that a 20 year old system was assumed to have duct losses of around 26%. The conversion efficiency of the gas ducted heater was then adjusted to take into account the duct losses.

The estimated average annual energy use, greenhouse gas emissions and running cost of the existing heaters prior to any upgrades being undertaken is shown in Table A17.

87 Assumptions based on field trial results from gas heating ductwork study undertaken by Graham Palmer [Palmer 2008].

TABLE A17: ESTIMATED AVERAGE ANNUAL ENERGY USE OF EXISTING HEATING PRIOR TO ANY UPGRADES

Heater Type	Gas Use (MJ/Yr)	Elec Use (MJ/Yr)	Total Energy Use (MJ/Yr)	GHG Emissions (kg/Yr)	Cost ($/Yr)
Gas ducted	62,689	1,254	63,943	3,850	$1,195
Gas room	24,119	241	24,360	1,408	$441
Room RAC	0	1,461	1,461	444	$114
Electric heating panel	0	8,436	8,436	2,564	$656
Average household	**40,992**	**1,102**	**42,094**	**2,603**	**$803**

A heater upgrade was modelled for all houses which had an 'inefficient' heater, as follows:

- Gas ducted heaters less than 5 Star were upgraded to a 6 Star unit;
- Gas room heaters less than 4 Star were upgraded to a heater with a rating greater than 4 stars – 4.8 Star for the convection heaters and 4.3 Star for the radiant heaters;
- Electric resistance heating was replaced by a room reverse-cycle air conditioner with a Coefficient of Performance (CoP) of 4.41;
- Room reverse-cycle air conditioners with a CoP less than 3.5 were upgraded to a unit with a CoP of 4.41.

It was assumed that some building shell upgrades had been undertaken prior to the heater being upgraded. All applicable upgrades up to and including underfloor insulation (see Table 21, Chapter 3) were assumed to have been undertaken. This meant that the heat load of the houses had already been reduced, and so the savings calculated were somewhat less than if the heating upgrade was assumed to have taken place before any building shell upgrades had been undertaken. It was assumed that any existing ductwork remained in place. In some cases the ductwork might be replaced when a new heater is installed, and an incentive is available through the Victorian *Energy Saver Incentive* scheme for new good quality ductwork to be installed for old gas ducted heating systems. Ductwork upgrades were not modelled for the OGA study houses, but for older systems have the potential to achieve significant energy savings[88].

88 Ductwork upgrades have been trialled and monitored as part of Sustainability Victoria's Energy Efficiency Retrofit Trials project, and results of this trial will be published in a forthcoming report. Graham Palmer's report [Palmer 2008] provides some measured data on the upgrade of 10 ducted heating systems.

TABLE A18: ASSUMPTIONS USED TO CALCULATE ADJUSTED CAPITAL COST OF NEW HEATERS

Heating Type	Assumed Lifetime (Yrs)[89]	Replacement Appliance Cost ($)[90]	Installation Cost ($)[91]	Differential Cost at End Life[92]
Gas ducted	20	$2,240 - $2,750	$700	$890
Gas room - convection	14	$1,195 - $1,295	$545	$280
Gas room - radiant	14	$2,090	$793 to $1,482 depending on flue $300 extra if wall furnace replaced	$280
Room RAC	13	$1,469	$780 - $1,120 $500 extra if window unit replaced	$330
Electric panel	NA	$1,469	$780 - $1,120	$2,249 - $2,589

89 Lifetimes for gas room heaters and room reverse-cycle air conditioners based on [BIS Shrapnel 2010b]. Lifetime of gas ducted heater based on industry estimates cited in the Gas Ducted Heater Product Profile [E3 2010b].

90 Appliance costs from www.gstore.com.au (gas heaters) and www.getprice.com.au (Room RAC), March 2013. A range of prices is shown where there is a range of heater output capacities.

91 Installation costs were provided by MEFL/RMIT.

92 Cost differentials based on: for gas ducted heater the difference in cost between a 4- and 6-Star Braemar heater (www.gstore.com.au March 2013); for gas room heater on the difference in cost between a 4.8 Star convection heater (www.gstore.com.au March 2013) and the average room heater, calculated from GfK 2006 gas heater sales data adjusted for inflation; for room RAC on the price-efficiency ratio cited in the 2010 air conditioner Regulation Impact Statement [E3 2010a], the current cost of 2.5 Star air conditioner and the efficiency difference between a 2- and 2.5-Star air conditioner.

The calculation of the paybacks for the heater upgrades use the adjusted capital cost rather than the full replacement costs, in recognition that in most cases this replacement will only be made at the end of life of the existing heater. The calculation of the adjusted capital cost requires both the average lifetime of the heating system to be assumed, as well as the differential cost between the current market average heater and the replacement high efficiency heating system. The assumptions used in this study are detailed in Table A18 above. Where a house had a reverse-cycle air conditioner which was used for both heating and cooling, 80% of the upgrade cost was allocated to the heater upgrade and 20% of the upgrade cost was allocated to the cooler. Where electric panel heating was replaced with a high efficiency reverse-cycle air conditioner the full cost of the air conditioner was used.

TABLE A19: MODELLED IMPACT OF REPLACING EXISTING HEATERS WITH NEW HIGH EFFICIENCY HEATERS

		Energy Saving (MJ/Yr)						
House No	Heating Type	Gas	Elec	Total	GHG Saving (kg/Yr)	Adjusted Cost ($)	Saving ($/Yr)	Payback (Yrs)
B1	Gas central	23,662	0	23,662	1,309	$890.0	$414.1	2.1
A13	Gas central	23,155	0	23,155	1,281	$890.0	$405.2	2.2
B9	Gas central	17,083	0	17,083	945	$890.0	$298.9	3.0
A11	Gas central	16,671	0	16,671	922	$890.0	$291.7	3.1
B30	Gas room	10,751	0	10,751	595	$580.0	$188.1	3.1
B16	Electric panel heater	0	6,690	6,690	2,033	$1,799.2	$520.3	3.5
A12	Gas room	3,352	0	3,352	185	$280.0	$58.7	4.8
B21	Gas central	22,592	0	22,592	1,250	$1,902.5	$395.4	4.8
A4	Gas room	3,319	0	3,319	184	$280.0	$58.1	4.8
C1	Gas central	31,731	0	31,731	1,756	$2,915.0	$555.3	5.2
C12	Electric panel heater	0	5,054	5,054	1,536	$2,249.0	$393.1	5.7
C15	Gas central	12,134	0	12,134	671	$1,227.5	$212.3	5.8
B11	Gas central	13,750	0	13,750	761	$1,402.5	$240.6	5.8
B4	Gas central	12,532	0	12,532	693	$1,402.5	$219.3	6.4
B8	Gas central	12,528	0	12,528	693	$1,452.5	$219.2	6.6
A8	Gas central	10,219	0	10,219	565	$1,197.5	$178.8	6.7
A1	Gas central	17,059	0	17,059	944	$2,017.5	$298.5	6.8
B3	Gas central	7,484	0	7,484	414	$890.0	$131.0	6.8
C11	Gas central	19,087	0	19,087	1,056	$2,426.0	$334.0	7.3
B26	Gas room	2,203	0	2,203	122	$280.0	$38.5	7.3
A5	Gas room	1,984	0	1,984	110	$280.0	$34.7	8.1
C3	Gas central	16,018	0	16,018	886	$2,426.0	$280.3	8.7
C4	Gas central	5,598	0	5,598	310	$992.5	$98.0	10.1
B5	Gas central	7,361	0	7,361	407	$1,340.0	$128.8	10.4
B6	Gas central	9,698	0	9,698	537	$1,790.0	$169.7	10.5
A14	Gas room	1,501	0	1,501	83	$280.0	$26.3	10.7
A9	Gas room	2,669	0	2,669	148	$580.0	$46.7	12.4
C2	Gas central	8,101	0	8,101	448	$1,915.0	$141.8	13.5

		Energy Saving (MJ/Yr)						
House No	Heating Type	Gas	Elec	Total	GHG Saving (kg/Yr)	Adjusted Cost ($)	Saving ($/Yr)	Payback (Yrs)
B27	Gas room	5,044	0	5,044	279	$1,360.0	$88.3	15.4
B10	Gas room	3,377	0	3,377	187	$1,023.7	$59.1	17.3
C8	Gas room	1,907	0	1,907	106	$580.0	$33.4	17.4
C13	Gas central	8,820	0	8,820	488	$2,837.5	$154.3	18.4
C9	Gas room	5,669	0	5,669	314	$2,028.6	$99.2	20.4
B17	Gas room	8,807	0	8,807	487	$3,165.7	$154.1	20.5
B29	Gas room	1,570	0	1,570	87	$580.0	$27.5	21.1
B12	Gas central	5,049	0	5,049	279	$2,222.5	$88.4	25.2
C7	Gas room	4,805	0	4,805	266	$2,139.3	$84.1	25.4
A3	Gas central	6,007	0	6,007	332	$2,735.0	$105.1	26.0
A2	Gas room	2,244	0	2,244	124	$1,025.7	$39.3	26.1
B28	Gas room	3,349	0	3,349	185	$1,917.1	$58.6	32.7
B15	Gas central	3,214	0	3,214	178	$1,915.0	$56.3	34.0
B25	Gas room	880	0	880	49	$580.0	$15.4	37.7
C10	Room RAC	0	520	520	158	$1,563.0	$40.5	38.6
A7	Gas room	334	0	334	18	$280.0	$5.8	48.0
B24	Gas room	997	0	997	55	$837.1	$17.4	48.0
B14	Room RAC	0	311	311	95	$1,681.1	$24.2	69.5
A6	Room RAC	0	176	176	53	$1,254.5	$13.7	91.7
C14	Room RAC	0	150	150	45	$1,444.9	$11.6	124.2
Av. – Across Stock		**6,239**	**215**	**6,454**	**411**	**$1,110.6**	**$125.9**	**8.8**
Av. - When Implemented		**7,798**	**269**	**8,067**	**513**	**$1,388.2**	**$157.4**	**8.8**
Av. - Central Heating		13,459	0	13,459	745	$1,676.8	$235.5	7.1
Av. - Room Heating		2,590	516	3,106	300	$1,122.8	$85.5	13.1

Upgrading of the heating system was found to be applicable to 48 (80.0%) of the OGA study houses. The modelled energy saving impact of the heater upgrade for the individual houses – when applied after the underfloor insulation building shell upgrade - is shown in Table A19. The average impact across the stock of 60 houses, as well as the average impact for the houses in which this measure was modelled, and the average impact for the houses with central heating and room heating are shown. The average impact across the stock is slightly lower than the average impact in the houses in which this measure was implemented, because this measure was found to be applicable in 4 out of 5 houses.

The stock average payback for the measure was 8.8 years and the median of the individual paybacks was 10.5 years. As would be expected, the energy savings for those houses with a central heating system were larger than for those houses with only room heating, and the payback period lower. Figure A25 shows the distribution of the paybacks for the individual houses, broken down by the type of heating system. Figure A26 provides the cumulative greenhouse abatement curve for the measure. Around 40% of the total savings are achieved for a payback of less than 5 years, and around 78% of the total savings are achieved for a payback of less than 10 years.

The Victorian *Energy Saver Incentive* scheme makes subsidies available for replacing old existing heating systems with new high efficiency heating systems. The scheme covers: the replacement of an existing gas ducted heater with a high efficiency ducted heater; the replacement of a central electric resistance heating system (e.g. in-slab electric heating) with either a high efficiency gas ducted heater or a high efficiency ducted reverse-cycle air conditioner; the replacement of an existing ducted reverse-cycle air conditioner with a high efficiency unit; and, the installation of either a high efficiency gas room heater or room reverse-cycle air conditioner. The level of the subsidy available depends on whether the household is located in Melbourne or regional Victoria, the climate zone the house is located in, and the output heating capacity of the new heater that is installed. This subsidy lowers the installation cost of the new heater, especially where central electric heating is replaced.

FIGURE A25: DISTRIBUTION OF PAYBACKS FOR HEATING UPGRADE

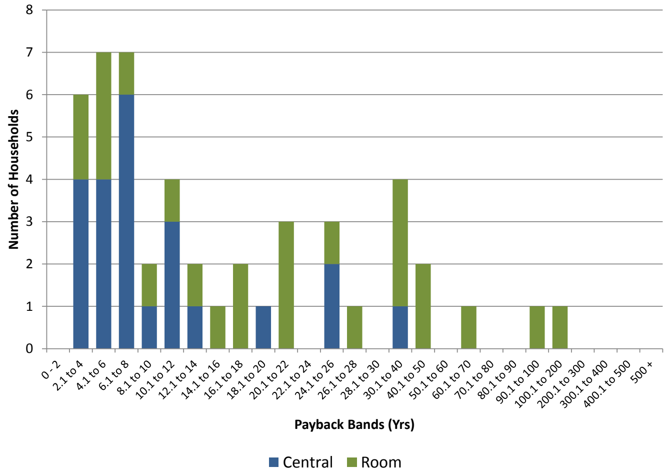
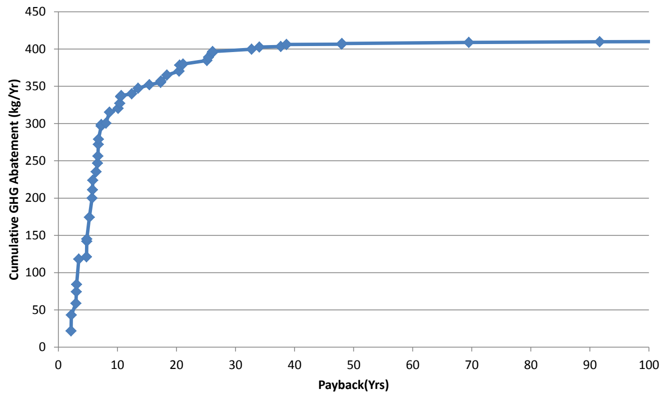


FIGURE A26: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE FOR HEATING UPGRADE



Cooling upgrade

Fixed cooling was installed in 35 (58.3%) of the OGA study houses. A summary of the main types of cooling installed is provided in Table 10, Chapter 2, and Figures 9 and 10 in this chapter show the distribution of the cooler ages as well as the energy efficiency (star rating) profile for the room refrigerative air conditioners.

Data was collected for the main fixed cooling system found in the OGA study houses, including the type, brand and model number, age, and where available the Energy Rating label data (where label was still affixed) and nameplate details. This data was used to estimate the energy efficiency of the coolers:

- Where the Energy Rating labels were still affixed to the room refrigerative air conditioners, the Star Rating was obtained directly from the label – for this study the Star Rating based on the 2000 Energy Rating algorithms was used[93], as this was the easiest way to compare the energy efficiency of all air conditioners found in the houses;
- Where only brand and model number were available for the refrigerative air conditioners, either current or historical lists of energy rating data were obtained and used to obtain the Star Rating (based on the 2000 rating scale);
- Where only the age of the refrigerative air conditioner was available, the efficiency of the appliance was assumed to be the same as the average efficiency for appliances sold in the year it was purchased, based on [EES 2008];
- No official published data is available on ducted evaporative coolers. The efficiency assigned to the evaporative coolers was based on the age of the evaporative cooler, and takes into account data published by manufacturers on the rated power consumption of the coolers and their 'effective cooling' capacity. It was assumed that coolers which were installed prior to 2000 had an Energy Efficiency Ratio (EER) of 13 and that coolers which were installed after 2000 had an EER of 15.

The Energy Rating algorithms for room refrigerative air conditioners were used to estimate the conversion efficiency of this type of cooler. As noted above, the conversion efficiency of the ducted evaporative coolers was based on their age. As with gas ducted heating it also took into account losses in the ductwork used to distribute cool air throughout the house. It was assumed that systems which were less than 5 years old had duct losses of 10%, and then for each year older than this duct losses were increased by 1% - this means that a 10 year old system was assumed to have duct losses of around 15%. The conversion efficiency of the ducted evaporative cooler was then adjusted to take into account the duct losses.

The estimated average annual electricity use, greenhouse gas emissions and running cost of the existing coolers prior to any upgrades being undertaken is shown in Table A20.

93 The Energy Rating algorithms used to assign the Star Ratings for air conditioners were revised in 2000 and then again in 2010. The effect of these revisions is to reduce the number of stars allocated for a certain level of energy efficiency performance.

TABLE A20: ESTIMATED AVERAGE ANNUAL ENERGY USE OF EXISTING COOLING PRIOR TO ANY UPGRADES

Cooler Type	Elec Use (MJ/Yr)	Elec Use (kWh/Yr)	GHG Emissions (kg/Yr)	Cost ($/Yr)
Room refrigerative air conditioner	863	240	262	$67.14
Ducted evaporative air conditioner	165	46	50	$12.83
Average household	**683**	**190**	**208**	**$53.14**

TABLE A21: ASSUMPTIONS USED TO CALCULATE ADJUSTED CAPITAL COST OF NEW COOLERS

Cooling Type	Assumed Lifetime (Yrs)[94]	Replacement Appliance Cost ($)[95]	Installation Cost ($)[96]	Differential Cost at End Life[97]
Room refrigerative air conditioner	13	$1,469	$780 - $1,120 $500 extra if window unit replaced	$330

94 The assumed life is based on [BIS Shrapnel 2010b]
95 Appliance costs from www.getprice.com.au, March 2013.
96 Installation costs were provided by MEFL/RMIT.
97 The same differential cost was used as for the reverse-cycle air conditioner upgrade, as most refrigerative air conditioners sold are now reverse-cycle units.

No cooler upgrade was modelled if the houses had ducted evaporative cooling, as this already has relatively low energy consumption for the area which is cooled. However, ducted evaporative coolers are available which use a variable speed motor (inverter driven) to drive the air circulation fan, and these units have a considerably lower power consumption than standard evaporative coolers when operated on the lower fan speeds. Replacing an existing ducted evaporative cooler with an inverter driven ducted evaporative cooler when it reaches end of life will produce energy savings.

A cooler upgrade was modelled for all houses which had a room refrigerative air conditioner with an EER of less than 3.5. In this case the air conditioner was assumed to be replaced with a split-system air conditioner with an EER of 3.85.

As with the heater upgrades, it was assumed that some building shell upgrades had been undertaken prior to the cooler being upgraded. All applicable upgrades up to and including underfloor insulation (see Table 21, Chapter 3) were assumed to have been undertaken. This meant that the cooling load of the houses had already been reduced, and so the savings calculated were somewhat less than if the cooling upgrade was assumed to have taken place before any building shell upgrades had been undertaken.

The calculation of the paybacks for the cooler upgrades use the adjusted capital cost rather than the full replacement costs, in recognition that in most cases this replacement will only be made at the end of life of the existing cooling system. The calculation of the adjusted capital cost required both the average lifetime of the cooling system to be assumed, as well as the differential cost between the current market average cooler and the replacement high efficiency cooling system. The assumptions used in this study are detailed in Table A21 below. Where a house had a reverse-cycle air conditioner which was used for both heating and cooling, 80% of the upgrade cost was allocated to the heater upgrade and 20% of the upgrade cost was allocated to the cooler. Where a house had an older style window/wall type air conditioner[98] an additional $500 cost was assumed to cover the cost to repair the hole in the wall or window once this air conditioner was removed.

98 This type of air conditioner is installed through a rectangular hole in the wall so that the compressor is located outside of the house and the evaporator and air handling unit is located inside the house. In modern split systems the compressor and evaporator / air handling unit are separate and connected by a length of refrigerant piping.

TABLE A22: MODELLED IMPACT OF REPLACING OLD COOLERS WITH NEW HIGH EFFICIENCY COOLERS

		Energy Saving (MJ/Yr)						
House No.	Cooling Type*	Gas	Elec	Total	GHG Saving (kg/Yr)	Adjusted Cost ($)	Saving ($/Yr)	Payback (Yrs)
B30	Room RAC	0	1,462	1,462	444	$830.0	$113.7	7.3
C3	Room COAC	0	2,624	2,624	797	$1,660.0	$204.1	8.1
B17	Room COAC	0	1,261	1,261	383	$830.0	$98.1	8.5
C8	Room COAC	0	1,173	1,173	356	$830.0	$91.2	9.1
A11	Room COAC	0	420	420	128	$330.0	$32.7	10.1
A14	Room COAC	0	438	438	133	$830.0	$34.0	24.4
C13	Room COAC	0	534	534	162	$1,068.1	$41.6	25.7
C14	Room RAC	0	151	151	46	$361.2	$11.7	30.9
C10	Room RAC	0	157	157	48	$390.8	$12.2	32.0
A10	Room COAC	0	252	252	76	$830.0	$19.6	42.4
A6	Room RAC	0	48	48	15	$313.6	$3.8	83.5
A15	Room RAC	0	282	282	86	$1,863.3	$21.9	84.9
A9	Room RAC	0	250	250	76	$2,101.4	$19.4	108.3
B6	Room RAC	0	125	125	38	$1,510.9	$9.7	155.8
B27	Room RAC	0	100	100	30	$1,215.7	$7.8	156.2
B5	Room RAC	0	50	50	15	$772.8	$3.9	197.1
B14	Room RAC	0	21	21	6	$420.3	$1.7	254.0
B3	Room RAC	0	93	93	28	$2,101.4	$7.3	289.2
B4	Room COAC	0	59	59	18	$1,806.2	$4.6	393.6
B29	Room COAC	0	67	67	20	$2,158.5	$5.2	413.9
B15	Room RAC	0	28	28	9	$1,953.8	$2.2	890.7
C9	Room RAC	0	11	11	3	$1,510.9	$0.8	1816.2
B16	Room COAC	0	3	3	1	$390.8	$0.2	1905.4
B13	Room RAC	0	7	7	2	$1,806.2	$0.5	3542.6
Av. – Across Stock		**0**	**160**	**160**	**49**	**$464.8**	**$12.5**	**37.3**
Av. - When Implemented		**0**	**401**	**401**	**122**	**$1,161.9**	**$31.2**	**37.3**

* RAC = reverse cycle air conditioner; COAC = cooling only (refrigerative) air conditioner.

Upgrading the cooling system was found to be applicable in 24 (40.0%) of the OGA study houses. The modelled energy saving impact of the cooler upgrade for the individual houses – when applied after the underfloor insulation building shell upgrade – is shown in Table A22. The average impact across the stock of 60 houses, as well as the average impact for the houses in which this measure was modelled is shown. The average impact across the stock is somewhat lower than the average impact in the houses in which this measure was implemented, because this measure was found to be applicable in only 2 out of 5 houses.

The stock average payback for the measure was 37.3 years and the median of the individual paybacks was 96.6 years. Figure A27 shows the distribution of the paybacks for the individual houses. Figure A28 provides the cumulative greenhouse abatement curve for the measure. Around 70% of the total savings are achieved for a payback of less than 10 years.

FIGURE A27: DISTRIBUTION OF PAYBACKS FOR COOLING UPGRADE

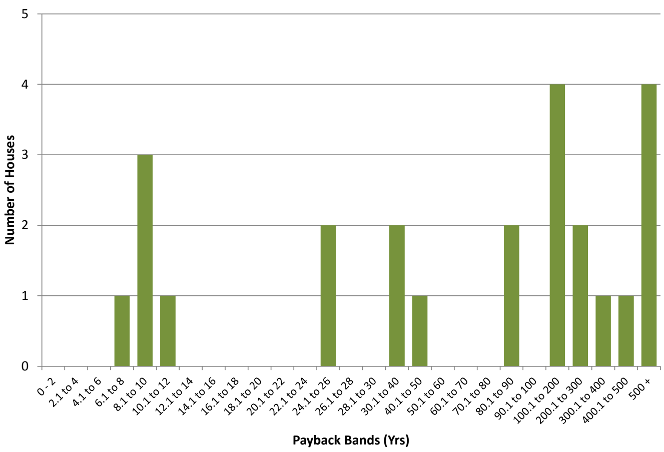
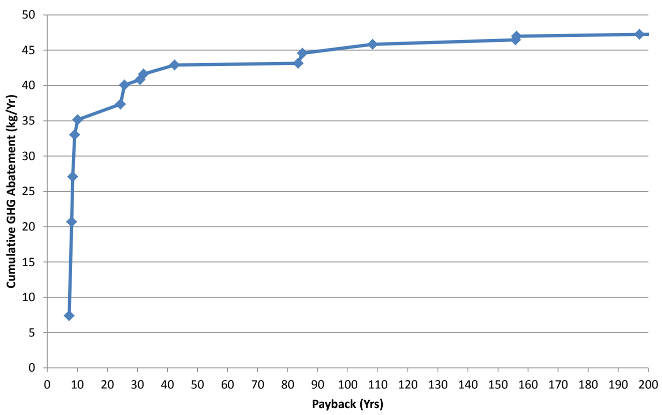


FIGURE A28: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE FOR COOLING UPGRADE



Shower rose upgrade

Showers are one of the main areas of hot water use in houses[99]. Older shower roses can have quite high flow rates (in excess of 12 Litres per minute) and newer shower roses are available in a range of lower flow rates – new shower roses are required to carry a Water Efficiency Label which shows their water efficiency rating (in Stars) as well as their flow rate measured under standard conditions. Replacing older high flow rate shower roses with a new low flow shower rose (3 Stars or 9 litres per minute or less) can therefore save a significant amount of water, hot water and also the energy used for heating the water.

A simple bucket test[100] was used to measure the flow rate of all shower roses found in the OGA study houses, and details of the typical usage of each shower rose (% of showers used for) were also recorded. A total of 87 shower roses were found in the houses or an average of 1.45 per house – 48 (55.2%) of the shower roses had a measured flow rate in excess of 9 Litres per minute. The distribution of the measured flow rates is shown in Figure 13, Chapter 2. The average measured flow rate of all shower roses was 12.6 Litres per minute, and the average measured flow rate at the household level (taking into account the reported extent to which each shower rose was used), was 13.5 Litres per minute.

The replacement of the existing shower rose with a new low flow shower rose was modelled for all shower roses with a measured flow rate equal to or greater than 10 Litres per minute. However, to estimate the water, hot water and energy savings which resulted from the shower rose retrofits, it was necessary to first make some adjustments to the flow rates measured for the shower roses.

A recent end-use metering study by Yarra Valley Water [YVW 2011] found that households that don't have low flow shower roses tend to self-regulate the actual shower flow rate to a much lower level than the flow rate which is measured using the bucket test. They found an average in-use flow rate of 7.3 Litres per minute for all shower roses monitored, 6.3 Litres per minute for the low flow shower roses and only 8.7 Litres per minute for the other (non-low flow) shower roses. To account for these findings and translate the measured shower flow rates into estimated in-use flow rates (eg when people are showering) we made the following assumptions:

- If the flow rate was less than or equal to 6.3 Litre per minute – no change;
- If the flow rate was between 6.3 and 10 Litre per minute – multiply by 0.83;
- If the flow rate was 10 Litre per minute or greater – set the value at the greater of the measured flow rate multiplied by 0.46 or 8.7.

99 We estimate that for the OGA study houses hot water for showering accounted for around 63% of overall household hot water use.
100 Shower turned fully on and time taken to fill a 2.5 litre bucket was recorded.

Adjusting the flow rates to be more consistent with the in-use flow rates measured in the Yarra Valley Water study gave an average in-use flow rate for all shower roses of 8.1 Litres per minute or 8.4 Litres per minute at the household level. The in-use flow rate of the replacement low flow shower rose was assumed to be 6.3 Litres per minute.

A number of further assumptions were made to estimate the annual water and hot water usage for showering in each of the OGA study houses:

- An average of 0.73 showers per day per person [YVW 2011];
- Average length of shower (when the water is flowing) of 7.1 minutes [YVW 2011];
- Average annual cold water temperature of 14.5°C and average hot water temperature of 60°C;
- Average temperature of shower water of 43°C. Most showers are likely to be set so that the water temperature (hot and cold water combined) is in the range of 40 to 42°C. The assumed temperature was set slightly higher than this, to allow for some drop in temperature of the hot water between the water heater and the shower rose.

Based on these assumptions the average annual water use for showering was 45,314 Litres per year and the average annual hot water use for showering was 28,384 Litres per year (26.5 Litres per person per day). Shower rose replacements were modelled for 56.7% of the houses, with an assumed upgrade cost of $75 per shower rose. Following the replacement the average annual water use for showering was estimated to be 35,698 Litres per year and the average annual hot water use for showering was estimated to be 22,360 Litres per year (20.9 Litres per person per day).

The estimated average annual gas and electricity use, greenhouse gas emissions and running cost of the existing water heating systems prior to any upgrades being undertaken is shown in Table A23.

TABLE A23: ESTIMATED AVERAGE ANNUAL ENERGY USE OF EXISTING WATER HEATERS PRIOR TO ANY UPGRADES

Water Heater Type	Gas Use (MJ/Yr)	Elec Use (MJ/Yr)*	Total Energy Use (MJ/Yr)	GHG Emissions (kg/Yr)	Cost ($/Yr)
Gas storage	16,685	-	16,685	920	$292.0
Gas instantaneous	12,730	-	12,730	700	$222.8
Gas boosted solar	8,843	-	8,843	490	$154.7
Electric storage	-	12,871	12,871	3,910	$643.6
Electric boosted solar	-	5,082	5,082	1,540	$254.1
Average household	**13,373**	**1,157**	**14,531**	**1,090**	**$291.9**

* Note that the small electricity use of gas instantaneous and potentially also gas boosted solar water heaters has been ignored for this estimate.

The saving in hot water use from installing a low flow shower rose translates into an energy saving for water heating. The shower rose upgrade was assumed to occur before any water heater upgrades were undertaken. To estimate the annual energy saving the annual hot water saving was first calculated, and this was divided by the conversion efficiency of the existing water heating system (see section below on Water Heating). Both the water and energy savings were calculated, and the annual "bill saving" shown is based on both the energy and water bill saving.

TABLE A24: MODELLED IMPACT OF LOW FLOW SHOWER ROSE RETROFIT

		Energy Saving (MJ/Yr)						
House No.	Water Saving (L/Yr)	Gas	Elec	Total	GHG Saving (Kg/Yr)	Bill Saving ($/Yr)	Cost ($)	Payback (Yrs)
B29	70,942	4,514	0	4,514	249.8	$309.0	$75	0.24
B16	41,430	6,394	0	6,394	353.8	$246.2	$75	0.30
B4	18,161	0	2,211	2,211	671.9	$169.4	$75	0.44
B3	28,377	4,380	0	4,380	242.3	$168.7	$75	0.44
B15	28,377	4,002	0	4,002	221.4	$162.0	$75	0.46
B21	28,377	3,978	0	3,978	220.1	$161.6	$75	0.46
A2	22,702	3,573	0	3,573	197.7	$136.1	$75	0.55
C8	20,715	3,313	0	3,313	183.3	$125.1	$75	0.60
B25	18,161	3,208	0	3,208	177.5	$115.0	$75	0.65
B13	18,161	3,113	0	3,113	172.2	$113.4	$75	0.66
A8	18,161	2,858	0	2,858	158.2	$108.9	$75	0.69
B7	13,621	2,478	0	2,478	137.1	$87.5	$75	0.86
C9	9,081	0	1,105	1,105	335.9	$84.7	$75	0.89
B18	13,459	2,205	0	2,205	122.0	$82.2	$75	0.91
A1	13,569	2,136	0	2,136	118.2	$81.4	$75	0.92
C6	26,918	4,305	0	4,305	238.2	$162.6	$150	0.92
C10	11,815	2,025	0	2,025	112.0	$73.7	$75	1.02
B20	6,729	0	819	819	248.9	$62.8	$75	1.19
B30	20,188	3,299	0	3,299	182.5	$123.2	$150	1.22
B12	19,675	3,130	0	3,130	173.2	$118.6	$150	1.27
B10	9,837	1,548	0	1,548	85.7	$59.0	$75	1.27
B19	8,797	1,724	0	1,724	95.4	$58.7	$75	1.28
B27	9,081	1,620	0	1,620	89.6	$57.8	$75	1.30
B11	20,188	2,847	0	2,847	157.5	$115.3	$150	1.30
B22	9,081	1,604	0	1,604	88.8	$57.5	$75	1.30
C2	9,081	1,604	0	1,604	88.8	$57.5	$75	1.30
A7	9,081	1,583	0	1,583	87.6	$57.1	$75	1.31
C1	9,081	1,572	0	1,572	87.0	$57.0	$75	1.32
B26	9,081	1,401	0	1,401	77.5	$54.0	$75	1.39

House No.	Water Saving (L/Yr)	Energy Saving (MJ/Yr) Gas	Elec	Total	GHG Saving (Kg/Yr)	Bill Saving ($/Yr)	Cost ($)	Payback (Yrs)
B5	7,328	1,033	0	1,033	57.2	$41.8	$75	1.79
B8	13,621	2,144	0	2,144	118.6	$81.7	$150	1.84
B14	5,018	930	0	930	51.5	$32.6	$75	2.30
C12	4,540	726	0	726	40.2	$27.4	$75	2.73
B1	4,540	715	0	715	39.5	$27.2	$75	2.75
Av. - Across Stock	**9,616**	**1,333**	**69**	**1,402**	**94.7**	**$57.9**	**$48.8**	**0.84**
Av. - When Implemented	**16,970**	**2,352**	**122**	**2,473**	**167.1**	**$102.3**	**$86.0**	**0.84**

Replacing an existing shower rose with a low flow shower rose was found to be possible in 34 (56.7%) of the OGA study houses. The modelled energy saving impact of the low flow shower rose retrofit for the individual houses are shown in Table A24. The average impact across the stock of 60 houses, as well as the average impact for the houses in which this measure was modelled is shown. The average impact across the stock is somewhat lower than the average impact in the houses in which this measure was implemented, because this measure was found to be applicable in fewer than 3 out of 5 houses.

The stock average payback for the measure was 0.84 years, making this the most cost effective of the energy efficiency upgrades modelled for the OGA study. The median of the individual paybacks was 1.1 years. In practice, the paybacks may be somewhat better than this. This upgrade can be undertaken as a DIY project, and under the Victorian Energy Saver Incentive scheme, an existing shower rose can be replaced with a low flow shower rose for free.

Figure A29 shows the distribution of the paybacks for the individual houses. Figure A30 provides the cumulative greenhouse abatement curve for the measure. Around 69% of the total savings are achieved for a payback of less than 1 year, and around 98% of the total savings are achieved for a payback of less than 2 years.

FIGURE A29: DISTRIBUTION OF PAYBACKS FOR SHOWER ROSE RETROFIT

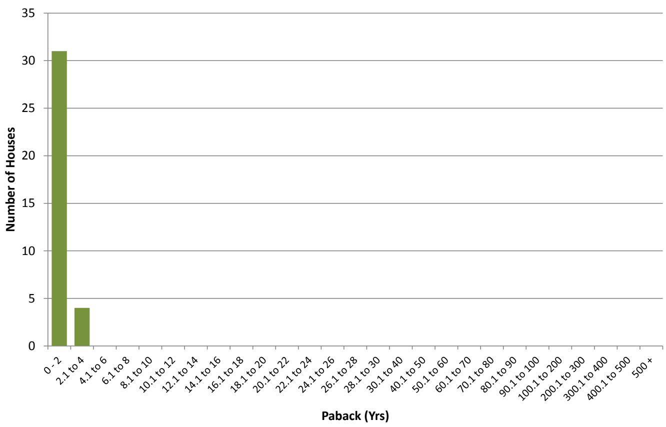
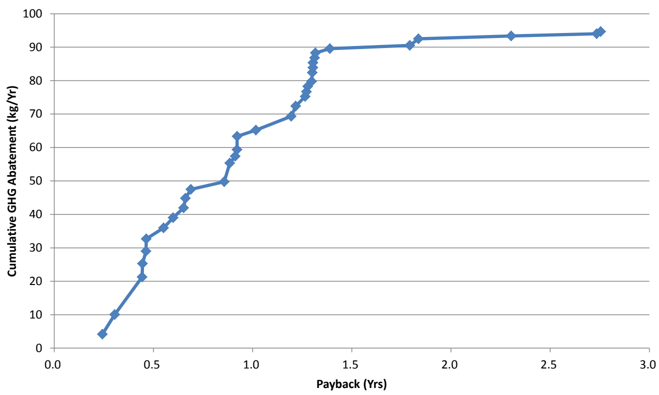


FIGURE A30: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE FOR SHOWER ROSE RETROFIT



Water heating upgrade – high efficiency gas

A summary of the main types of water heating installed in the OGA study houses is provided in Table 11, Chapter 2, and Figures 11 and 12 in this chapter show the distribution of the water heater ages as well as the energy efficiency (Star Rating) profile for the gas water heaters respectively.

Data was collected for the main water heating system found in the OGA study houses, including the type, brand and model number, age, and where available the Energy Rating label data (for the gas water heaters where the label was still affixed) and nameplate details. This data was used to estimate the energy efficiency of the water heaters:

- Where the Energy Rating labels were still affixed to the gas water heaters the Star Rating was obtained directly from the label;
- Where only brand and model number were available for the gas water heaters, either current or historical lists of energy rating data were obtained and used to obtain the Star Rating;
- Where only the age of the water heater was available, the efficiency of the water heater was assumed to be the same as the average efficiency for appliances sold in the year it was purchased, based on [EES 2008].

The Energy Ratings of gas water heaters depend on the thermal efficiency[101] of the water heater and are calculated based on an average daily hot water use of 200 litres per day raised 45°C above the cold water temperature. While published data is available on the Energy Ratings, published data is not available on both the conversion efficiency and the maintenance rate for the gas water heaters[102]. Data tables for both gas storage water heaters and gas instantaneous water heaters prepared by Energy Efficient Strategies [EES 2008] were used as the basis of estimating the thermal efficiency of the gas water heaters from their energy rating. The conversion efficiency of the electric storage water heaters was assumed to be 98% and the maintenance rate was based on the minimum energy performance standard (MEPS) level in operation when the water heater was purchased. The thermal performance of the existing solar water heaters was based on the thermal efficiency of the reference water heaters used in the solar water heater standards (AS4234), and a solar contribution of 60% was assumed.

A water heater upgrade was modelled for all OGA study houses which had an 'inefficient' water heater, as follows:

- Gas storage water heaters with an energy rating of less than 5 Stars were upgraded to a 5.2 Star gas storage water heater;
- Gas instantaneous water heaters with an energy rating of less than 5 Stars were upgraded to a gas instantaneous water heater with a rating of 5.9 Stars;
- All electric storage water heaters were found to be in houses with a reticulated (mains) gas connection, and were assumed to be replaced with a 5.2 Star gas storage water heater;
- No upgrade was modelled for those houses which had either a gas-boosted solar water heater or an electric-boosted solar water heater.

Modelling was also undertaken based on replacing the existing gas and electric storage water heaters with a gas-boosted solar water heater, however this was found to be less cost-effective in most cases compared to replacement with a high efficiency gas water heater. The results for modelling an upgrade to a gas-boosted solar water heater are provided in the next section.

To model the cost-effectiveness of the water heater upgrades, it was first necessary to estimate the amount of hot water each house was using per year. As it was not possible to directly measure the amount of hot water each house was using, the following process was used to estimate the annual hot water usage of the households:

- The hot water usage for showering was estimated based on the number of people in each household, an estimate of the in-use flow rate of the shower rose, and various assumptions concerning showering behaviour in the average household (see Shower Rose above). It was assumed that the water heater upgrade was undertaken after the low flow shower rose upgrade;
- The annual hot water usage of the washing machine and dishwasher (where present and in use) was based on the household's reported use of the appliance and various assumptions concerning average hot water use:
  - It was assumed that 50% of all clothes washing was undertaken on a cold wash cycle and that the average imported[103] hot water use of a top loading washing machine was 60.4 Litres per cycle and of a front loading washing machine was 10.7 Litres per cycle when used on a warm wash cycle[104];
  - It was assumed that the average hot water use of the dishwashers was 4.2 Litres per load[105].
- Houses without a dishwasher were assumed to use 17 litres of hot water per day for hand washing dishes, and houses with a dishwasher were assumed to use 50% of this[106];
- It was assumed that 7.53 Litres per day per person of hot water was used for personal hygiene (baths, hand washing, shaving, etc)[107].

Based on these assumptions it was estimated that the OGA study houses had an average annual hot water use of 39,315 Litres per year, or around 108 Litres per day after the low flow shower rose upgrade had been applied[108]. As the OGA study houses had a higher penetration of front load washing machines compared to the Victorian average – 55% compared to 33.5% - the average hot water usage of these houses is likely to be below the overall Victorian average.

101 This includes both the efficiency of either the gas burner or electric element of converting the energy input into hot water (conversion efficiency) as well as the energy input required for any gas pilot light or to account for losses through the wall of storage water heaters during the day (maintenance rate). In the case of the solar water heaters an annual average solar contribution was assumed, reducing the annual energy input required for a certain amount of water heated.

102 Different combinations of conversion efficiency and maintenance rate can give the same energy rating.

103 This is the hot water which is sourced from the water heating system. Some washing machines, especially front loading machines, will heat water internally.

104 Frequency of cold water washing was based on usage reported by a washing machine manufacturer based on analysis of data downloaded from machines in the field. Average hot water usage figures based on [EES 200] using figures for 2006.

105 Based on [EES 2008] using data from 2006. This assumes average total water use of 17.1 Litres per load, and that 24% of the dishwashers are connected to a hot water supply.

106 Little data is available on hot water use for washing dishes by hand. It was assumed that there was on average 1.5 washes per day, with the average wash using 12 Litres of water (78% or 9.4 Litres of which was hot water) and had 2 Litres of hot water wasted in "pipe losses".

107 The [YVW 2011] study reported an average of 3.24 Litres per person to day for baths, or around 1.53 Litres per day per person of hot water. We have allowed 2 Litres per person per day for other uses and 4 Litres per person of "pipe losses", giving a total of 7.53 Litres per person per day.

108 Prior to the low flow shower rose upgrade it was estimated that the average OGA study house had an annual hot water use of 45,339 Litres per year or 124 Litres per day.

The estimated annual energy use of the water heaters found in the OGA study houses prior to any (low flow shower rose or water heater) upgrades is shown in Table A23 above. The estimated annual energy use of the water heaters after the low flow shower rose upgrade, and prior to the water heater upgrade is shown in Table 25.

The calculation of the paybacks for the water heater upgrades use the adjusted capital cost rather than the full replacement costs, in recognition that in most cases this replacement will only be made at the end of life of the existing water heater. The calculation of the adjusted capital cost required both the average lifetime of the water heating system to be assumed, as well as the differential cost between the current market average water heater and the replacement high efficiency gas water heater. The assumptions used in this study are detailed in Table A26.

TABLE A25: ESTIMATED AVERAGE ANNUAL ENERGY USE OF EXISTING WATER HEATERS PRIOR TO WATER HEATER UPGRADES

Water Heater Type	Gas Use (MJ/Yr)	Elec Use (MJ/Yr)*	Total Energy Use (MJ/Yr)	GHG Emissions (kg/Yr)	Cost ($/Yr)
Gas storage	15,115	-	15,115	840	$264.5
Gas instantaneous	11,337	-	11,337	630	$198.4
Gas boosted solar	7,713	-	7,713	430	$135.0
Electric storage	-	12,044	12,044	3,660	$602.2
Electric boosted solar	-	5,082	5,082	1,540	$254.1
Average household	**12,040**	**1,004**	**13,128**	**1,000**	**$265.1**

* Note that the small electricity use of gas instantaneous and potentially also gas boosted solar water heaters has been ignored for this estimate.

TABLE A26: ASSUMPTIONS USED TO CALCULATE ADJUSTED CAPITAL COST OF NEW GAS WATER HEATER

Heating Type	Lifetime (Yrs)[109]	Appliance Replacement Cost ($)[110]	Installation Cost ($)	Differential Cost at End Life [111]
Gas storage	12	$1,300	$378	$423
Gas instantaneous	13	$1,230	$378 $1,651 if old unit replaced	$230
Electric storage water heater	13	$1,300	$1,130	$1,325

109 Lifetimes for water heaters based on [BIS Shrapnel 2012c].
110 Appliance and installation costs provided by MEFL/RMIT.
111 Cost differentials based on cost of new high efficiency replacement water heaters and average cost of the different types of water heaters reported in [BIS Shrapnel 2012c]. The cost for replacing an electric water heater with high efficiency gas takes into account the additional cost of reticulating the gas supply to the water heater.

TABLE A27: MODELLED IMPACT OF WATER HEATER UPGRADE – HIGH EFFICIENCY GAS

		Energy Saving (MJ/Yr)						
House No.	Water Heater Type	Gas	Elec	Total	GHG Saving (kg/Yr)	Bill Saving ($/Yr)	Adjusted Cost ($)	Payback (Yrs)
A7	Gas Instantaneous	5,257	0	5,257	291	$92.0	$230	2.5
B18	Gas Instantaneous	4,804	0	4,804	266	$84.1	$230	2.7
B4	Electric Storage	-17,658	15,247	-2,411	3,656	$453.3	$1,325	2.9
A14	Electric Storage	-15,372	13,262	-2,110	3,180	$394.1	$1,410	3.6
B17	Electric Storage	-18,456	15,572	-2,884	3,711	$455.6	$1,665	3.7
A12	Gas Storage	5,801	0	5,801	321	$101.5	$423	4.2
A5	Gas Storage	5,650	0	5,650	313	$98.9	$423	4.3
C9	Electric Storage	-10,623	9,138	-1,485	2,189	$271.0	$1,325	4.9
B30	Gas Storage	4,626	0	4,626	256	$81.0	$423	5.2
B24	Gas Storage	4,377	0	4,377	242	$76.6	$423	5.5
A2	Gas Storage	3,823	0	3,823	212	$66.9	$423	6.3
A6	Gas Storage	3,652	0	3,652	202	$63.9	$423	6.6
A8	Gas Storage	3,567	0	3,567	197	$62.4	$423	6.8
C5	Gas Storage	3,241	0	3,241	179	$56.7	$423	7.5
B8	Gas Storage	3,186	0	3,186	176	$55.8	$423	7.6
C8	Gas Storage	3,088	0	3,088	171	$54.0	$423	7.8
B20	Electric Storage	-8,160	6,999	-1,161	1,676	$207.2	$1,750	8.4
A3	Gas Storage	4,081	0	4,081	226	$71.4	$632	8.9
B10	Gas Storage	2,723	0	2,723	151	$47.6	$423	8.9
C12	Gas Storage	3,041	0	3,041	168	$53.2	$528	9.9
A9	Gas Storage	3,514	0	3,514	194	$61.5	$632	10.3
B16	Gas Storage	2,432	0	2,432	135	$42.6	$528	12.4
C7	Gas Instantaneous	2,210	0	2,210	122	$38.7	$522	13.5
C6	Gas Storage	4,263	0	4,263	236	$74.6	$1,051	14.1
B2	Gas Storage	2,868	0	2,868	159	$50.2	$737	14.7

		Energy Saving (MJ/Yr)						
House No.	Water Heater Type	Gas	Elec	Total	GHG Saving (kg/Yr)	Bill Saving ($/Yr)	Adjusted Cost ($)	Payback (Yrs)
B12	Gas Storage	3,299	0	3,299	183	$57.7	$946	16.4
B3	Gas Storage	2,922	0	2,922	162	$51.1	$841	16.5
A1	Gas Storage	3,503	0	3,503	194	$61.3	$1,051	17.1
B1	Gas Storage	3,019	0	3,019	167	$52.8	$1,051	19.9
B7	Gas Instantaneous	1,170	0	1,170	65	$20.5	$548	26.8
B26	Gas Storage	2,423	0	2,423	134	$42.4	$1,521	35.9
A4	Gas Storage	1,919	0	1,919	106	$33.6	$1,260	37.5
B19	Gas Instantaneous	1,347	0	1,347	75	$23.6	$1,290	54.7
B14	Gas Instantaneous	1,047	0	1,047	58	$18.3	$1,396	76.2
B28	Gas Storage	996	0	996	55	$17.4	$1,521	87.2
Av. - Across Stock		**460**	**1,004**	**1,463**	**330**	**$58.2**	**$477.3**	**8.2**
Av. - When Implemented		**788**	**1,721**	**2,509**	**566**	**$99.8**	**$818.3**	**8.2**
Av .- Gas storage		3,417	0	3,417	189	$59.8	$706.2	11.8
Av. - Gas instantaneous		2,639	0	2,639	146	$46.2	$702.6	15.2
Av. - Electric storage		-14,054	12,044	-2,010	2,882	$356.2	$1,495.0	4.2

Upgrading the existing water heating system to a high efficiency gas water heating system was found to be possible in 35 (58.3%) of the OGA study houses. The modelled energy saving impact of this water heater upgrade for the individual houses – when applied after the low flow shower rose upgrade - is shown in Table A27. The average impact across the stock of 60 houses, as well as the average impact for the houses in which this measure was modelled is shown. A breakdown of the results is also provided based on the type of existing water heating system. The average impact across the stock is lower than the average impact in the houses in which this measure was implemented, because this measure was found to be applicable in 3 out of 5 houses.

The annual greenhouse and energy bill savings were much higher for the electric water heater upgrade compared to the gas water heater upgrades, reflecting the much higher greenhouse intensity of electricity and the higher cost of electricity compared to gas. This resulted in a lower average payback for the electric water heater upgrade compared to the gas water heater upgrade, even though the upgrade cost was higher. An incentive is currently available for replacing an existing electric water heater with a high efficiency gas water heater under the Victorian *Energy Saver Incentive* Scheme. This could mean that in practice the upgrade costs are somewhat lower than shown in Table A27, and the payback period also lower, making this a very cost effective upgrade.

For the gas water heaters, the energy, greenhouse gas and energy bill savings were higher when a gas storage water heater was upgraded compared to an instantaneous gas water heater. This reflects the higher average efficiency of the existing instantaneous gas water heaters compared to the existing gas storage water heaters.

The stock average payback for the measure was 8.2 years and the median of the individual paybacks was 8.9 years. Figure A31 shows the distribution of the paybacks for the individual houses. Figure A32 provides the cumulative greenhouse abatement curve for the measure. Around 70% of the total savings are achieved for a payback of less than 5 years, and around 90% of the total savings are achieved for a payback of less than 10 years, with the majority of the savings resulting from the replacement of the electric water heaters with high efficiency gas water heaters.

FIGURE A31: DISTRIBUTION OF PAYBACKS FOR WATER HEATER UPGRADE – HIGH EFFICIENCY GAS

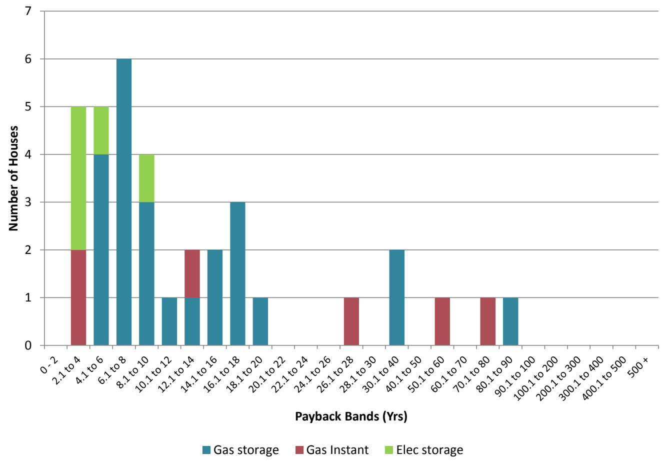
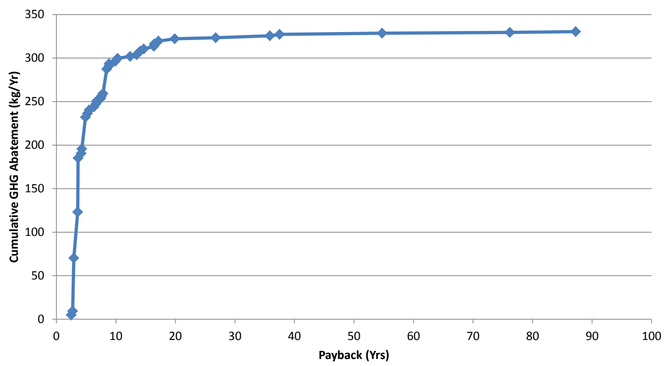


FIGURE A32: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE FOR HIGH EFFICIENCY GAS WATER HEATER



Water heating upgrade – gas boosted solar

In addition to modelling the replacement of the existing water heating system with a high efficiency gas water heater (see Water Heater – High Efficiency Gas above), we also modelled the replacement of the existing water heater with a gas-boosted solar system. A water heater upgrade was modelled for all OGA study houses which had:

- A gas storage or gas instantaneous water heater if the daily household hot water consumption was greater than 50 Litres per day following the installation of a low flow shower rose. Below this level of hot water use it was difficult to estimate the energy saving which was likely to be achieved, and also the paybacks were likely to be quite long;
- An electric storage water heater;
- No upgrade was modelled for those houses which had either a gas-boosted solar water heater or an electric-boosted solar water heater.

The average daily hot water use for each of the houses and the energy efficiency of the existing water heater was determined in the same was as for the upgrade to a high efficiency gas water heater (see the previous section). Where a gas-boosted solar water heater upgrade was modelled the choice of the replacement system depended on the daily hot water use of the household:

- Where the daily hot water use was less than 150 Litres per day, the replacement system was assumed to be one with a 71% solar contribution when rated on a small load (equivalent to 120 Litres per day raised by 45°C);
- Where the daily hot water use was equal to or greater than 150 Litres per day, the replacement system was assumed to be one with a 72% solar contribution when rated on a medium load (equivalent to 200 Litres per day raised by 45°C).

Estimating the annual energy consumption of solar water heaters is challenging, as the energy input for the water heater comes from both solar energy (via the solar collector) and the boost energy source (gas for a gas-boosted solar water heater). The solar water heater test standard AS4234 assesses the solar contribution[112] at a certain daily hot water use, but in practice the actual solar contribution depends on how much hot water a particular household uses. To account for this, the following formula was used to convert the rated solar contribution into an estimate of the actual solar contribution[113]:

$$SC = SC_{rated} - \{[(\text{daily hot water use} / \text{rated hot water use}) - 1]\} \times 0.21$$

Where

SC = Actual solar contribution, expressed as a fraction between 0 and 1

SC_{rated} = Rated solar contribution, expressed as a fraction between 0 and 1

The estimated annual energy use of the solar water heater was the annual energy use of the reference solar water heater for the daily hot water use of each house, multiplied by 1 minus SC.

The calculation of the paybacks for the water heater upgrades use the adjusted capital cost rather than the full replacement costs, in recognition that in most cases this replacement will only be made at the end of life of the existing water heater. The calculation of the adjusted capital cost required both the average lifetime of the water heating system to be assumed, as well as the differential cost between the current market average water heater and the replacement gas-boosted solar water heater. The assumptions used in this study are detailed in Table A28 below. The differential costs do not include any government incentive which may be available for installing a gas boosted solar water heater.

112 This is the proportion of the water heater's annual energy use which is provided by solar energy, expressed as a percentage or a number between 0 and 1. The solar contribution is calculated with reference to a "reference water heater" with certain assumed characteristics. For gas boosted solar water heaters it is a system with the performance equivalent to a 3 star gas water heater – assumed to have a conversion efficiency of 75% and a daily maintenance rate of 18 MJ/day.

113 When the daily hot water use of the household is less than the rated hot water use of the solar water heater, the actual solar contribution is greater than the rated contribution. When the daily hot water use is greater than the rated hot water use of the solar water heater, the actual solar contribution is less than the rated contribution.

TABLE A28: ASSUMPTIONS USED TO CALCULATE ADJUSTED CAPITAL COST OF NEW GAS-BOOSTED SOLAR WATER HEATER

Heating Type	Lifetime (Yrs)[114]	Appliance and Installation Cost ($)[115]	Differential Cost at End Life[116]
Gas storage	12	$5,400 - $6,300	$4,145
Gas instantaneous	13	$5,400 - $6,300	$4,022
Electric storage water heater	13	$5,750 - $6,650	$4,645

114 Lifetimes for water heaters based on [BIS Shrapnel 2012c].

115 Prices based on RRP listed on SV solar water heater rebate website April 2013. Higher price is for unit rated for medium delivery. Prices do not include any rebates or other incentives.

116 Cost differentials based on cost of new high efficiency replacement water heaters and average cost of the different types of water heaters reported in [BIS Shrapnel 2012c]. The cost for replacing an electric water heater with high efficiency gas takes into account the additional cost of reticulating the gas supply to the water heater.

TABLE A29: MODELLED IMPACT OF WATER HEATER UPGRADE – GAS-BOOSTED SOLAR WATER HEATER

House No.	Water Heater Type	Gas	Elec	Total	GHG Saving (kg/Yr)	Bill Saving ($/Yr)	Adjusted Cost ($)	Payback (Yrs)
B4	Electric storage	-5,346	14,900	9,554	4,230	$651.5	$4,645	7.1
B17	Electric storage	-5,801	15,225	9,424	4,310	$659.7	$5,262	8.0
A14	Electric storage	-6,201	13,027	6,827	3,620	$542.9	$4,730	8.7
C9	Electric storage	-3,055	8,903	5,849	2,540	$391.7	$4,145	10.6
A3	Gas storage	17,575	-347	17,228	870	$290.2	$4,504	15.5
A2	Gas storage	15,895	-347	15,548	770	$260.8	$4,145	15.9
B20	Electric storage	-1,855	6,764	4,910	1,950	$305.8	$5,070	16.6
A12	Gas storage	14,937	-235	14,702	760	$249.6	$4,145	16.6
A5	Gas storage	14,600	-235	14,365	740	$243.8	$4,145	17.0
B30	Gas storage	13,438	-235	13,203	670	$223.4	$4,145	18.6
A6	Gas storage	12,901	-235	12,666	640	$214.0	$4,145	19.4
A8	Gas storage	12,663	-235	12,428	630	$209.9	$4,145	19.8
C6	Gas storage	15,923	-347	15,576	780	$261.3	$5,223	20.0
A9	Gas storage	12,500	-235	12,265	620	$207.0	$4,354	21.0
C7	Gas instantaneous	12,596	-347	12,249	590	$203.1	$4,325	21.3
B8	Gas storage	11,306	-235	11,071	550	$186.1	$4,145	22.3
B24	Gas storage	10,655	-235	10,420	520	$174.7	$4,022	23.0
A1	Gas storage	12,466	-235	12,231	620	$206.4	$4,773	23.1
B3	Gas storage	11,915	-235	11,680	590	$196.8	$4,563	23.2
C5	Gas storage	10,530	-235	10,295	510	$172.5	$4,145	24.0
B6	Gas instantaneous	13,110	-347	12,763	620	$212.1	$5,249	24.7
A7	Gas instantaneous	9,486	-235	9,251	450	$154.3	$4,022	26.1
B18	Gas instantaneous	9,390	-235	9,155	450	$152.6	$4,022	26.4
B12	Gas storage	10,788	-235	10,553	530	$177.0	$4,668	26.4
B16	Gas storage	9,597	-235	9,362	460	$156.2	$4,250	27.2
B1	Gas storage	10,567	-235	10,332	510	$173.2	$4,773	27.6
B2	Gas storage	9,819	-235	9,584	470	$160.1	$4,459	27.9
B5	Gas storage	12,771	-347	12,424	600	$206.1	$5,761	27.9

House No.	Water Heater Type	Gas	Elec	Total	GHG Saving (kg/Yr)	Bill Saving ($/Yr)	Adjusted Cost ($)	Payback (Yrs)
B21	Gas storage	10,605	-235	10,370	520	$173.8	$5,086	29.3
B28	Gas storage	10,305	-235	10,070	500	$168.6	$5,243	31.1
A13	Gas storage	9,467	-235	9,232	450	$153.9	$4,877	31.7
C14	Gas storage	9,448	-235	9,213	450	$153.6	$4,877	31.8
B25	Gas instantaneous	10,293	-347	9,946	460	$162.8	$5,249	32.2
A4	Gas storage	9,175	-235	8,940	440	$148.8	$4,982	33.5
B26	Gas storage	9,545	-235	9,310	460	$155.3	$5,243	33.8
B11	Gas storage	8,795	-235	8,560	420	$142.2	$5,191	36.5
B13	Gas instantaneous	7,232	-235	6,997	330	$114.8	$4,340	37.8
B15	Gas storage	7,988	-235	7,753	370	$128.0	$5,191	40.5
B7	Gas instantaneous	6,784	-235	6,549	300	$107.0	$4,340	40.6
C3	Gas instantaneous	7,027	-235	6,792	320	$111.2	$4,563	41.0
C4	Gas instantaneous	8,035	-235	7,800	370	$128.9	$5,369	41.7
C13	Gas storage	7,718	-235	7,483	360	$123.3	$5,191	42.1
A10	Gas instantaneous	7,545	-235	7,310	350	$120.3	$5,082	42.2
C2	Gas instantaneous	5,737	-235	5,502	250	$88.6	$4,354	49.1
B27	Gas instantaneous	5,082	-235	4,847	210	$77.2	$4,658	60.4
B14	Gas instantaneous	5,493	-235	5,258	230	$84.4	$5,188	61.5
B19	Gas instantaneous	5,303	-235	5,068	220	$81.1	$5,082	62.7
C1	Gas instantaneous	4,286	-235	4,051	170	$63.3	$4,145	65.5
B22	Gas instantaneous	4,825	-235	4,590	200	$72.7	$5,294	72.8
Av. - All houses		**7,064**	**795**	**7,859**	**630**	**$163.4**	**$3,825.4**	**23.4**
Av. - When Implemented		**8,650**	**973**	**9,624**	**770**	**$200.0**	**$4,684.1**	**23.4**
Av. - Gas storage		11,568	-251	11,317	560	$189.9	$4,656.8	24.5
Av. - Gas instantaneous		7,639	-256	7,383	340	$120.9	$4,705.1	38.9
Av. - Electric storage		-4,451	11,764	7,313	3,330	$510.3	$4,770.4	9.3

Upgrading the existing water heating system to gas boosted solar water heating system was found to be possible in 49 (81.7%) of the OGA study houses. The modelled energy saving impact of this water heater upgrade for the individual houses – when applied after the low flow shower rose upgrade - is shown in Table A29. The average impact across the stock of 60 houses, as well as the average impact for the houses in which this measure was modelled is shown. A breakdown of the results is also provided based on the type of existing water heating system. The average impact across the stock is slightly lower than the average impact in the houses in which this measure was implemented, because this measure was found to be applicable in four out of five houses.

The annual greenhouse and energy bill savings were much higher for the electric water heater upgrade compared to the gas water heater upgrades, reflecting the much higher greenhouse intensity of electricity and the higher cost of electricity compared to gas. This resulted in a significantly lower average payback for the electric water heater upgrades compared to the gas water heater upgrades, even though the upgrade cost was slightly higher. An incentive is available for replacing both existing electric and gas water heaters with a gas-boosted solar water heater under the Victorian Government's Energy Saver Incentive Scheme[117], and an incentive for installing a new solar water heater is also available via Small Technology Certificates (STCs). This would mean that in practice the upgrade costs are somewhat lower than shown in Table A29, and the payback period also lower. In particular, this makes replacing an existing electric water heater with a gas boosted solar water heater a very cost effective option where a household has mains gas reticulated to the property.

For the gas water heaters, the energy, greenhouse and energy bill savings were higher when a gas storage water heater was upgraded compared to an instantaneous gas water heater. This reflects the higher average efficiency of the existing instantaneous gas water heaters compared to the existing gas storage water heaters.

The stock average payback for the measure was 23.4 years and the median of the individual paybacks was 27.2 years. Figure A33 shows the distribution of the paybacks for the individual houses. Figure A34 provides the cumulative greenhouse abatement curve for the measure. Around 38% of the total savings are achieved for a payback of less than 10 years, and around 59% of the total savings are achieved for a payback of less than 20 years, with the majority of the savings resulting from the replacement of the electric water heaters with the gas boosted solar water heaters.

FIGURE A33: DISTRIBUTION OF PAYBACKS FOR WATER HEATER UPGRADE – GAS BOOSTED SOLAR WATER HEATER

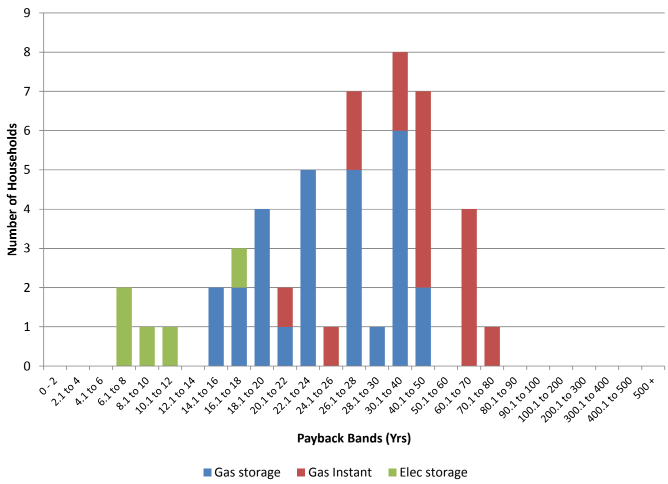
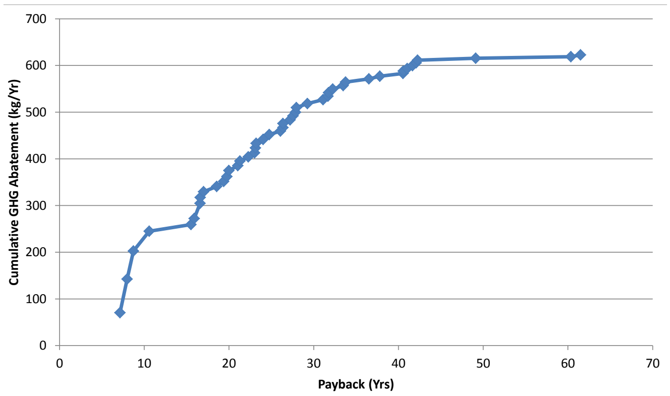


FIGURE A34: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE FOR GAS BOOSTED SOLAR WATER HEATER



117 An incentive is also available for replacing the electric water heater with either a high efficiency gas water heater or a solar-electric or heat pump water heater.

Refrigerator upgrade

A summary of the main types of refrigerators[118] installed in the OGA study houses is provided in Table 12, Chapter 2, and Figures 14 and 15 in this chapter show the distribution of the refrigerator ages as well as the energy efficiency (star rating) profile for the refrigerators. A total of 75 refrigerators were found in the 60 houses, giving an average ownership of 1.25 per house.

Data was collected for refrigerators found in the OGA study houses, including the type, brand and model number, age, and where available the Energy Rating label data (where label was still affixed) and nameplate details. This data was used to estimate the energy efficiency of the refrigerators:

- Where the Energy Rating labels were still affixed to the refrigerators, the Star Rating and Comparative Energy Consumption[119] was obtained directly from the label – for this study the Star Rating used is based on the 2010 energy rating algorithms[120];
- Where only brand and model number were available for the refrigerators, either current or historical lists of energy rating data were obtained and used to obtain the Star Rating (based on the 2010 rating scale) and the Comparative Energy Consumption;
- Where only the age and type of the refrigerator was available, the Comparative Energy Consumption of the refrigerator was assumed to be the same as the average for that type of refrigerator sold in the year it was purchased, based on [EES 2008].

The Comparative Energy Consumption of the refrigerators was used to estimate their annual energy consumption. The tested CEC figure was discounted by 15% to give an estimate of the annual energy consumption which was more realistic for Victorian climates. The annual energy consumption figure was also adjusted to take into account the likely degradation in the performance of the refrigerator over its lifetime:

- If the refrigerator was 5 years old or less, no adjustment was made;
- If the refrigerator was more than 5 years old, the annual energy consumption was increased by 1.5% for every year from 5 years to the age of the refrigerator. The energy consumption of a refrigerator that was 10 years old was increased by 7.5%, while the energy consumption of a refrigerator that was 20 years old was increased by 22.5%.

The estimated average annual energy use, greenhouse gas emissions and running costs of the existing refrigerators is shown in Table A30. Figures are shown for both the individual refrigerators as well as for the average household.

118 Includes 2-door fridges (separate fresh food and freezer compartments), 1-door fridge (fresh food section and temporary freezer located in the one compartment), chest freezer and upright freezer.

119 The Comparative Energy Consumption (CEC) is the annual energy consumption (kWh per year) of the refrigerator when tested under standard conditions.

120 The energy rating algorithms used to assign the Star Ratings for refrigerators were revised in 2000 and then again in 2010. The effect of these revisions is to reduce the number of stars allocated for a certain level of energy efficiency performance.

TABLE A30: ESTIMATED AVERAGE ANNUAL ENERGY USE OF EXISTING REFRIGERATORS

Refrigerator Type	Electricity Use (kWh/Yr)	GHG Emissions (kg/Yr)	Running Cost ($/Yr)
2-door refrigerator	604	661	$169
1-door refrigerator	404	442	$113
Chest freezer	395	433	$111
Upright freezer	505	553	$142
Average refrigerator	**569**	**623**	**$159**
Average household	**711**	**779**	**$199**

A refrigerator upgrade was modelled in the following cases, based on the refrigerators which were available in the market in August 2012:

- 2-door refrigerators with a total capacity less than 300 Litres and an Energy Rating of 1.5 Stars or less were upgraded to a refrigerator with a rating of 2 or 2.5 Stars, depending on the capacity of the refrigerator;
- 2-door refrigerators with a total capacity of 300 Litres or more and an Energy Rating of 2.5 Stars or less were upgraded to a refrigerator with a rating of 3, 3.5 or 4 Stars, depending on the capacity of the refrigerator;
- 1-door refrigerators with a total capacity less than 200 Litres and an Energy Rating of 2.5 Stars or less were upgraded to a refrigerator with a rating of 3 Stars;
- 1-door refrigerators with a total capacity of 200 Litres or more and an energy rating of 1.5 Stars or less were upgraded to a refrigerator with a rating of 2 Stars;
- Chest freezers with a total capacity less than 250 Litres and an energy rating of 2.5 Stars or less were upgraded to a chest freezer with a rating of 3 Stars;
- Chest freezers with a total capacity of 250 Litres or more and an energy rating of 2 Stars or less were upgraded to a chest freezer with a rating of 2.5 Stars;
- Upright freezers with a star rating of less than 3 Stars were upgraded to an upright freezer with a Star rating of 3.5 stars.

The total capacity of the replacement refrigerator was chosen to be similar to the total capacity of the existing refrigerator.

The calculation of the paybacks for the refrigerator upgrades use the adjusted capital cost rather than the full replacement costs, in recognition that in most cases this replacement will only be made at the end of life of the existing refrigerator. The calculation of the adjusted capital cost required both the average lifetime of the refrigerator to be assumed, as well as the differential cost between the current market average refrigerator and the replacement high efficiency refrigerator. The assumptions used in this study are detailed in Table A31 below.

TABLE A31: ASSUMPTIONS USED TO CALCULATE ADJUSTED CAPITAL COST OF NEW REFRIGERATOR

Refrigerator Type & Volume	Lifetime (Yrs)[121]	Replacement Appliance Cost[122]	Differential Cost at End Life[123]
2-door, 200 to 350 Litres	17	$653	$161
2-door, 350 to 470 Litres	17	$1,377	$574
2-door, 470 to 600 Litres	17	$1,752	$618
2-door, > 600 Litres	17	$2,980	$1,360
1-door refrigerator < 200 Litres	17	$396	$216
1-door refrigerator > 200 Litres	17	$983	$275
Chest freezer < 250 Litres	17	$377	$190
Chest freezer > 250 Litres	17	$616	$311
Upright freezer	17	$1,599	$807

121 The assumed life is based on [EES 1999].
122 Prices from www.getprice.com.au, August 2012.
123 The differential cost is based on the difference between the cost of the upgrade refrigerator models (calculated from the www.getprice.com.au website in August 2012), and the average sale price of different types and capacity ranges of refrigerators estimated from Gfk June 2012 refrigerator sales data.

TABLE A32: MODELLED IMPACT OF THE REFRIGERATOR UPGRADE

House No.	Type of Fridge	Elec Saving (kWh/Yr)	Elec Saving (MJ/Yr)	GHG Saving (kg/Yr)	Bill Saving ($/Yr)	Adjusted Cost ($)	Payback (Yrs)
B10	1 door fridge	452	1,628	495	$126.6	$216.0	1.7
B28	2 door fridge	917	3,300	1,003	$256.7	$574.0	2.2
C9.2	chest freezer	295	1,063	323	$82.6	$190.4	2.3
B20	2 door fridge	767	2,762	839	$214.9	$574.0	2.7
B6.1	1 door fridge	363	1,306	397	$101.6	$275.0	2.7
C4.1	2 door fridge	707	2,544	773	$197.9	$574.0	2.9
C14	2 door fridge	718	2,586	786	$201.2	$618.0	3.1
B2	2 door fridge	636	2,290	696	$178.1	$574.0	3.2
B21.2	2 door fridge	603	2,172	660	$168.9	$574.0	3.4
A15	2 door fridge	522	1,879	571	$146.2	$574.0	3.9
C3.2	upright freezer	619	2,229	677	$173.4	$807.4	4.7
B30.1	2 door fridge	567	2,043	621	$158.9	$751.4	4.7
B27.2	1 door fridge	194	700	213	$54.4	$290.1	5.3
C9.1	2 door fridge	510	1,837	558	$142.9	$762.9	5.3
B30.2	1 door fridge	188	677	206	$52.6	$290.1	5.5

House No.	Type of Fridge	Elec Saving (kWh/Yr)	Elec Saving (MJ/Yr)	GHG Saving (kg/Yr)	Bill Saving ($/Yr)	Adjusted Cost ($)	Payback (Yrs)
B9	2 door fridge	424	1,525	464	$118.6	$668.5	5.6
B5	2 door fridge	554	1,995	606	$155.2	$884.8	5.7
B14.3	2 door fridge	375	1,349	410	$105.0	$668.5	6.4
C1.2	1 door fridge	162	585	178	$45.5	$290.1	6.4
B6.2	upright freezer	445	1,600	486	$124.5	$807.4	6.5
C1.1	2 door fridge	396	1,426	433	$110.9	$762.9	6.9
B23	2 door fridge	170	611	186	$47.5	$363.6	7.6
C3.1	2 door fridge	721	2,595	789	$201.8	$1,550.6	7.7
B17	2 door fridge	369	1,330	404	$103.4	$904.6	8.7
A11	2 door fridge	378	1,361	414	$105.9	$999.1	9.4
B13	2 door fridge	731	2,630	799	$204.6	$2,027.1	9.9
B25.1	1 door fridge	203	732	223	$57.0	$566.5	9.9
A14	2 door fridge	312	1,122	341	$87.3	$904.6	10.4
A3	2 door fridge	348	1,252	380	$97.4	$1,046.4	10.7
C13	2 door fridge	696	2,506	761	$194.9	$2,217.6	11.4
B8	2 door fridge	281	1,013	308	$78.8	$999.1	12.7
B29	2 door fridge	379	1,364	415	$106.1	$1,351.8	12.7
C8	2 door fridge	217	782	238	$60.8	$810.2	13.3
B18	2 door fridge	362	1,302	396	$101.3	$1,351.8	13.3
C7	2 door fridge	244	879	267	$68.4	$951.9	13.9
B16	2 door fridge	352	1,267	385	$98.5	$1,418.5	14.4
A6	2 door fridge	198	714	217	$55.5	$951.9	17.2
B21.1	2 door fridge	451	1,624	493	$126.3	$2,408.2	19.1
A10	2 door fridge	184	663	201	$51.5	$1,046.4	20.3
A13.1	2 door fridge	184	663	201	$51.5	$1,046.4	20.3
A8	2 door fridge	209	753	229	$58.5	$1,235.3	21.1
B14.1	2 door fridge	344	1,239	377	$96.4	$2,217.6	23.0
C11	2 door fridge	238	857	260	$66.6	$1,551.9	23.3
C15	2 door fridge	206	740	225	$57.6	$1,351.8	23.5
A4	2 door fridge	193	695	211	$54.0	$1,618.6	30.0
B25.2	chest freezer	49	178	54	$13.8	$436.6	31.6

House No.	Type of Fridge	Elec Saving (kWh/Yr)	Elec Saving (MJ/Yr)	GHG Saving (kg/Yr)	Bill Saving ($/Yr)	Adjusted Cost ($)	Payback (Yrs)
A9	2 door fridge	126	453	138	$35.2	$1,140.8	32.4
B3	2 door fridge	128	459	139	$35.7	$1,235.3	34.6
C10	2 door fridge	169	609	185	$47.4	$1,718.6	36.3
A1	2 door fridge	129	465	141	$36.2	$1,418.5	39.2
C6.1	2 door fridge	129	465	141	$36.2	$1,418.5	39.2
A5	2 door fridge	99	358	109	$27.8	$1,140.8	41.0
C12	2 door fridge	129	465	141	$36.2	$1,518.5	42.0
A7	2 door fridge	107	386	117	$30.0	$1,418.5	47.3
B4	2 door fridge	181	652	198	$50.7	$2,789.4	55.0
A2	1 door fridge	43	156	48	$12.2	$733.1	60.2
C5	2 door fridge	138	496	151	$38.6	$2,598.8	67.4
B19.2	chest freezer	15	55	17	$4.3	$355.0	82.9
B27.1	2 door fridge	123	444	135	$34.5	$2,884.7	83.6
B12	2 door fridge	9	33	10	$2.6	$294.6	114.7
B1	2 door fridge	65	236	72	$18.3	$2,503.5	136.6
Av. - Across Stock		**334**	**1,202**	**365**	**$93.5**	**$1,103.7**	**11.8**
Av. - When Implemented		**328**	**1,182**	**359**	**$91.9**	**$1,085.6**	**11.8**
Av. - 2-door fridge		346.9	1,248.8	379	$97.1	$1,244.2	12.8
Av. - 1-door fridge		229.5	826.3	251	$64.3	$380.1	5.9
Av. - Chest freezer		119.9	431.8	131	$33.6	$327.3	9.7
Av. - Upright freezer		531.9	1,914.8	582	$148.9	$807.4	5.4

Upgrading an existing inefficient refrigerator to a high efficiency refrigerator was found to be possible for 61 (81.3%) of the refrigerators found in the OGA study houses. The upgrade of one or more refrigerators was modelled for 52 (86.7%) for the houses. The modelled energy saving impact of the refrigerator upgrade is shown in Table A32. The average impact across the stock of 60 houses, as well as the average impact for the houses in which this measure was modelled is shown. A breakdown of the results is also provided based on the type of existing refrigerator. The average impact across the stock of houses is slightly larger than the average impact for each refrigerator upgrade because there was an average of 1.02 refrigerator upgrades per house.

The stock average payback for the measure was 11.8 years and the median of the individual paybacks was 12.7 years. Figure A35 shows the distribution of the paybacks for the individual houses. Figure A36 provides the cumulative greenhouse abatement curve for the measure. Around 36% of the total savings are achieved for a payback of less than 5 years, and around 65% of the total savings are achieved for a payback of less than 10 years.

An incentive is currently available for purchasing a high efficiency refrigerator under the Victorian Government's *Energy Saver Incentive* Scheme, although this incentive is currently quite low and has not been taken up widely. Where accessed, this incentive would result in slight reduction in the payback for the upgrade.

FIGURE A35: DISTRIBUTION OF PAYBACKS FOR REFRIGERATOR UPGRADE

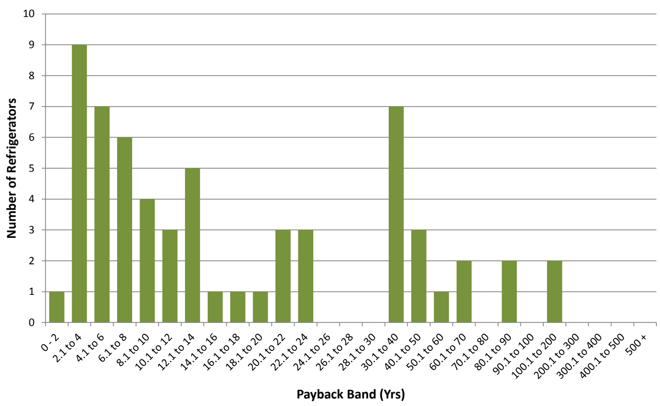
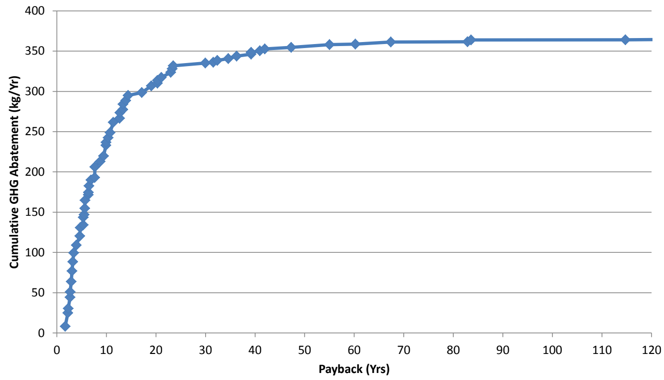


FIGURE A36: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE FOR REFRIGERATOR UPGRADE



Clothes washer upgrade

A summary of the main types of clothes washers installed in the OGA study houses is provided in Table 13, Chapter 2, and Figures 16 and 17 in this chapter show the distribution of the clothes washer ages as well as the energy efficiency (Star Rating) profile for the clothes washer stock. The penetration of front loading machines in the OGA study houses (55%) is substantially higher than the penetration of front loading machines in the Victorian housing stock (33.5% in 2011). This means that the energy saving potential estimated for the OGA study houses is lower than might be achieved across the wider Victorian housing stock.

Data was collected for the clothes washers found in the OGA study houses, including the type, brand and model number, age, and where available the Energy Rating label data (where label was still affixed) and nameplate details. This data was used to estimate the energy efficiency of the clothes washers:

Where the Energy Rating labels were still affixed to the machines, the Star Rating and Comparative Energy Consumption[124] was obtained directly from the label;

Where only brand and model number were available for the machines, either current or historical lists of energy rating data were obtained and used to obtain the Star Rating and the Comparative Energy Consumption. These lists were also used to obtain data on the amount of water used per load cycle for each clothes washer.

The Comparative Energy Consumption of the clothes washers – which is based on using the machine once per day - was used to estimate their annual energy consumption of the machine for each household, and the water consumption data was used to estimate the annual water usage. The estimated energy and water use of the clothes washers was based on the following assumptions:

- The annual number of loads washed was based on the average number of loads washed each week reported by the households;
- The annual water use by the clothes washers was based on the number of loads washed each year multiplied by the water use of the machine for each load cycle;
- 50% of the loads were washed on a cold water cycle and 50% were washed on a warm water cycle – this is consistent with field data reported by some clothes washer manufacturers;
- It was assumed that the clothes washer's motor and other electrics consumed 0.14 kWh (0.5 MJ) per wash cycle. This was assumed to be the only energy use when the machine was used on a cold wash cycle;
- When used on a warm wash cycle some energy use was attributed to the motor and other electrics (0.14 kWh per cycle) and the rest was assumed to be the energy required to heat the water;
- Top loading machines were assumed to heat all water externally using the water heater which was present after the water heater upgrade. The few front loading machines which had a dual hot and cold water connection were also assumed to heat all water externally. The other front loading machines were assumed to have a cold-only water connection, and therefore heated all water internally using an electric element;
- The annual running costs of the clothes washers were based on both the annual water cost and the annual energy cost (possibly a combination of electricity and gas used).
- The estimated average annual energy and water use, greenhouse gas emissions and running costs of the existing clothes washers is shown in Table A33.

124 The Comparative Energy Consumption (CEC) is the annual energy consumption (kWh per year) of the washing machine when used once per day.

TABLE A33: ESTIMATED AVERAGE ANNUAL ENERGY AND WATER USE OF EXISTING CLOTHES WASHERS

Clothes Washer Type	Annual Water Use (L/Yr)	Annual Gas Use (MJ/Yr)	Annual Elec Use (MJ/Yr)	Total Annual Energy Use (MJ/Yr)	Annual GHG Emissions (kg/Yr)	Annual Running Cost ($/Yr)*
Front loader	17,428	146	272	418	91	$79.98
Top loader	29,655	681	132	813	78	$115.80
Average household	**22,931**	**387**	**209**	**596**	**85**	**$96.10**

* Running cost includes both energy (including water heating) and water costs.

A clothes washer upgrade was modelled for those houses which had a clothes washer with an energy efficiency rating of less than 3.5 Stars. The existing machine was assumed to be replaced with a machine with a rating of either 3.5 or 4 Stars, depending on the load capacity of the existing machine. The total capacity of the replacement clothes washer was chosen to be similar to the total capacity of the existing clothes washer. The replacement machine was a front loader with a dual hot and cold water connection.

The calculation of the paybacks for the clothes washer upgrades use the adjusted capital cost rather than the full replacement costs, in recognition that in most cases this replacement will only be made at the end of life of the existing clothes washer.

The calculation of the adjusted capital cost required both the average lifetime of the clothes washer to be assumed, as well as the differential cost between the current market average clothes washer and the replacement high efficiency clothes washer. The assumptions used in this study are detailed in Table A34 below.

TABLE A34: ASSUMPTIONS USED TO CALCULATE ADJUSTED CAPITAL COST OF NEW CLOTHES WASHER

Clothes Washer Type & Capacity	Assumed Lifetime (Yrs)[125]	Replacement Appliance Cost[126]	Differential Cost at End Life[127]
6.5 kg, 3.78 Star front loader	12	$661	$85
7 kg, 4.05 Star, front loader	12	$670	$12
7.5 kg, 4.09 Star front loader	12	$810	$78
8.5 kg, 4.02 Star front loader	12	$1,186	$229
10 kg, 3.92 Star front loader	12	$1,607	$416

TABLE A35: MODELLED IMPACT OF THE CLOTHES WASHER UPGRADE

		Energy Saving (MJ/Yr)							
House No.	Clothes Washer Type	Gas	Elec	Total	Water Saving (L/Yr)	GHG Saving (kg/Yr)	Bill Saving ($/Yr)	Adjusted Cost ($)	Payback (Yrs)
B4	T	693	0	693	63,726	38	$218.8	$12.0	0.1
B30	T	899	0	899	40,872	50	$148.3	$12.0	0.1
A13	T	344	0	344	31,668	19	$108.7	$12.0	0.1
C7	T	724	0	724	22,204	40	$84.7	$12.0	0.1
B11	T	219	0	219	12,480	12	$44.3	$12.0	0.3
A6	T	97	0	97	9,048	5	$31.0	$12.0	0.4
C9	T	159	0	159	5,460	9	$20.5	$12.0	0.6
A5	T	513	0	513	19,032	28	$70.7	$78.4	1.1
B27	T	358	0	358	9,672	20	$37.6	$78.4	2.1
B28	T	1,402	0	1,402	20,639	78	$91.5	$228.7	2.5
B17	T	1,254	0	1,254	66,560	69	$237.8	$614.9	2.6
C5	T	179	0	179	9,750	10	$34.7	$200.3	5.8
B25	T	300	0	300	9,984	17	$37.6	$231.2	6.1
B9	F	-73	0	-73	3,432	-4	$9.8	$66.8	6.8
B1	T	351	0	351	12,152	19	$45.5	$707.2	15.5
A9	F	91	0	91	6,880	5	$23.9	$395.7	16.6
B22	T	179	0	179	8,112	10	$29.4	$505.3	17.2
A3	T	320	0	320	4,805	18	$21.2	$395.7	18.7

125 The assumed life is based on [BIS Shrapnel 2012a].
126 Prices based on average cost of 4 Star machine of the given load capacity using Gfk June 2013 washing machine sales data.
127 The differential cost is based on the difference between the cost of the upgrade washing machine models and the average sale price of different capacity washing machines estimated from Gfk June 2013 washing machine sales data.

		Energy Saving (MJ/Yr)							
House No.	Clothes Washer Type	Gas	Elec	Total	Water Saving (L/Yr)	GHG Saving (kg/Yr)	Bill Saving ($/Yr)	Adjusted Cost ($)	Payback (Yrs)
C2	T	207	0	207	9,620	11	$34.8	$707.2	20.3
C11	T	0	171	171	4,056	52	$21.7	$505.3	23.3
C10	F	-367	384	17	-1,040	96	$20.0	$505.1	25.2
B13	F	-181	0	-181	4,368	-10	$11.0	$286.1	26.0
A1	F	17	0	17	3,120	1	$10.4	$286.1	27.5
B7	F	-320	245	-75	416	57	$14.8	$450.5	30.4
B10	T	62	0	62	3,120	3	$11.2	$340.9	30.4
B15	T	111	0	111	3,775	6	$14.2	$450.5	31.8
B18	T	144	0	144	4,836	8	$18.2	$707.2	38.9
B20	T	60	0	60	2,964	3	$10.7	$505.3	47.4
B14	T	193	0	193	2,028	11	$10.0	$560.1	56.3
B8	F	-138	179	41	-582	47	$9.6	$642.3	66.8
B3	F	128	0	128	624	7	$4.3	$560.1	131.3
A7	F	55	0	55	1,092	3	$4.5	$614.9	136.8
A10	F	142	0	142	364	8	$3.7	$749.0	204.0
Av. Across Stock		**135**	**16**	**152**	**6,587**	**12**	**$24.9**	**$190.9**	**7.7**
Av. When Implemented		**246**	**30**	**276**	**11,977**	**23**	**$45.3**	**$347.2**	**7.7**
Av. - Top loader		381	7	389	16,372	23	$60.1	$300.0	5.0
Av. - Front loader		-65	81	16	1,867	21	$11.2	$455.7	40.7

Upgrading an existing clothes washer to a high efficiency clothes washer was found to be possible for 33 (55.0%) of the OGA study houses. The modelled energy saving impact of the clothes washer upgrade is shown in Table A35. The average impact across the stock of 60 houses, as well as the average impact for the houses in which this measure was modelled is shown. A breakdown of the results is also provided based on the type of existing clothes washer. The average impact across the stock of houses is lower than the average impact when implemented, as this measure was found to be applicable in just over half of the houses.

The majority of the bill savings were due to the water savings (85.7%). This follows from the modelling assumption that 50% of all washes were undertaken on a cold wash cycle, as on the cold wash cycle the energy savings are essentially zero[128]. Where households wash mainly on only a warm (or hot) wash cycle, the energy savings would be greater; where households wash only on a cold wash cycle the bill savings would be due to only the water savings.

The stock average payback for the measure was 7.7 years, making this upgrade one of the more cost effective upgrade measures. The median of the individual paybacks was 17.2 years. The stock average payback where a top loading machine was replaced was 5.0 years, substantially lower than the average payback where a front loading machine was replaced (40.7 years). This is due to the higher energy and water use of top loading clothes washers compared to front loading washers. Figure A37 shows the distribution of the paybacks for the individual houses. Figure A38 provides the cumulative greenhouse abatement curve for the measure. Around half of the total savings are achieved for a payback of less than 5 years, and around 60% of the total savings are achieved for a payback of less than 20 years.

128 In some cases when upgrading from a top loading machine to a front loading machine the energy use on a cold wash cycle might be slightly higher for the front loading machine.

FIGURE A37: DISTRIBUTION OF PAYBACKS FOR THE CLOTHES WASHER UPGRADE

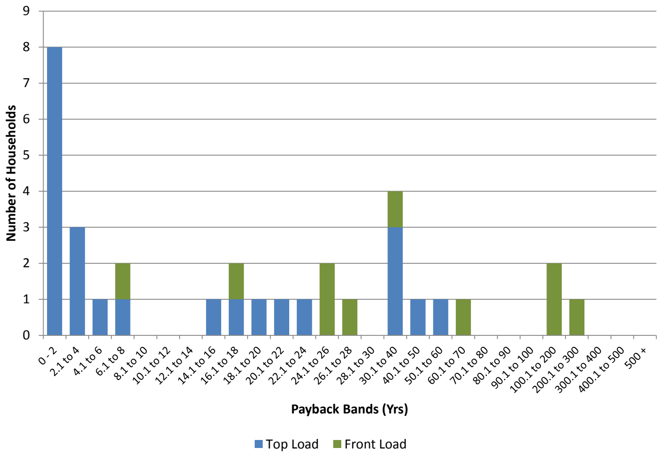
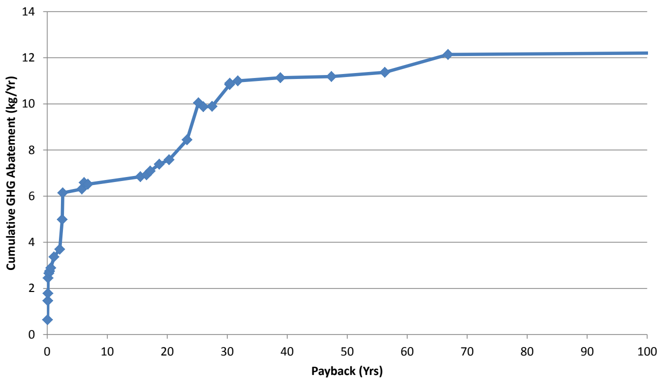


FIGURE A38: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE FOR CLOTHES WASHER UPGRADE



Dishwasher upgrade

A summary of the dishwashers installed in the OGA study houses is provided in Table 14, Chapter 2, and Figures 18 and 19 in this chapter show the distribution of the dishwasher ages as well as the energy efficiency (star rating) profile for the washing machine stock. The penetration of dishwashers in the OGA study houses (67%) is a bit higher than the penetration of dishwashers in the Victorian housing stock (58.4% in 2011). This means that the energy saving potential estimated for the OGA study houses may be slightly higher than might be achieved across the wider Victorian housing stock.

Data was collected for the dishwashers found in the OGA study houses, including the type, brand and model number, age, and where available the Energy Rating label data (where label was still affixed) and nameplate details. This data was used to estimate the energy efficiency of the dishwashers:

Where the Energy Rating labels were still affixed to the dishwashers, the Star Rating and Comparative Energy Consumption[129] was obtained directly from the label;

Where only brand and model number were available for the dishwashers, either current or historical lists of energy rating data were obtained and used to obtain the Star Rating and the Comparative Energy Consumption. These lists were also used to obtain data on the amount of water used per load cycle for each dishwasher.

The Comparative Energy Consumption of the dishwashers – which is based on using the dishwasher once per day – was used to estimate their annual energy consumption for each household, and the water consumption data was used to estimate the annual water usage. The estimated energy and water use of the washing machines was based on the following assumptions:

- The annual number of loads of dishes washed was based on the average number of loads washed each week reported by the households;
- The annual water use by the dishwashers was based on the number of loads washed each year multiplied by the water use of the dishwasher for each load cycle;
- All machines were connected to the manufacturers' recommended water connection, which is usually to a cold water supply – this means that all water is heated internally using an electric element[130];
- The annual energy use (all electricity) of the dishwashers was based on the number of loads washed each year multiplied by the energy use of the dishwasher for each load cycle (obtained from the CEC).

The estimated average annual energy and water use, greenhouse gas emissions and running costs of the existing washing machines is shown in Table A36.

129 The Comparative Energy Consumption (CEC) is the annual energy consumption (kWh per year) of the washing machine when used once per day, based on the manufacturers' recommended water connection.

130 In practice some dishwashers may have been connected to a hot water supply, meaning that hot water was used for all cycles, and some dishwashers may have had a dual hot and cold water supply with hot water imported from a gas water heater. This may mean that in some cases we have overestimated the value of the energy savings and the greenhouse gas savings which can be achieved.

TABLE A36: ESTIMATED AVERAGE ANNUAL ENERGY AND WATER USE OF EXISTING DISHWASHERS

Annual Water Use (L/Yr)	Annual Elec Use (MJ/Yr)	Annual Elec Use (kWh/Yr)	Annual GHG Emissions (kg/Yr)	Annual Running Cost ($/Yr)*
3,975	716	199	218	$68.57

* Running cost based both on energy and water costs.

A dishwasher upgrade was modelled for those houses which had a dishwasher with an energy efficiency rating of 3.0 stars or less:

- Dishwashers with a load capacity of 12 place settings or more were assumed to be replaced with a 4-Star, 14 place setting model;
- Dishwashers with a load capacity of 10 place settings or less were assumed to be replaced with a 3-Star, 9 place setting model.

The calculation of the paybacks for the dishwasher upgrades uses the adjusted capital cost rather than the full replacement costs, in recognition that in most cases this replacement will only be made at the end of life of the existing dishwasher. The calculation of the adjusted capital cost required both the average lifetime of the dishwasher to be assumed, as well as the differential cost between the current market average dishwasher and the replacement high efficiency unit. The assumptions used in this study are detailed in Table A37 below.

TABLE A37: ASSUMPTIONS USED TO CALCULATE ADJUSTED CAPITAL COST OF NEW DISHWASHER

Dishwasher type and capacity	Assumed Lifetime (Yrs)[131]	Replacement Appliance Cost[132]	Differential Cost at End Life[133]
9 place setting, 3-Star	12	$1,186	$370
14 place setting, 4-Star	12	$1,086	$270

TABLE A38: MODELLED IMPACT OF THE DISHWASHER UPGRADE

House No.	Elec Saving (kWh/yr)	Elec Saving (MJ/Yr)	Water Saving (L/Yr)	GHG Saving (kg/Yr)	Bill Saving ($/Yr)	Adjusted Cost ($)	Payback (Yrs)
B27	249	898	5,715	273	$88.34	$270.0	3.1
B21	116	417	2,171	127	$39.45	$338.0	8.6
B1	87	314	1,402	95	$28.94	$270.0	9.3
C7	67	242	1,310	74	$23.08	$338.0	14.6
B8	76	273	1,131	83	$24.91	$406.0	16.3
A1	109	394	1,934	120	$36.91	$610.0	16.5
C5	48	172	801	52	$16.00	$270.0	16.9
C6	197	711	-328	216	$54.23	$950.0	17.5
A13	89	320	-764	97	$22.37	$406.0	18.1
B11	88	318	1,583	97	$29.85	$542.0	18.2
B6	93	334	3,130	101	$36.12	$746.0	20.7
C3	93	334	3,130	101	$36.12	$746.0	20.7
B18	141	506	546	154	$41.14	$950.0	23.1
A11	99	355	2,694	108	$36.38	$950.0	26.1
B16	68	245	962	74	$22.17	$710.0	32.0

131 The assumed life is based on [BIS Shrapnel 2012a].
132 Replacement appliance cost is based in www.getprice.com.au May 2013. Installation costs of $150 were also assumed.
133 The differential cost is based on the difference between the cost of the upgrade dishwasher models and the average sale price of dishwashers estimated from Gfk February 2013 dishwasher sales data.

House No.	Elec Saving (kWh/yr)	Elec Saving (MJ/Yr)	Water Saving (L/Yr)	GHG Saving (kg/Yr)	Bill Saving ($/Yr)	Adjusted Cost ($)	Payback (Yrs)
B9	18	64	556	19	$6.79	$270.0	39.8
A9	62	224	333	68	$18.47	$814.0	44.1
C1	17	62	185	19	$5.45	$270.0	49.5
B3	22	79	1,711	24	$11.69	$678.0	58.0
A15	22	78	192	24	$6.73	$406.0	60.4
C11	32	116	432	35	$10.41	$882.0	84.7
B12	15	56	855	17	$7.10	$610.0	85.9
C15	8	29	87	9	$2.56	$270.0	105.6
C10	22	77	198	24	$6.66	$814.0	122.1
B14	18	66	299	20	$6.11	$1,018.0	166.7
B26	10	35	302	11	$3.69	$950.0	257.4
Av. All houses	**31**	**112**	**509**	**34**	**$10.4**	**$258.1**	**24.9**
Av. When Implemented	**72**	**258**	**1,176**	**79**	**$23.9**	**$595.5**	**24.9**

Upgrading an existing dishwasher to a high efficiency dishwasher was found to be possible for 26 (43.3%) of the OGA study houses. The modelled energy and water saving impact of the dishwasher upgrade is shown in Table A38. The majority of the bill savings were due to the energy savings (84.1%). The average impact across the stock of 60 houses, as well as the average impact for the houses in which this measure was modelled is shown. The average impact across the stock of houses is lower than the average impact when implemented, as this measure was found to be applicable in just over two out of five houses.

The stock average payback for the measure was 24.9 years and the median of the individual paybacks was 24.6 years. Figure A39 shows the distribution of the paybacks for the individual houses. Figure A40 provides the cumulative greenhouse abatement curve for the measure. Around half of the total savings are achieved for a payback of less than 5 years, and around 60% of the total savings are achieved for a payback of less than 20 years.

FIGURE A39: DISTRIBUTION OF PAYBACKS FOR THE DISHWASHER UPGRADE

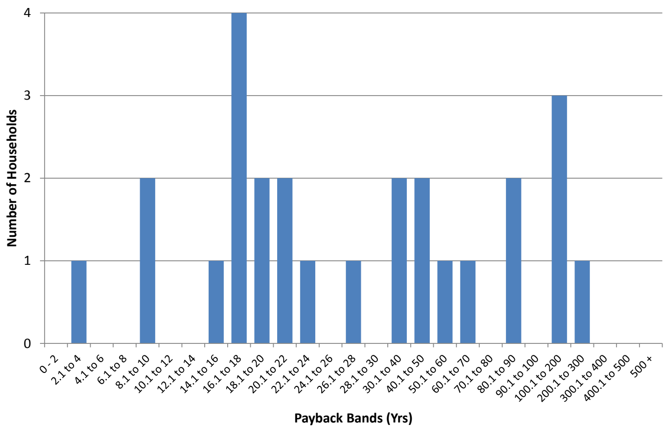
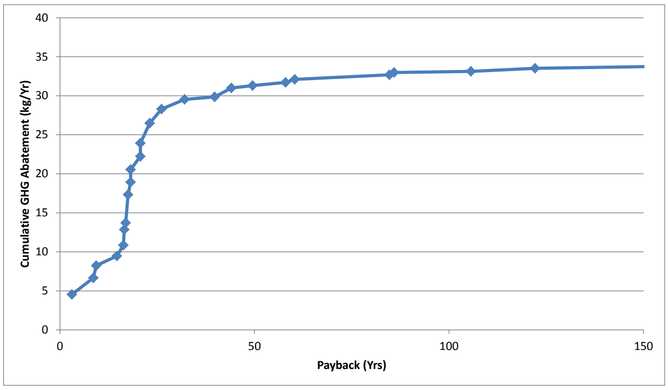


FIGURE A40: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE FOR THE DISHWASHER UPGRADE



Clothes dryer upgrade – heat pump

A summary of the clothes dryers installed in the OGA study houses is provided in Table 15, Chapter 2, and Figures 20 and 21 in this chapter show the distribution of the clothes dryer ages as well as the energy efficiency (Star Rating) profile for the clothes dryer stock. The penetration of clothes dryers in the OGA study houses (45.0%) is lower than the penetration of clothes dryers in the Victorian housing stock (54.1% in 2011). This means that the energy saving potential estimated for the OGA study houses may be lower than might be achieved across the wider Victorian housing stock.

Data was collected for the clothes dryers found in the OGA study houses, including the type, brand and model number, age, and where available the Energy Rating label data (where label was still affixed) and nameplate details. This data was used to estimate the energy efficiency of the clothes dryers:

- Where the Energy Rating labels were still affixed to the clothes dryers, the Star Rating and Comparative Energy Consumption[134] was obtained directly from the label;
- Where only brand and model number were available for the clothes dryers, either current or historical lists of energy rating data were obtained and used to obtain the Star Rating and the Comparative Energy Consumption.

The Comparative Energy Consumption of the clothes dryers – which is based on the dryer being used once per week (or 52 times per year) - was used to estimate their annual energy consumption for each household, based on the following assumptions:

- Annual usage was assumed to be the number of household occupants multiplied by 33.8[135];
- The annual energy use (all electricity) of the clothes dryers was based on the number of loads dried each year multiplied by the energy use of the clothes dryer for each load cycle (obtained from the CEC).

The estimated average annual energy use, greenhouse gas emissions and running costs of the existing clothes dryers is shown in Table A39.

All existing clothes dryers were conventional dryers which use an electric element to heat the air used to dry the clothes. While more efficient conventional dryers are available, there is relatively little variation in the efficiency and energy consumption of these dryers. Significant energy savings are only possible by replacing conventional dryers with heat pump clothes dryers. These work on a similar principle to a reverse-cycle air conditioner running on a heating cycle. Rather than using an electric element to generate heat, they use a heat pump to extract heat from the room air and transfer it to the air inside the clothes dryer. An upgrade to a 6 or 7 Star heat pump clothes dryers was modelled for all conventional clothes dryers:

- Dryers with a load capacity of 6.5 kg or less were assumed to be replaced with a 7 Star, 6.5 kg model;
- Dryers with a load capacity of 7 kg were assumed to be replaced with a 6 Star, 7 kg model.

The replacement of low efficiency conventional clothes dryers with a higher efficiency conventional clothes dryer was also modelled, and the results for this are presented in the next section.

The calculation of the paybacks for the clothes dryer upgrades uses the adjusted capital cost rather than the full replacement costs, in recognition that in most cases this replacement will only be made at the end of life of the existing clothes dryer. The calculation of the adjusted capital cost required both the average lifetime of the clothes dryer to be assumed, as well as the differential cost between the current market average clothes dryer and the replacement high efficiency unit. The assumptions used in this study are detailed in Table A40 below.

134 The 2000 version of the Comparative Energy Consumption (CEC) was used. This is the annual energy consumption (kWh per year) of the clothes dryer when used once per week.

135 The 2007 Victorian Utility Consumption Household Survey [DHS 2008] estimated average annual use in Victoria of 87.6 loads dried per year for an average household size of 2.59 people, giving an estimated average annual use of 33.8 loads per person. For this study we did not use the household's reported dryer usage as it was likely to be very seasonally dependent and so the reported use could be quite unreliable.

TABLE A39: ESTIMATED AVERAGE ANNUAL ENERGY USE OF EXISTING CLOTHES DRYERS

Av. No of People	Annual Elec Use (MJ/Yr)	Annual Elec Use (kWh/Yr)	Annual GHG Emissions (kg/Yr)	Annual Running Cost ($/Yr)
3.4	1,619.3	449.8	492	$125.9

TABLE A40: ASSUMPTIONS USED TO CALCULATE ADJUSTED CAPITAL COST OF NEW CLOTHES DRYER

Clothes dryer type and capacity	Lifetime (Yrs)[136]	Replacement Appliance Cost[137]	Differential Cost at End Life[138]
6.5 kg, 7-Star	16	$1,850	$1,419
7 kg, 6-Star	16	$1,799	$1,368

136 The assumed life is based on [EES 2008].

137 Replacement appliance cost is based in www.getprice.com.au August 2012.

138 The differential cost is based on the difference between the cost of the upgrade clothes dryer models (from the www.getprice.com.au website in August 2012), and the average sale price of clothes dryers estimated from Gfk June 2012 clothes dryer sales data.

TABLE A41: MODELLED IMPACT OF THE CLOTHES DRYER UPGRADE

House No	Elec Saving (kWh/Yr)	Elec Saving (MJ/Yr)	GHG Saving (kg/Yr)	Bill Saving ($/Yr)	Adjusted Cost ($)	Payback (Yrs)
A2	439.1	1,580.9	480.4	$123.0	$1,580.6	12.9
B21	409.0	1,472.5	447.5	$114.5	$1,553.7	13.6
B29	390.3	1,404.9	426.9	$109.3	$1,580.6	14.5
B3	356.4	1,283.2	389.9	$99.8	$1,526.8	15.3
B4	390.3	1,404.9	426.9	$109.3	$1,823.1	16.7
B13	308.5	1,110.5	337.5	$86.4	$1,580.6	18.3
A13	273.2	983.5	298.9	$76.5	$1,445.9	18.9
B25	272.8	982.2	298.5	$76.4	$1,445.9	18.9
A1	273.2	983.5	298.9	$76.5	$1,580.6	20.7
C6	273.2	983.5	298.9	$76.5	$1,634.5	21.4
B17	273.2	983.5	298.9	$76.5	$1,823.1	23.8
B6	208.0	748.8	227.6	$58.2	$1,419.0	24.4
B30	204.9	737.6	224.1	$57.4	$1,580.6	27.6
B5	221.1	796.1	241.9	$61.9	$1,796.1	29.0
B2	173.4	624.2	189.7	$48.6	$1,526.8	31.4
C5	195.1	702.5	213.5	$54.6	$1,742.3	31.9
B18	178.2	641.6	195.0	$49.9	$1,607.6	32.2
B8	160.0	575.9	175.0	$44.8	$1,445.9	32.3
C11	165.9	597.1	181.5	$46.4	$1,634.5	35.2
B16	170.4	613.5	186.4	$47.7	$1,772.1	37.1
C2	110.6	398.1	121.0	$31.0	$1,688.4	54.5
C14	81.6	293.9	89.3	$22.9	$1,419.0	62.1
B27	89.8	323.1	98.2	$25.1	$1,661.4	66.1
B14	93.7	337.2	102.5	$26.2	$1,809.6	69.0
B9	68.2	245.6	74.6	$19.1	$1,580.6	82.8
B24	67.6	243.5	74.0	$18.9	$1,823.1	96.3
C3	38.9	139.9	42.5	$10.9	$1,580.6	145.3
Av. - Across stock	**98.1**	**353.2**	**107.3**	**$27.5**	**$727.7**	**26.5**
Av. - When Implemented	**218.0**	**784.9**	**238.5**	**$61.1**	**$1,617.2**	**26.5**

Upgrading an existing clothes dryer to a high efficiency heat pump clothes dryer was modelled for all 27 OGA study houses (45.0%) which had a clothes dryer. The modelled energy saving impact of the clothes dryer upgrade is shown in Table A41. The average impact across the stock of 60 houses, as well as the average impact for the houses in which this measure was modelled is shown. The average impact across the stock of houses is lower than the average impact when implemented, as this measure was found to be applicable in just under half of the houses.

The stock average payback for the measure was 26.5 years and the median of the individual paybacks was 29.0 years. Figure A41 shows the distribution of the paybacks for the individual houses. Figure A42 provides the cumulative greenhouse abatement curve for the measure. Around 27% of the total savings are achieved for a payback of less than 15 years, and around 53% of the total savings are achieved for a payback of less than 20 years.

The replacement of an existing conventional clothes dryer with a heat pump clothes dryer is eligible for an incentive under the Victorian Energy Saver Incentive Scheme, although the incentive is relatively small and the uptake to date has been low. An increasing number of models of heat pump dryers have come on to the market in recent years and the price of units has been declining. This trend is expected to continue, making this upgrade measure more cost effective.

FIGURE A41: DISTRIBUTION OF PAYBACKS FOR THE HEAT PUMP CLOTHES DRYER UPGRADE

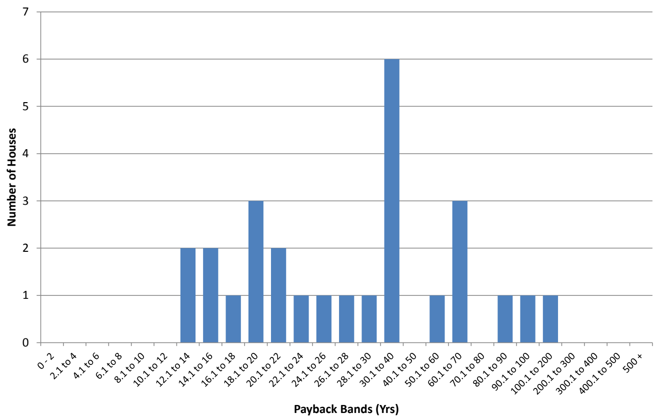
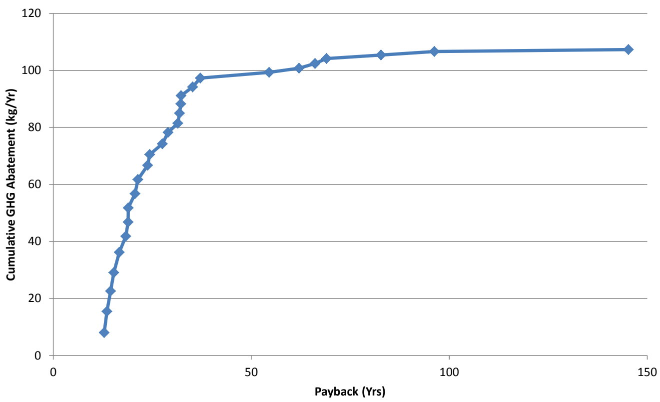


FIGURE A42: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE FOR THE HEAT PUMP CLOTHES DRYER UPGRADE



Clothes dryer upgrade – conventional

In addition to modelling the replacement of the existing conventional clothes dryers with a high efficiency heat pump clothes dryer (see Clothes Dryer – Heat Pump above), we modelled the replacement of the existing clothes dryers with a higher efficiency conventional clothes dryer. A dryer upgrade was modelled for all OGA study houses which had a clothes dryer with a capacity of 4.5 kg or greater and an energy efficiency of 2.0 Stars or less. The energy savings were calculated in the same way as for the heat pump clothes dryer upgrade.

As with the heat pump clothes dryer upgrade, the calculation of the paybacks for the clothes dryer upgrades uses the adjusted capital cost rather than the full replacement costs. The assumptions used in this study are detailed in Table A34 below.

TABLE A42: ASSUMPTIONS USED TO CALCULATE ADJUSTED CAPITAL COST OF NEW CLOTHES DRYER

Clothes dryer type and capacity	Lifetime (Yrs)[139]	Replacement Appliance Cost[140]	Differential Cost at End Life[141]
4.5 kg, 2.04 Star	16	$357	$24
5 kg, 2.22 Star	16	$403	$8
6 kg, 2.17 Star	16	$536	$105
7 kg, 2.21 Star	16	$565	$134

139 The assumed life is based on [EES 2008].
140 Prices based on www.getprice.com.au August 2012.
141 The differential cost is based on the difference between the cost of the upgrade clothes dryer models and the average sale price of clothes dryers estimated from Gfk June 2012 clothes dryer sales data.

TABLE A43: MODELLED IMPACT OF THE CLOTHES DRYER UPGRADE

House No.	Elec Saving (kWh/Yr)	Elec Saving (MJ/Yr)	GHG Saving (kg/Yr)	Bill Saving ($/Yr)	Adjusted Cost ($)	Payback (Yrs)
C14	29.7	106.9	32.5	$8.3	$8.0	1.0
A13	52.0	187.3	56.9	$14.6	$44.8	3.1
B25	51.7	186.1	56.5	$14.5	$44.8	3.1
B21	148.9	535.9	162.8	$41.7	$131.4	3.2
B3	96.3	346.5	105.3	$27.0	$106.8	4.0
A2	113.9	410.1	124.6	$31.9	$156.1	4.9
B29	65.0	234.2	71.2	$18.2	$156.1	8.6
B2	43.3	155.9	47.4	$12.1	$106.8	8.8
A1	52.0	187.3	56.9	$14.6	$148.9	10.2
B13	48.3	173.8	52.8	$13.5	$156.1	11.5
B18	48.1	173.3	52.7	$13.5	$180.8	13.4
B30	39.0	140.5	42.7	$10.9	$148.9	13.6
B9	12.9	46.5	14.1	$3.6	$148.9	41.1
C6	13.0	46.8	14.2	$3.6	$205.5	56.4
B17	13.0	46.8	14.2	$3.6	$378.3	103.9
B4	10.4	37.5	11.4	$2.9	$509.1	174.7
B24	2.6	9.4	2.8	$0.7	$378.3	519.3
Av. Across stock	**14.0**	**50.4**	**15.3**	**$3.9**	**$50.2**	**12.8**
Av. When Implemented	**49.4**	**177.9**	**54.1**	**$13.8**	**$177.0**	**12.8**

Upgrading an existing clothes dryer to a high efficiency conventional clothes dryer was found to be applicable to 17 OGA study houses (28.3%). The modelled energy saving impact of the clothes dryer upgrade is shown in Table A43. The average impact across the stock of 60 houses, as well as the average impact for the houses in which this measure was modelled is shown. The average impact across the stock of houses is somewhat lower than the average impact when implemented, as this measure was found to be applicable in just under one out of five houses.

The stock average payback for the measure was 12.8 years – this is lower than for upgrading to a heat pump clothes dryer, but the energy savings are also substantially lower. The median of the individual paybacks was 10.2 years. Figure A43 shows the distribution of the paybacks for the individual houses. Figure A44 provides the cumulative greenhouse abatement curve for the measure. Around 60% of the total savings are achieved for a payback of less than 5 years, and around 78% of the total savings are achieved for a payback of less than 10 years.

FIGURE A43: DISTRIBUTION OF PAYBACKS FOR CLOTHES DRYER UPGRADE

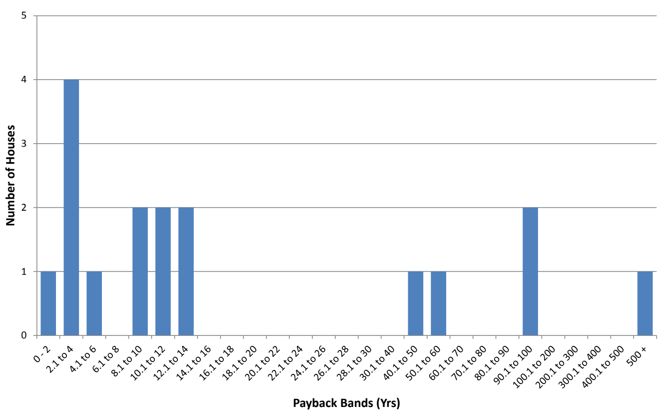
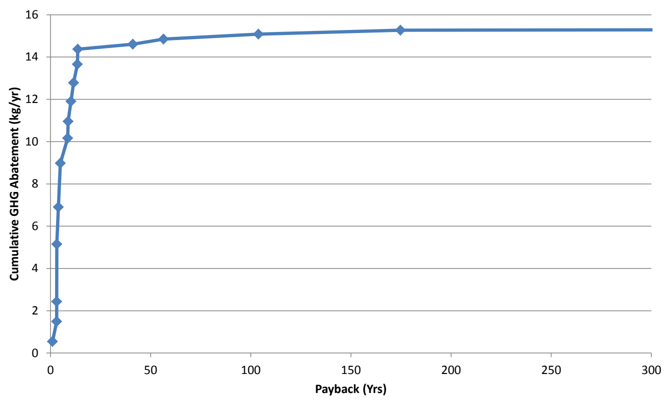


FIGURE A42: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE FOR CLOTHES DRYER UPGRADE



Television upgrade

A summary of the main types of televisions installed in the OGA study houses is provided in Table 17, Chapter 2, and Figures 22 and 23 in this chapter show the distribution of the television ages as well as the energy efficiency (Star Rating) profile for the televisions, based on the 2009 version of the energy rating algorithms. A total of 109 televisions were found in the 60 houses. Average ownership was 1.91 TVs per house in the 57 houses (95%) which had a television.

Data was collected for all televisions found in the OGA study houses, including the type, brand and model number, age, screen size and where available the Energy Rating label data (where label was still affixed) and nameplate details. This data was used to estimate the energy efficiency and energy performance of the televisions:

- Where the Energy Rating labels were still affixed to the televisions, the Star Rating and Comparative Energy Consumption[142] was obtained directly from the label – for this study the Star Rating used is based on the 2009 energy rating algorithms[143];
- Where only brand and model number were available for the televisions, either current or historical lists of energy rating data were used to obtain the Star Rating (based on the 2009 rating scale) and the Comparative Energy Consumption;
- Where only the age and type of the television was available (this applies to most TVs purchased before 2009), the Star Rating was based on the type and age of the television as shown in Table A38 below. The screen size and Star Rating were then used to calculate the Comparative Energy Consumption using the 2009 version of the energy rating algorithm.

The Comparative Energy Consumption of the televisions (based on usage of 10 hours per day) was used to estimate the annual energy consumption of the televisions:

- For half of the OGA study houses data was available on the reported average daily usage of the televisions;
- Where reported usage data was not available the following assumptions were made[144]:
  - the main TV was used for 5.3 hours per day;
  - all other TVs were used for 1.1 hours per day.
- The actual hours of use per day was divided by 10, and then multiplied by the Comparative Energy Consumption to estimate the annual energy consumption for each TV.

The estimated average annual energy use, greenhouse gas emissions and running costs of the existing televisions is shown in Table A45. In addition to the averages for the different TV types, averages are shown for all televisions as well as for the average household with a television.

TABLE A44: ASSUMED ENERGY EFFICIENCY OF TVS WHERE ONLY AGE IS KNOWN

TV Type & Year of Purchase	Assumed Star Rating[145]	Assumed Aspect Ratio[146]
CRT - all ages	2.0	0.75
LCD - 2007	2.5	0.5625
LCD - 2008	3.5	0.5625
LCD - 2009	4.0	0.5625
LCD - 2010	4.8	0.5625
LCD - 2011	4.9	0.5625
LCD - 2012	6.3	0.5625
Plasma - 2007	1.0	0.5625
Plasma - 2008	1.5	0.5625
Plasma - 2009	2.5	0.5625
Plasma - 2010	4.6	0.5625
Plasma - 2011	4.7	0.5625
Plasma - 2012	5.2	0.5625
Rear Projection - all ages	2.5	0.75

142 The Comparative Energy Consumption (CEC) is the annual energy consumption (kWh per year) of the television when used for 10 hours per day. In most cases this is likely to be higher than actual in-use energy consumption.

143 Mandatory Energy Rating labels for televisions were first introduced in 2009, although a voluntary labelling scheme commenced in 2008. The Energy Rating algorithms used to assign the Star Ratings for televisions were subsequently revised in 2013, resulting in a reduction of 3 Stars for the same level of energy efficiency performance.

144 Data collected and analysed by Energy Efficient Strategies (EES) as part of SV's Vic-REMP study suggested average daily use of 4.0 hours per day for the main TV and 0.8 hours per day for the secondary TVs, although we believe this represents below average usage. EES advise (personal communication) than other field measurements they have undertaken on 150 TVs gave an average of 5.3 hours per day for the main TV and 1.1 hours per day for the secondary TVs.

145 Data for LCD and Plasma TVs for 2010 to 2012 is based on GfK sales data for flat screen TVs.

146 The Aspect Ratio is used to calculate the screen area of the television from the screen size measured across the diagonal in cm. The screen area and Star Rating Index are used to calculate the Comparative Energy Consumption (CEC) of the television.

TABLE A45: ESTIMATED AVERAGE ANNUAL ENERGY USE OF EXISTING TELEVISIONS

Television Type	Annual Electricity Use (kWh/Yr)	Annual GHG Emissions (kg/Yr)	Annual Running Cost ($/Yr)
CRT	89.6	98	$25.1
LCD	177.0	194	$49.6
Plasma	493.9	540	$138.3
Rear projection	450.4	493	$126.1
Average television	**150.4**	**165**	**$42.2**
Average household	**287.6**	**315**	**$80.5**

An upgrade to an 8 Star television (2009 rating) was modelled for all TVs with a rating of less than 6 Stars (2009). The screen size of the replacement television was chosen to be similar to the screen size of the existing television, although all CRT televisions with a screen size less than 66 cm (26") were upgraded to a 66 cm model.

The calculation of the paybacks for the television upgrades use the adjusted capital cost rather than the full replacement costs, in recognition that in most cases this replacement will only be made at the end of life of the existing television. The calculation of the adjusted capital cost required both the average lifetime of the television to be assumed, as well as the differential cost between the current market average television and the replacement high efficiency television. The assumptions used in this study are detailed in Table A46.

Upgrading an existing inefficient television to a high efficiency television was found to be possible for 106 (97.2%) of the televisions found in the OGA study houses, with television upgrades being modelled in all 57 of the houses which had one or more TVs present. The energy efficiency of new televisions being sold has increased quite rapidly over the last 3 years, meaning that the vast majority of them could be upgraded to a much more efficient model. In practice TVs are unlikely to be upgraded until they reach their end of life. However, a fairly common practice is to replace the main TV with a new TV, with the old main TV then becoming one of the secondary TVs in the home.

TABLE A46: ASSUMPTIONS USED TO CALCULATE ADJUSTED CAPITAL COST OF NEW TELEVISION

TV Type & Volume	Assumed Lifetime (Yrs)[147]	Replacement Appliance Cost[148]	Differential Cost at End Life[149]
66 cm (26"), 8.0 Star	16	$399	$114
81 cm (32"), 8.8 Star	16	$609	$174
107 cm (42"), 8.3 Star	16	$1,223	$349
127 (50"), 8.6 Star	16	$1,126	$321
137 (54"), 8.9 Star	16	$1,940	$553

147 The assumed life is based on the modelling assumptions used in the Television MEPS Regulatory Impact Statement [E3 2009].

148 Prices based on www.getprice.com.au August 2012

149 The differential cost is based on the difference between the cost of the upgrade television models and estimated average sale price for TVs with the same screen size. Analysis of data from the Gfk February 2013 television sales data suggested a price ratio of 1.4 between the average TV sold (all types and sizes) and an 8 Star television.

TABLE A47: MODELLED IMPACT OF THE TELEVISION UPGRADE

House / TV No.	Type of TV	Elec Saving (kWh/Yr)	Elec Saving (MJ/Yr)	GHG Saving (kg/Yr)	Bill Saving ($/Yr)	Adjusted Cost ($)	Payback (Yrs)
A2	CRT	192.0	691.1	271.9	$53.7	$274.2	5.1
A15	CRT	72.0	259.1	102.0	$20.2	$113.8	5.6
A6.1	CRT	180.4	649.4	232.4	$50.5	$336.9	6.7
B9	CRT	172.2	619.8	234.8	$48.2	$336.9	7.0
B22.1	Rear	316.3	1,138.8	452.0	$88.6	$673.2	7.6
A4	Plasma	453.0	1,630.8	575.6	$126.8	$1,025.4	8.1
B8.1	CRT	172.2	619.8	234.8	$48.2	$391.3	8.1
A9	CRT	120.0	431.9	170.0	$33.6	$274.2	8.2
A1.1	CRT	180.4	649.4	232.4	$50.5	$418.5	8.3
C4.1	Plasma	377.5	1,359.1	485.7	$105.7	$895.1	8.5
B13.2	Plasma	450.5	1,621.8	598.8	$126.1	$1,075.7	8.5
B19	Plasma	434.6	1,564.5	552.5	$121.7	$1,059.1	8.7
B28.1	CRT	177.3	638.4	240.5	$49.7	$445.7	9.0
C5.1	LCD	168.8	607.5	228.5	$47.3	$445.7	9.4
B2	CRT	167.1	601.5	229.3	$46.8	$445.7	9.5
B10	CRT	167.1	601.5	229.3	$46.8	$445.7	9.5
B26.2	CRT	127.2	457.8	180.2	$35.6	$345.5	9.7
C8	CRT	133.8	481.8	181.5	$37.5	$364.1	9.7
B11	LCD	183.7	661.1	247.4	$51.4	$500.2	9.7
C15.1	CRT	77.5	278.9	115.7	$21.7	$220.7	10.2
B29	CRT	172.2	619.8	234.8	$48.2	$500.2	10.4
C1	CRT	133.8	481.8	181.5	$37.5	$391.3	10.4
B27.2	LCD	295.9	1,065.2	400.7	$82.8	$895.1	10.8
B21.3	LCD	305.5	1,099.7	440.1	$85.5	$975.1	11.4
B12.1	LCD	330.7	1,190.6	467.8	$92.6	$1,075.7	11.6
B20	CRT	102.7	369.6	153.3	$28.7	$345.5	12.0
B16.2	Plasma	316.9	1,141.0	452.7	$88.7	$1,075.7	12.1
B5.1	LCD	295.9	1,065.2	400.7	$82.8	$1,004.4	12.1
B23.2	CRT	172.2	619.8	234.8	$48.2	$609.0	12.6
B3.1	LCD	295.9	1,065.2	400.7	$82.8	$1,059.1	12.8

House / TV No.	Type of TV	Elec Saving (kWh/Yr)	Elec Saving (MJ/Yr)	GHG Saving (kg/Yr)	Bill Saving ($/Yr)	Adjusted Cost ($)	Payback (Yrs)
A7	Plasma	295.9	1,065.2	383.7	$82.8	$1,075.7	13.0
B25.3	LCD	283.2	1,019.6	386.9	$79.3	$1,059.1	13.4
C15.2	CRT	96.8	348.7	144.7	$27.1	$381.2	14.1
C2.2	CRT	68.9	248.0	92.9	$19.3	$282.5	14.6
B30.2	LCD	135.2	486.6	194.3	$37.8	$554.6	14.7
B24	LCD	86.8	312.4	136.0	$24.3	$363.3	15.0
B18.1	LCD	131.3	472.8	190.2	$36.8	$554.6	15.1
C3.1	LCD	370.0	1,332.0	526.4	$103.6	$1,680.0	16.2
B6.2	LCD	223.0	802.9	349.9	$62.4	$1,025.4	16.4
A5	CRT	48.0	172.8	68.0	$13.4	$220.7	16.4
A8	LCD	104.0	374.2	140.0	$29.1	$500.2	17.2
B6.1	CRT	43.6	156.8	57.3	$12.2	$228.1	18.7
B14.1	LCD	212.1	763.6	309.1	$59.4	$1,113.7	18.8
B13.1	CRT	37.9	136.4	51.1	$10.6	$200.8	18.9
B21.1	CRT	35.7	128.6	48.7	$10.0	$200.8	20.1
A14	LCD	191.2	688.3	260.0	$53.5	$1,113.7	20.8
B4.1	LCD	184.3	663.3	307.5	$51.6	$1,075.7	20.9
C9.1	LCD	160.3	577.1	219.0	$44.9	$949.8	21.2
C14.1	LCD	157.3	566.5	262.1	$44.1	$975.1	22.1
B23.1	CRT	18.2	65.6	28.5	$5.1	$113.8	22.3
C11.3	CRT	31.9	114.8	42.6	$8.9	$220.7	24.7
C11.1	LCD	139.9	503.5	233.0	$39.2	$975.1	24.9
B1.2	LCD	159.3	573.4	251.3	$44.6	$1,113.7	25.0
A13.2	CRT	26.4	95.0	37.4	$7.4	$185.1	25.0
A11	LCD	69.3	249.5	93.4	$19.4	$500.2	25.8
B8.2	CRT	18.2	65.6	28.5	$5.1	$131.6	25.8
C13	CRT	17.9	64.6	27.4	$5.0	$131.6	26.2
B7.3	CRT	37.9	136.4	51.1	$10.6	$282.5	26.6
C3.2	CRT	28.0	100.7	42.2	$7.8	$220.7	28.2
B21.4	CRT	16.1	57.9	26.1	$4.5	$131.6	29.2
A6.2	CRT	26.4	95.0	37.4	$7.4	$220.7	29.9

House / TV No.	Type of TV	Elec Saving (kWh/Yr)	Elec Saving (MJ/Yr)	GHG Saving (kg/Yr)	Bill Saving ($/Yr)	Adjusted Cost ($)	Payback (Yrs)
A13.1	LCD	143.0	514.8	200.0	$40.0	$1,223.0	30.5
B7.2	CRT	21.3	76.7	31.8	$6.0	$185.1	31.0
B21.5	CRT	21.3	76.7	31.8	$6.0	$185.1	31.0
B30.1	CRT	27.3	98.3	38.4	$7.6	$238.6	31.2
C14.4	CRT	66.9	240.9	90.7	$18.7	$609.0	32.5
B15.2	LCD	114.0	410.2	201.7	$31.9	$1,113.7	34.9
C14.3	LCD	35.3	127.2	58.0	$9.9	$345.5	34.9
B7.1	LCD	118.2	425.5	206.4	$33.1	$1,168.4	35.3
B15.1	CRT	30.1	108.3	41.4	$8.4	$309.9	36.8
B14.3	CRT	21.3	76.7	31.8	$6.0	$220.7	37.0
B17.2	LCD	111.3	400.7	198.8	$31.2	$1,168.4	37.5
B8.3	CRT	10.5	37.6	20.0	$2.9	$113.8	38.9
B3.2	CRT	80.9	291.3	104.5	$22.7	$895.1	39.5
C14.2	LCD	27.3	98.2	49.2	$7.6	$345.5	45.3
B14.2	CRT	37.9	136.4	51.1	$10.6	$500.2	47.1
B21.2	CRT	22.1	79.6	32.7	$6.2	$292.0	47.2
B6.3	CRT	21.3	76.7	31.8	$6.0	$292.0	49.0
A1.2	CRT	26.4	95.0	37.4	$7.4	$363.3	49.2
B28.2	CRT	22.1	79.6	32.7	$6.2	$309.9	50.0
B17.1	CRT	22.9	82.6	33.6	$6.4	$381.2	59.3
B12.2	CRT	35.7	128.6	48.7	$10.0	$609.0	60.9
B13.3	LCD	57.5	206.9	78.9	$16.1	$1,004.4	62.4
B18.2	CRT	9.4	33.7	18.8	$2.6	$185.1	70.5
B18.3	CRT	9.4	33.7	18.8	$2.6	$185.1	70.5
C7	LCD	27.8	100.2	48.0	$7.8	$554.6	71.2
B5.2	CRT	11.0	39.7	20.6	$3.1	$220.7	71.6
B5.3	CRT	11.0	39.7	20.6	$3.1	$220.7	71.6
B27.1	LCD	50.6	182.2	71.3	$14.2	$1,113.7	78.6
A3	CRT	12.0	43.2	17.0	$3.4	$292.0	86.9
B25.2	LCD	15.5	56.0	25.5	$4.4	$381.2	87.6
B22.2	LCD	20.5	73.7	32.0	$5.7	$581.8	101.6

House / TV No.	Type of TV	Elec Saving (kWh/Yr)	Elec Saving (MJ/Yr)	GHG Saving (kg/Yr)	Bill Saving ($/Yr)	Adjusted Cost ($)	Payback (Yrs)
B26.1	CRT	10.5	37.6	20.0	$2.9	$309.9	105.9
B4.2	LCD	19.0	68.4	30.4	$5.3	$581.8	109.3
B1.1	LCD	18.7	67.5	30.2	$5.2	$581.8	110.9
C6.1	LCD	31.3	112.8	54.3	$8.8	$975.1	111.2
B25.1	CRT	9.4	33.7	18.8	$2.6	$309.9	118.1
B26.3	CRT	9.4	33.7	18.8	$2.6	$309.9	118.1
B25.4	LCD	10.1	36.4	19.6	$2.8	$345.5	122.1
C6.2	LCD	14.5	52.1	24.6	$4.0	$581.8	143.7
C9.2	LCD	10.2	36.9	15.6	$2.9	$554.6	193.3
B1.3	LCD	6.5	23.5	15.7	$1.8	$381.2	208.3
B16.1	LCD	4.3	15.4	13.2	$1.2	$381.2	317.3
A12	CRT	3.2	11.6	11.3	$0.9	$292.0	323.6
C5.2	LCD	4.2	15.2	6.1	$1.2	$500.2	424.0
C4.2	LCD	1.0	3.4	1.6	$0.3	$345.5	1295.3
Av. Across stock		**193.2**	**695.6**	**273.2**	**$54.1**	**$964.3**	**17.8**
Av. When implemented		**109.4**	**393.8**	**154.7**	**$30.6**	**$545.8**	**17.8**
Av. - CRT		64.7	233.0	90.5	$18.1	$307.9	17.0
Av. - LCD		123.8	445.7	182.0	$34.7	$784.6	22.6
Av. - Plasma		388.1	1,397.1	508.1	$108.7	$1,034.4	9.5

The modelled energy saving impact of the television upgrade is shown in Table A47. The average impact across the stock of 60 houses, as well as the average impact for each individual TV upgrade is shown. A breakdown of the results is also provided based on the type of existing TV. The average impact across the stock of houses is somewhat larger than the average impact for each television upgrade because there was an average ownership 1.91 TVs per house (compared to an average of 1.82 TVs per house across the stock).

The stock average payback for the measure was 17.8 years and the median of the individual paybacks was 25.0 years. Paybacks were lowest for the replacement of Plasma televisions, reflecting the very inefficient nature of the Plasma televisions which were available in the early stages of the flat screen TV market. Figure A43 shows the distribution of the paybacks for the individual television upgrades, broken down into the different TV types. Figure A44 provides the cumulative greenhouse abatement curve for the measure. Around 35% of the total savings are achieved for a payback of less than 10 years, and around 74% of the total savings are achieved for a payback of less than 20 years.

An incentive is currently available for purchasing a high efficiency television under the Victorian *Energy Saver Incentive* Scheme. Where accessed, this incentive would result in slight reduction in the payback for the upgrade. The energy efficiency of new televisions is continuing to increase while at the same time the price of the new televisions is decreasing. This means that the economics of replacing old inefficient televisions – especially early models of flat screen televisions – will improve over time.

FIGURE A43: DISTRIBUTION OF PAYBACKS FOR THE TELEVISION UPGRADE

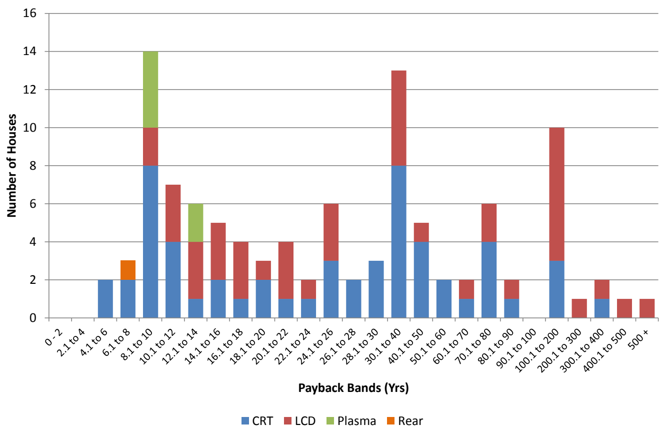
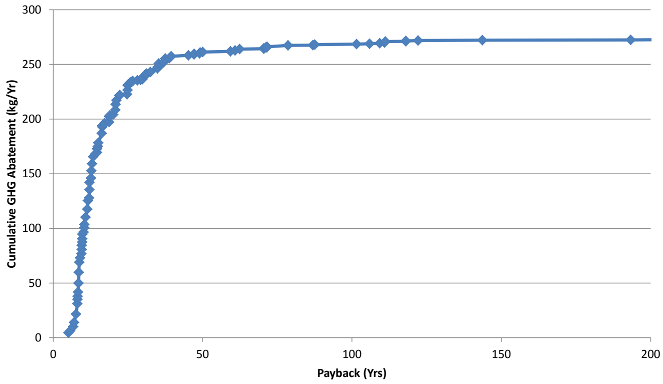


FIGURE A44: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE FOR THE TELEVISION UPGRADE



A5: Effect of Application Order on Energy Savings

Introduction

The main analysis presented in the OGA study report is based on an assumed order in which the building shell, heating and cooling, and the upgrade measures for the "wet" appliances are applied. This approach has been undertaken so that we do not double-count the savings which can be achieved from the individual upgrade measures when estimating the overall energy savings.

The order of application of the measures will have some impact on the estimated savings achieved for each individual measure, due to potential interactions between the different upgrade measures, which could include:

- Interactions between the different building shell upgrade measures. These interactions are quite complicated, and would require multiple FirstRate5 runs for each house to test the impact of applying a certain measure at a different point in the upgrade process than the one assumed. For this reason we did not explore this issue further. The effect is expected to be fairly small;
- The point of application in the process of the heating and cooling upgrades. For example, the energy savings achieved from the wall insulation measure would be expected to be larger if the heating/cooling upgrades were assumed to be undertaken after this measure. Conversely, the energy savings achieved for the heating/cooling upgrade measures would be expected to be smaller if they were assumed to be undertaken after the wall insulation measure. This is expected to be one of the main interactions between the upgrade measures which impact on heating and cooling energy savings, and is explored in more detail below;
- The point of application of the water heating upgrade relative to the low flow shower rose upgrade. This is expected to be one of the main interactions for the appliance upgrade measures and is explored in more detail below;
- Potential interactions between the lighting and appliance measures and the heating/cooling upgrade measures. Upgrading to higher efficiency lighting or televisions will reduce the heat load created by these in both summer and winter. This could increase the energy savings from the heating upgrade (as heating would need to work a bit harder to maintain internal temperatures) and decrease the savings from the cooling upgrade (as cooling would not have to work as hard). However, the lighting and appliance upgrades would also generate some cooling savings. These interactions are expected to be relatively minor. They are not well understood in the residential context and are difficult to model, so have not been studied further;
- The point of application of the water heating upgrade relative to the clothes washer and dishwasher upgrades. This interaction is expected to be relatively minor, due to the relatively low hot water consumption of these appliances, and was not explored further.

Percentage energy savings from building shell upgrades

We have calculated the average savings achieved by the different building shell upgrade measures, expressed as a percentage of the initial heating and cooling energy use of the houses for two different scenarios: (1) heating and cooling upgrades undertaken first – this results in the lowest energy saving for the building shell measures; (2) building shell upgrades undertaken before any heating and cooling upgrades – this results in the highest energy saving for the building shell measures. The range of results achieved is shown in Table A48 – the percentage savings used in our main analysis (see Table 27, Chapter 4) are shown in bold in this table.

In most cases changing the order of the building shell upgrade relative to the heating/cooling upgrade results in around a 20 to 30% increase (or decrease) in the level of savings which are achieved from a given building shell upgrade.

TABLE A48: IMPACT OF THE ORDER OF HEATING AND COOLING UPGRADES ON BUILDING SHELL SAVINGS

	Av. Saving Across Stock		Av. Saving When Implemented	
Measure	**Heating**	**Cooling**	**Heating**	**Cooling**
Draught sealing	14.0% to **18.0%**	6.7% to **8.4%**	14.2% to **18.3%**	7.1% to **8.9%**
Ceiling insulation (easy)	2.1% to **2.5%**	1.0% to **1.6%**	18.2% to **21.4%**	8.8% to **13.9%**
Ceiling insulation (difficult)	**3.4%** to 4.7%	**4.7%** to 7.1%	**10.1%** to 14.0%	**16.4%** to 24.7%
Reduce sub-floor ventilation	1.1% to **1.3%**	0.1% to **0.3%**	4.9% to **6.0%**	1.3% to **2.4%**
Seal wall cavity	1.5% to **2.0%**	1.4% to **1.8%**	3.1% to **3.9%**	2.2% to **2.9%**
Under floor insulation	2.6% to **3.3%**	-7.6% to **-9.6%**	6.5% to **8.2%**	-16.6% to **-21.1%**
Ceiling insulation top-up	**1.7%** to 2.3%	**2.8%** to 3.3%	**4.0%** to 5.4%	**7.6%** to 9.0%
Wall insulation	**12.5%** to 15.6%	**9.7%** to 11.8%	**13.1%** to 16.5%	**10.9%** to 13.4%
Drapes & pelmets	**5.9%** to 7.9%	**2.5%** to 3.4%	**5.9%** to 7.9%	**2.5%** to 3.5%
Double glazing	**5.7%** to 7.3%	**6.7%** to 9.2%	**5.7%** to 7.3%	**6.7%** to 9.4%
External shading	-	**3.7%** to 4.7%	-	**6.5%** to 8.2%

Cost-benefit analysis of building shell upgrades

We have undertaken the cost-benefit analysis for the building shell upgrades for both the situation where the heating and cooling upgrades are undertaken before any building shell upgrades, and for the situation where the building shell upgrades are undertaken before the heating and cooling upgrades. The results of this analysis are presented below in Tables A49 to A52.

TABLE A49: IMPACT OF BUILDING SHELL UPGRADES WHEN IMPLEMENTED – HEATING AND COOLING UPGRADES UNDERTAKEN FIRST

		Av. Energy Saving (MJ/Yr)						
Measure	**% Houses Applied to**	**Gas**	**Elec**	**Total**	**Av. GHG Saving (kg/Yr)**	**Av. Cost ($)**	**Av. Saving ($/Yr)**	**Av. Payback (Yrs)**
Ceiling insulation (easy)	11.7%	7,083	214	**7,297**	463	$673	$140.6	4.8
Draught sealing	98.3%	6,222	147	**6,369**	386	$1,037	$120.3	8.6
Ceiling insulation (difficult)	33.3%	4,891	204	**5,095**	333	$835	$101.5	8.2
Reduce sub-floor ventilation	21.7%	2,135	39	**2,174**	130	$769	$40.4	19.0
Seal wall cavity	50.0%	1,439	36	**1,475**	90	$541	$28.0	19.3
Ceiling insulation top-up	43.3%	1,970	50	**2,020**	124	$774	$38.4	20.2
Underfloor insulation	40.0%	3,472	23	**3,495**	198	$1,962	$62.6	31
Wall insulation	95.0%	5,561	136	**5,697**	349	$4,167	$107.9	39
Drapes & pelmets	100.0%	2,209	54	**2,263**	139	$2,036	$42.9	47
Double glazing	100.0%	2,278	66	**2,344**	146	$12,145	$45.0	270
External shading	31.7%	0	27	**27**	8	$1,464	$2.1	694

The total energy savings from the building shell upgrades are around 28% larger if the all building shell upgrades are undertaken before the heating and cooling upgrades compared to the situation where the heating and cooling upgrades are undertaken before the building shell upgrades. For our main analysis we assumed the heating cooling upgrades were undertaken after the underfloor insulation upgrade – the building shell savings would be around 12% lower than in our analysis if the heating/cooling upgrades were undertaken first, and around 13% higher if the heating/cooling upgrades were undertaken last.

TABLE A50: IMPACT OF BUILDING SHELL UPGRADES ACROSS STOCK – HEATING AND COOLING UPGRADES UNDERTAKEN FIRST

		Av. Energy Saving (MJ/Yr)						
Measure	% Houses Applied to	Gas	Elec	Total	Av. GHG Saving (kg/Yr)	Av. Cost ($)	Av. Saving ($/Yr)	Av. Payback (Yrs)
Ceiling insulation (easy)	11.7%	826	25	851	54	$79	$16.4	4.8
Draught sealing	98.3%	6,118	144	6,263	379	$1,020	$118.3	8.6
Ceiling insulation (difficult)	33.3%	1,630	68	1,698	111	$278	$33.8	8.2
Reduce sub-floor ventilation	21.7%	463	9	471	28	$167	$8.8	19.0
Seal wall cavity	50.0%	719	18	738	45	$270	$14.0	19.3
Ceiling insulation top-up	43.3%	854	22	875	54	$335	$16.6	20.2
Underfloor insulation	40.0%	1,389	9	1,398	79	$785	$25.0	31
Wall insulation	95.0%	5,283	129	5,412	332	$3,959	$102.5	39
Drapes & pelmets	100.0%	2,209	54	2,263	139	$2,036	$42.9	47
Double glazing	100.0%	2,278	66	2,344	146	$12,145	$45.0	270
External shading	31.7%	0	9	9	3	$464	$0.7	697
Total (ex Double glazing)		**19,491**	**486**	**19,978**	**1,223**	**$9,392**	**$379.0**	**24.8**
Total (ex Drapes & Pelmets)		**19,560**	**498**	**20,059**	**1,230**	**$19,501**	**$381.1**	**51.2**

TABLE A51: IMPACT OF BUILDING SHELL UPGRADES WHEN IMPLEMENTED – HEATING AND COOLING UPGRADES UNDERTAKEN LAST

		Av. Energy Saving (MJ/Yr)						
Measure	**% Houses Applied to**	**Gas**	**Elec**	**Total**	**Av. GHG Saving (kg/Yr)**	**Av. Cost ($)**	**Av. Saving ($/Yr)**	**Av. Payback (Yrs)**
Ceiling insulation (easy)	11.7%	8,210	277	8,487	546	$673	$165.2	4.1
Draught sealing	98.3%	7,942	225	8,167	595	$1,037	$156.5	6.6
Ceiling insulation (difficult)	33.3%	6,100	358	6,458	446	$835	$134.6	6.2
Reduce sub-floor ventilation	21.7%	2,720	53	2,774	167	$769	$51.7	14.9
Seal wall cavity	50.0%	1,806	48	1,853	113	$541	$35.3	15.3
Ceiling insulation top-up	43.3%	2,699	68	2,767	170	$774	$52.5	14.7
Underfloor insulation	40.0%	4,507	25	4,532	255	$1,962	$80.9	21.2
Wall insulation	95.0%	7,001	209	7,210	450	$4,167	$138.8	30
Drapes & pelmets	100.0%	2,853	107	2,960	190	$2,036	$58.2	35
Double glazing	100.0%	2,927	116	3,043	197	$12,145	$60.3	202
External shading	31.7%	0	37	37	11	$1,464	$2.9	512

TABLE A52: IMPACT OF BUILDING SHELL UPGRADES ACROSS STOCK – HEATING AND COOLING UPGRADES UNDERTAKEN LAST

		Av. Energy Saving (MJ/Yr)						
Measure	**% Houses Applied to**	**Gas**	**Elec**	**Total**	**Av. GHG Saving (kg/Yr)**	**Av. Cost ($)**	**Av. Saving ($/Yr)**	**Av. Payback (Yrs)**
Ceiling insulation (easy)	11.7%	958	32	990	64	$79	$19.3	4.1
Draught sealing	98.3%	7,810	221	8,031	585	$1,020	$153.9	6.6
Ceiling insulation (difficult)	33.3%	2,033	119	2,153	149	$278	$44.9	6.2
Reduce sub-floor ventilation	21.7%	589	11	601	36	$167	$11.2	14.9
Seal wall cavity	50.0%	903	24	927	57	$270	$17.7	15.3
Ceiling insulation top-up	43.3%	1,169	29	1,199	74	$335	$22.8	14.7
Underfloor insulation	40.0%	1,803	10	1,813	102	$785	$32.4	24
Wall insulation	95.0%	6,651	198	6,849	428	$3,959	$131.8	30.0
Drapes & pelmets	100.0%	2,853	107	2,960	190	$2,036	$58.2	35.0
Double glazing	100.0%	2,927	116	3,043	197	$12,145	$60.3	201.6
External shading	31.7%	0	12	12	4	$464	$0.9	512.1
Total (ex Double glazing)		**24,769**	**765**	**25,533**	**1,688**	**$9,392**	**$493.0**	**19.0**
Total (ex Drapes & Pelmets)		**24,843**	**774**	**25,616**	**1,695**	**$19,501**	**$495.0**	**39.4**

Cost-benefit analysis of heating and cooling upgrades

We have repeated the cost-benefit analysis for the heating and cooling upgrades based on the assumption that the upgrades are undertaken before the building shell upgrades, and based on the assumption that the upgrades are undertaken after all building shell upgrades. The results of this analysis are presented in Tables A53 and A54 below.

The point in the upgrade process at which the heating and cooling upgrades takes place can have a significant impact on the energy savings achieved, and therefore the paybacks. Heating savings are around 43% higher compared to our main analysis if the heating upgrade is undertaken before the building shell upgrades, and around 43% lower if they are undertaken after all of the building shell upgrades. This is because the building shell upgrades have a significant effect on the heating load which the heaters have to satisfy.

TABLE A53: IMPACT OF THE ORDER OF HEATING UPGRADES ON SAVINGS

		Energy Saving (MJ/Yr)						
Measure	**% Houses Applied to**	**Gas**	**Elec**	**Total**	**Av. GHG Saving (kg/Yr)**	**Av. Saving ($/Yr)**	**Av. Cost ($)**	**Av. Payback (Yrs)**
Across stock								
Heating – upgrade first	80.0%	8,782	420	9,202	613.6	$186.4	$1,111	6.0
Heating - analysis	80.0%	6,239	215	6,454	410.5	$125.9	$1,111	8.8
Heating - upgrade last	80.0%	3,504	207	3,710	256.7	$77.4	$1,111	14.4
When Implemented								
Heating - upgrade first	80.0%	10,977	525	11,503	767.0	$233.0	$1,388	6.0
Heating - analysis	80.0%	7,798	269	8,067	513.1	$157.4	$1,388	8.8
Heating - upgrade last	80.0%	4,380	258	4,638	320.8	$96.7	$1,388	14.4

The situation for the cooling upgrades is quite different. Cooling savings are around 2% lower compared to our main analysis if the cooling upgrade is undertaken before the building shell upgrades. This seems counterintuitive but occurs because upgrades such as draught sealing, underfloor insulation, reducing sub-floor ventilation and sealing the wall cavity lead to a slight increase in the cooling load in the houses which have a cooling upgrade. The cooling savings are around 50% lower than in our main analysis if they are assumed to occur after all of the building shell upgrades.

TABLE A54: IMPACT OF THE ORDER OF COOLING UPGRADES ON SAVINGS

		Energy Saving (MJ/Yr)						
Measure	% Houses Applied to	Gas	Elec	Total	Av. GHG Saving (kg/Yr)	Av. Saving ($)	Av. Cost ($/Yr)	Av. Payback (Yrs)
Across stock								
Cooling - upgrade first	40.0%	0	158	158	47.9	$12.3	$464.8	37.9
Cooling - analysis	40.0%	0	160	160	48.7	$12.5	$464.8	37.3
Cooling - upgrade last	40.0%	0	79	79	24.1	$6.2	$464.8	75.3
When Implemented								
Cooling - upgrade first	40.0%	0	394	394	119.7	$30.6	$1,161.9	37.9
Cooling - analysis	40.0%	0	401	401	121.7	$31.2	$1,161.9	37.3
Cooling - upgrade last	40.0%	0	198	198	60.3	$15.4	$1,161.9	75.3

It's important to note that while the application order has an impact on the energy savings achieved for an individual upgrade measure, the average total energy savings achieved from the building shell and heating and cooling upgrades (around 29,200 MJ/yr) remain essentially the same, irrespective of the order in which the upgrades are applied.

Cost-benefit analysis of water heating upgrades

We have tested the impact of undertaking the water heating upgrades before the low flow shower rose upgrades on the cost-benefit analysis, and vice versa. The results of this analysis are presented in Tables A55 to A57. Undertaking the gas water heater upgrade before the low flow shower rose upgrade increases average energy savings by around 5 to 6% – for both the high efficiency gas and gas boosted solar scenarios, giving a slight reduction in the stock average payback.

TABLE A55: IMPACT OF THE ORDER OF THE WATER HEATING UPGRADES ON SAVINGS – HIGH EFFICIENCY GAS

Measure	% Houses Applied to	Energy Saving (MJ/Yr)			Av. GHG Saving (kg/Yr)	Av. Saving ($)	Av. Cost ($/Yr)	Av. Payback (Yrs)
		Gas	Elec	Total				
Across stock								
HE Gas - first	58.3%	467	1,073	1,540	351.8	$61.8	$477.3	7.7
HE Gas - analysis	58.3%	460	1,004	1,463	330.4	$58.2	$477.3	8.2
When Implemented								
HE Gas - first	58.3%	800	1,839	2,639	603.1	$106.0	$818.3	7.7
HE Gas - analysis	58.3%	788	1,721	2,509	566.5	$99.8	$818.3	8.2

TABLE A56: IMPACT OF THE ORDER OF THE WATER HEATING UPGRADES ON SAVINGS – GAS BOOSTED SOLAR

Measure	% Houses Applied to	Energy Saving (MJ/Yr)			Av. GHG Saving (kg/Yr)	Av. Saving ($)	Av. Cost ($/Yr)	Av. Payback (Yrs)
		Gas	Elec	Total				
Across stock								
Solar - first	81.7%	7,502	864	8,366	677.6	$174.5	$3,825.4	21.9
Solar - analysis	81.7%	7,064	795	7,859	632.4	$163.4	$3,825.4	23.4
When Implemented								
Solar - first	81.7%	9,186	1,058	10,244	829.7	$213.6	$4,684.1	21.9
Solar - analysis	81.7%	8,650	973	9,624	774.4	$200.0	$4,684.1	23.4

Undertaking the low flow shower rose measure after the high efficiency gas water heater upgrade reduces the average savings by around 5%, leading to a slight increase in the stock average payback. However, the low flow shower rose upgrade measure remains the most cost effective upgrade measure.

TABLE A57: IMPACT OF THE ORDER OF THE WATER HEATING UPGRADES ON SAVINGS – LOW FLOW SHOWER ROSE

		Energy Saving (MJ/Yr)						
Measure	% Houses Applied to	Gas	Elec	Total	Av. GHG Saving (kg/Yr)	Av. Saving ($)	Av. Cost ($/Yr)	Av. Payback (Yrs)
Across stock								
LF Shower Rose - analysis	56.7%	1,333	69	1,402	94.7	$57.9	$48.8	0.84
LF Shower Roes - after HE Gas water heater	56.7%	1,331	0	1,331	73.6	$54.5	$48.8	0.89
When Implemented								
LF Shower Rose - analysis	56.7%	2,352	122	2,473	167.1	$102.3	$86.0	0.84
LF Shower Roes - after HE Gas water heater	56.7%	2,349	0	2,349	130.0	$96.1	$86.0	0.89

A6: Assumptions for Upgrade Analysis

Energy tariffs and greenhouse coefficients

The greenhouse gas emission coefficients and energy tariffs which have been used in the OGA study analysis are provided in Table A48.

The greenhouse coefficient for natural gas uses the figure from the National Greenhouse Accounts Factors workbook[150] for 2012.

The greenhouse coefficient used for electricity is a marginal greenhouse coefficient and this is lower than the current average greenhouse coefficient for electricity in Victoria of 1.32 kg/kWh[151]. This is because Victorian electricity generation is dominated by brown coal generators, but the marginal generators (and imports of electricity) which top up this supply during shoulder and peak electricity use periods have a lower greenhouse intensity. It is generally considered to be more accurate to use marginal greenhouse coefficients when estimating greenhouse abatement from electricity, especially in the residential sector where most electricity consumption occurs during the shoulder and peak periods.

The energy tariffs are based on the electricity and natural gas tariffs available in the Melbourne market in 2013. It is expected that these energy prices will continue to grow in real terms, increasing the value of the savings obtained from energy efficiency improvements and making them more cost effective.

TABLE A58: ASSUMED GREENHOUSE COEFFICIENTS AND ENERGY TARIFFS

Fuel	GHG Emission Factors		Energy Tariffs	
	Kg/ MJ	kg/ kWh	c/MJ	c/ kWh
Electricity – General	0.304	1.094	7.78	28.0
Electricity - Off Peak	0.304	1.094	5.00	18.0
Natural gas	0.05533	0.199	1.75	6.30

The value of the water savings from energy efficiency improvements relating to wet appliances are based on $3.24 per KL[152], a typical tariff available in the Melbourne market in 2013. As with the energy tariffs the cost of water is likely to continue to grow in real terms.

150 Australian National Greenhouse Accounts Factors, Department of Climate Change and Energy Efficiency, July 2012.

151 Average greenhouse coefficients are based on total energy use in Victoria divided by total emissions to produce this electricity. The current average is from the Australian National Greenhouse Accounts Factors July 2013, Department of Industry, Innovation, Climate Change, Science, Research & Tertiary Education. Marginal greenhouse coefficients are based on the greenhouse savings from the marginal generators when electricity savings are achieved in the energy market. The marginal coefficient used is based on the marginal coefficients recommended for preparing RIS documents for the E3 Committee, prepared by George Wilkenfeld, 14 July 2008.

152 Based on Yarra Valley Water tariff for Melbourne, April 2013 - $1.78/KL for water (block 1), $1.95/KL sewerage charge (linked to water use) and annual sewerage disposal factor of 75%.

Building shell upgrade costs

The cost assumptions which were used to estimate the total cost of the various building shell upgrades are set out in Table A49. These cost assumptions were developed by MEFL and RMIT based on a range of sources which are cited in the Table. The unit costs for the ceiling and underfloor insulation measures were reviewed and updated in 2015, based on feedback that the ceiling insulation costs were too high and the underfloor insulation costs too low.

TABLE A59: ASSUMED COSTS FOR THE BUILDING SHELL UPGRADES

No.	Upgrade	Description	Unit	Unit Cost ($)	Extra costs	Source
1	**Easy ceiling insulation**	Glasswool batt R2.0	m^2	$6.90	-	ICANZ 2012[153]
		Glasswool batt R2.5	m^2	$7.80	-	ICANZ 2012
		Glasswool batt R3.0	m^2	$8.70	-	ICANZ 2012
		Glasswool batt R3.5	m^2	$9.60	-	ICANZ 2012
2	**Draught sealing**	Comprehensive air sealing, based air leakage sites identified using blower door test	-	Cost estimate supplied by ABT	-	Air Barrier Technologies (ABT)
3	**Seal wall cavity**	Cost per lineal meter with RFL (incl GST) - tiled roof	m	$10.59	-	Based on estimate of Tony Isaacs using Rawlinsons
		Cost per lineal meter - no RFL (incl GST) - tiled roof	m	$8.73	-	Based on estimate of Tony Isaacs using Rawlinsons
		Cost per lineal meter with RFL (incl GST) - tin roof	m	$17.30	-	Based on estimate of Tony Isaacs using Rawlinsons
		Cost per lineal meter - no RFL (incl GST) - tin roof	m	$15.43	-	Based on estimate of Tony Isaacs using Rawlinsons
4	**Reduce sub-floor ventilation**	Cost for sealing up totally open sub-floor with fibre-cement (applicable for all floors)	m^2	$26.39	-	Based on estimate of Tony Isaacs using Rawlinsons
5	**Underfloor insulation**	Glasswool batt R1.5	m^2	$17.35	-	ICANZ 2012

153 *The Value of Insulation Based Residential Energy Savings Measures in Australia*, ICANZ, Sept 2012. Prepared by Energy Efficient Strategies.

No.	Upgrade	Description	Unit	Unit Cost ($)	Extra costs	Source
6	**Wall insulation**	Cost for single storey brick cavity wall house with tile roof and limited drilling required	m^2	$32.50	$250	Industry sources
		Cost for framed houses where significant drilling is required	m^2	$42.50	$250	Industry sources
		Cost for single story cavity brick walls with roofing iron instead of tiles	m^2	$37.50	$250	Industry sources
		Cost for double story brick cavity wall house with tile roof and limited drilling required	m^2	$36.00	$250	Industry sources
		Cost for double story cavity brick walls with roofing iron instead of tiles	m^2	$37.50	$250	Industry sources
		Safety harness for difficult houses/ double story houses	fixed cost	-	$250	Industry sources
7	**Ceiling insulation - difficult**	Glasswool batt R2.5	m^2	$7.80	-	ICANZ 2012
		Additional cost for removing tin or tiles - large area	fixed cost	-	$671.00	Based on discussion with industry sources and using labour rates from Cordell
		Additional cost for removing tin or tiles - medium area	fixed cost	-	$469.70	Based on discussion with industry sources and using labour rates from Cordell
		Additional cost for removing tin or tiles - small area	fixed cost	-	$335.50	Based on discussion with industry sources and using labour rates from Cordell
		Glasswool batt R2	m^2	$6.90	-	ICANZ 2012
		Glasswool batt R2.5	m^2	$7.80	-	ICANZ 2012
		Glasswool batt R3	m^2	$8.70	-	ICANZ 2012
		Glasswool batt R3.5	m^2	$9.60	-	ICANZ 2012
9a	**Double glazed windows**	Double glazed window with aluminium frame	m^2	$580.00	-	Average calculated from Autumn 2010 Archicentre cost guide
9b	**Installation of drapes and pelmets**	Installation of drapes	m^2	$110.46	-	Average derived from survey of curtain shops
		Installation of pelmets	per lineal meter	$52.18	-	Cordell - July/Aug/Sep 2010
10	**External awnings**	Canvas awning	m^2	$154.34	-	Average derived from survey of blind shops

A7: Cumulative Savings Curves

Cumulative curves for greenhouse gas abatement are provided for the building shell upgrades, lighting and appliance upgrade, and for all measures are provided in Chapter 4. In this Appendix we provide the cumulative abatement curves and cumulative cost curves for all measures, as well as cumulative savings curves for both electricity and gas. These curves have all been normalised, so they indicate what is possible in the average house, based on our analysis of the stock of 60 OGA study houses.

Building shell upgrades – excluding double glazing

FIGURE A45: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE

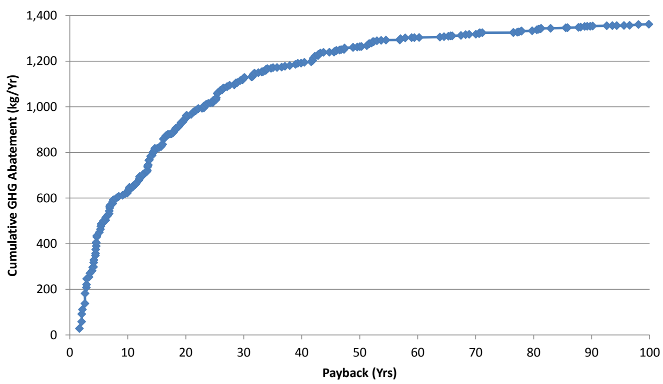


FIGURE A46: NORMALISED CUMULATIVE COST CURVE

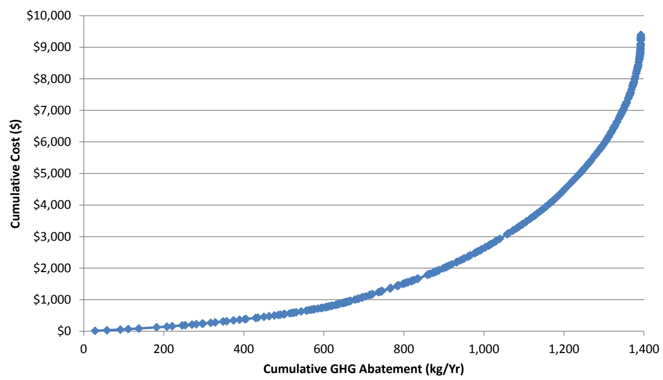


FIGURE A47: NORMALISED CUMULATIVE ENERGY SAVING CURVE

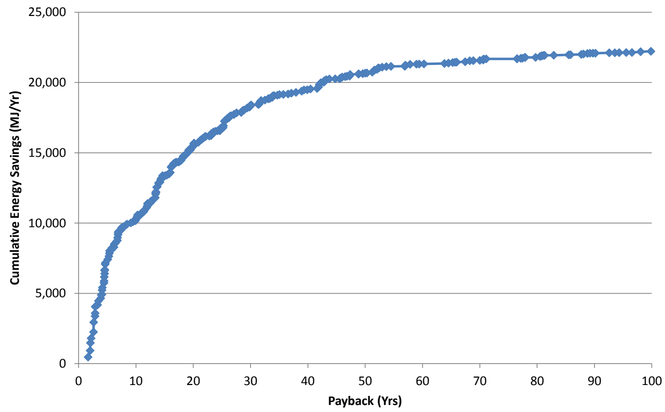


FIGURE A48: NORMALISED CUMULATIVE GAS SAVING CURVE

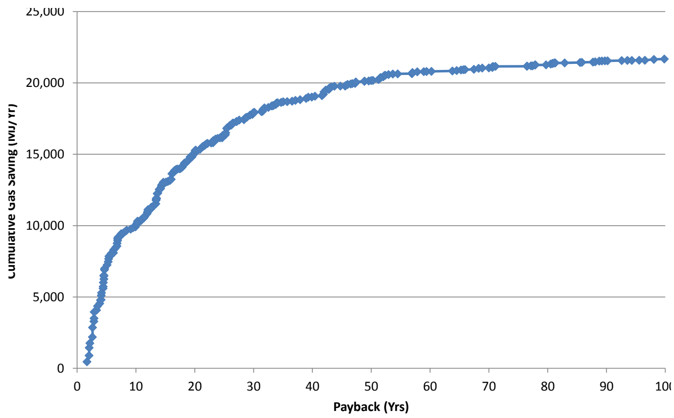
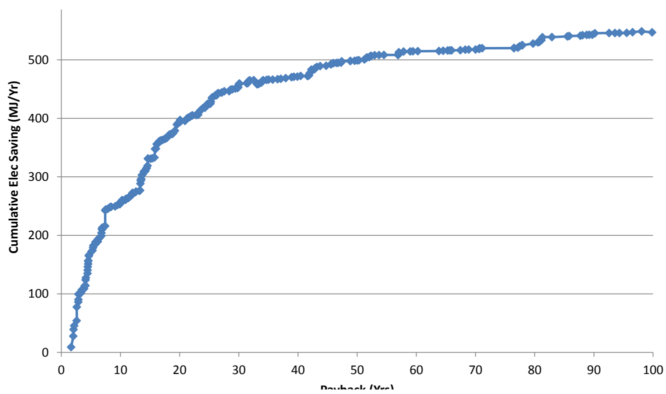


FIGURE A49: NORMALISED CUMULATIVE ELECTRICITY SAVING CURVE



Building shell upgrades – excluding drapes

FIGURE A50: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE

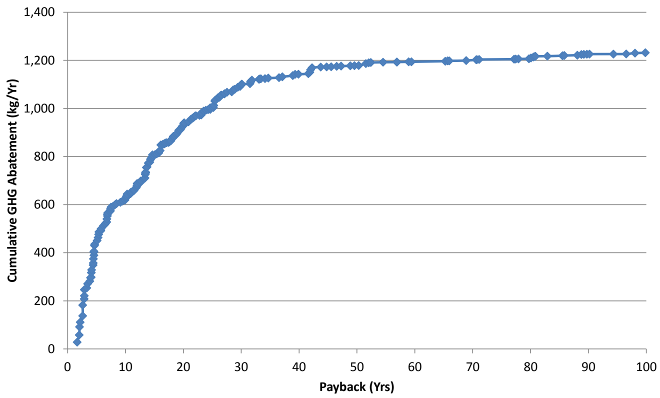


FIGURE A51: NORMALISED CUMULATIVE COST CURVE

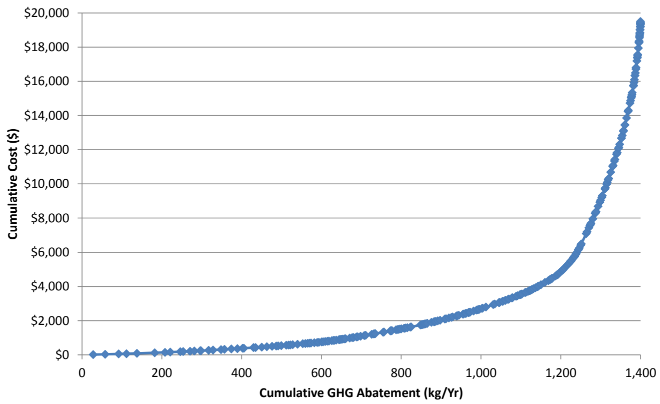


FIGURE A52: NORMALISED CUMULATIVE ENERGY SAVING CURVE

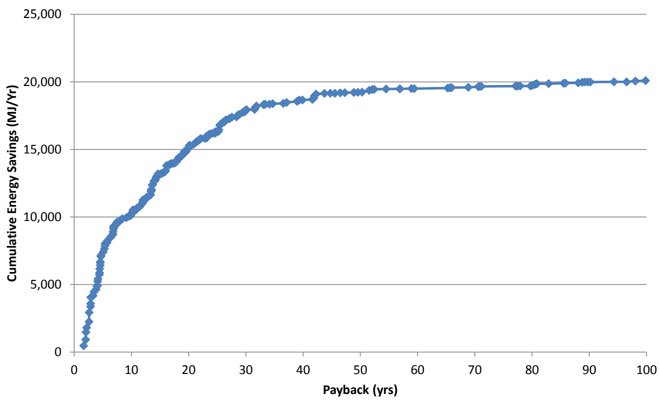


FIGURE A53: NORMALISED CUMULATIVE GAS SAVING CURVE

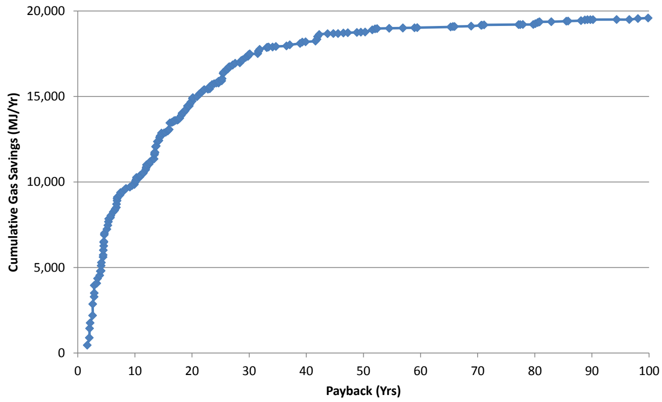
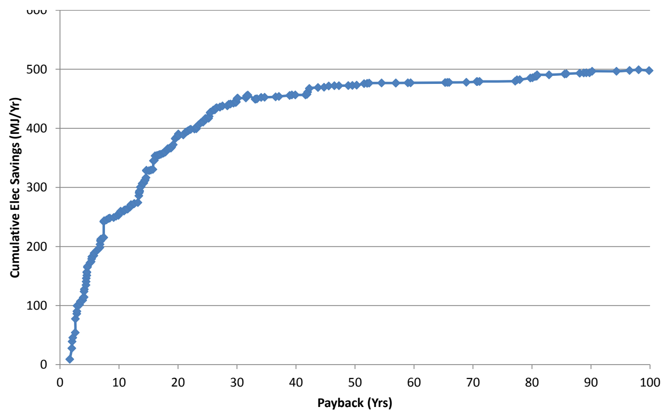


FIGURE A54: NORMALISED CUMULATIVE ELECTRICITY SAVING CURVE



Lighting and appliance upgrades

FIGURE A55: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE

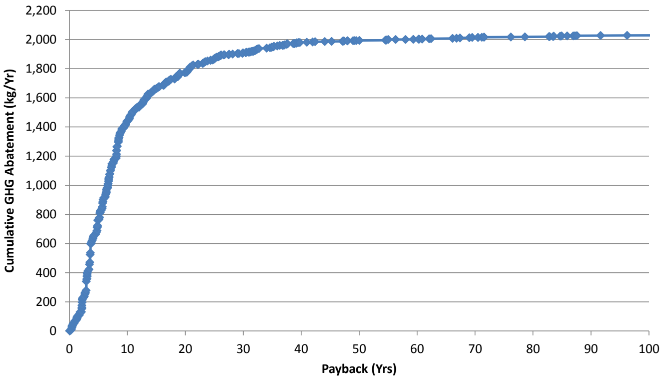


FIGURE A56: NORMALISED CUMULATIVE COST CURVE

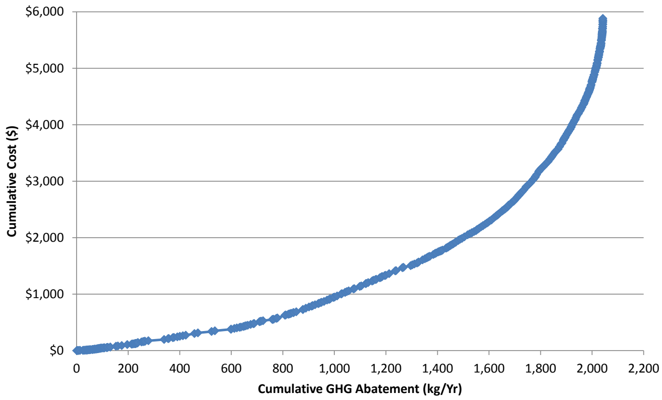


FIGURE A57: NORMALISED CUMULATIVE ENERGY SAVING CURVE

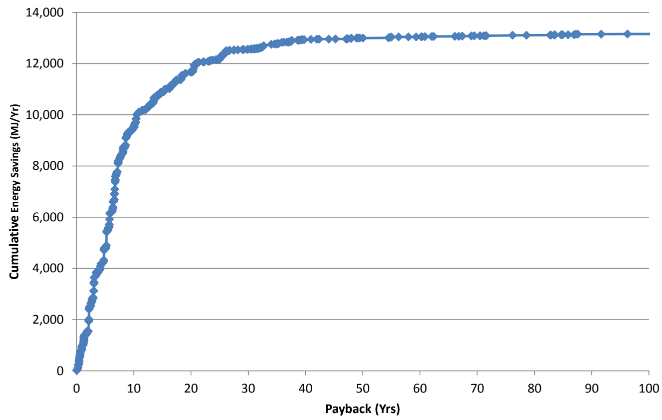


FIGURE A58: NORMALISED CUMULATIVE GAS SAVING CURVE

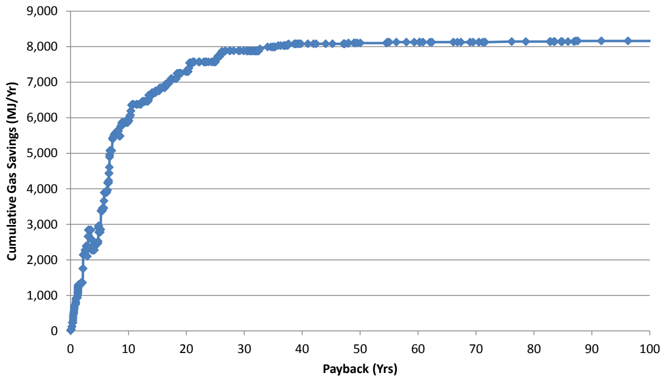
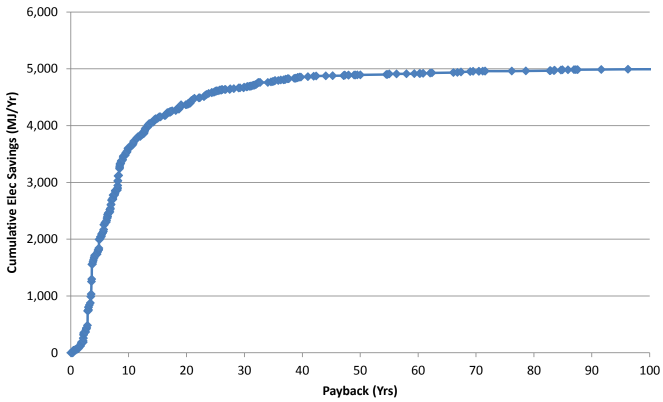


FIGURE A59: NORMALISED CUMULATIVE ELECTRICITY SAVING CURVE



All upgrades – excluding double glazing

FIGURE A60: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE

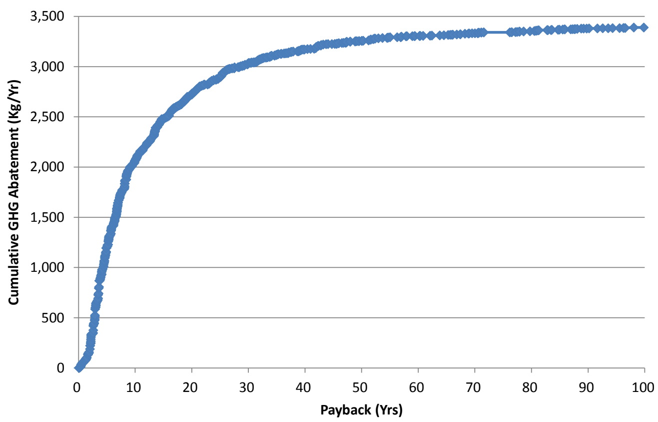


FIGURE A61: NORMALISED CUMULATIVE COST CURVE

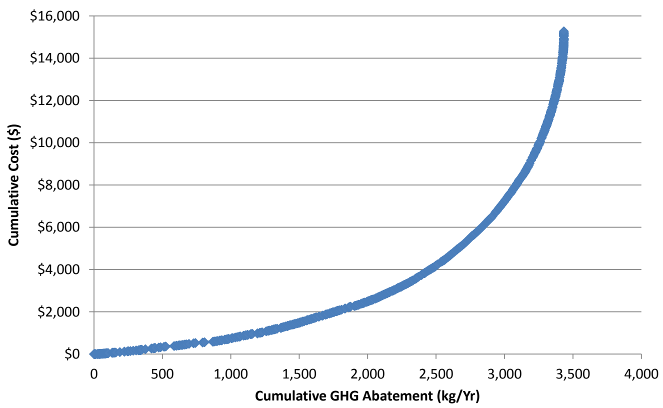


FIGURE A62: NORMALISED CUMULATIVE ENERGY SAVING CURVE

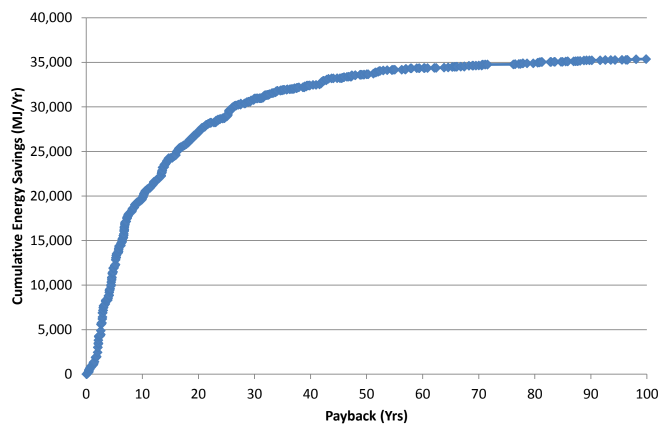


FIGURE A63: NORMALISED CUMULATIVE GAS SAVING CURVE

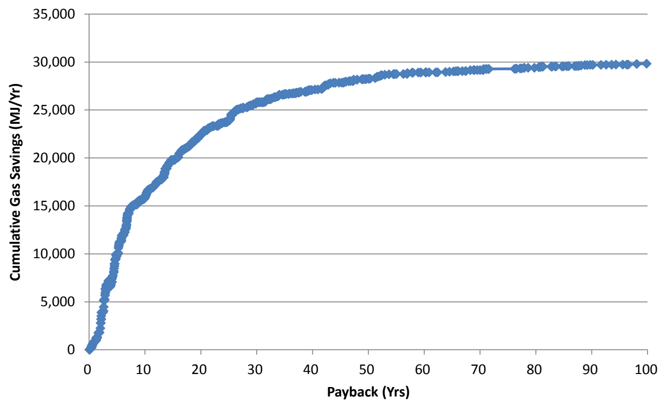
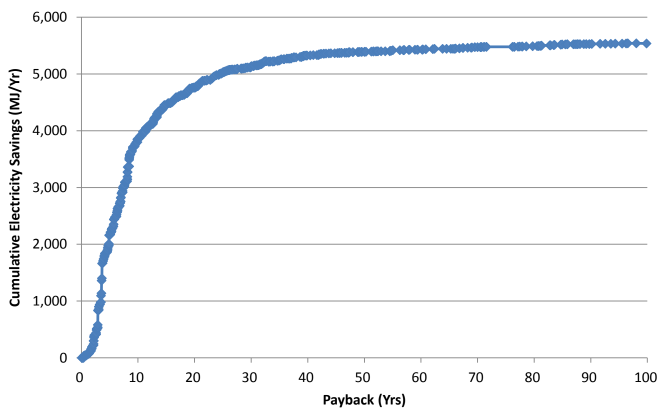


FIGURE A64: NORMALISED CUMULATIVE ELECTRICITY SAVING CURVE



All upgrades – excluding drapes

FIGURE A65: NORMALISED CUMULATIVE GREENHOUSE ABATEMENT CURVE

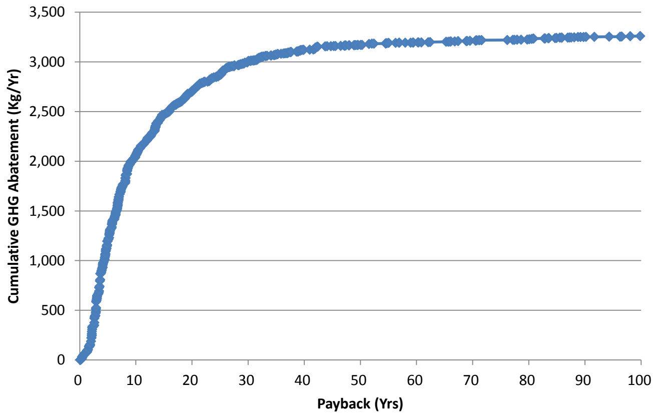


FIGURE A68: NORMALISED CUMULATIVE GAS SAVING CURVE

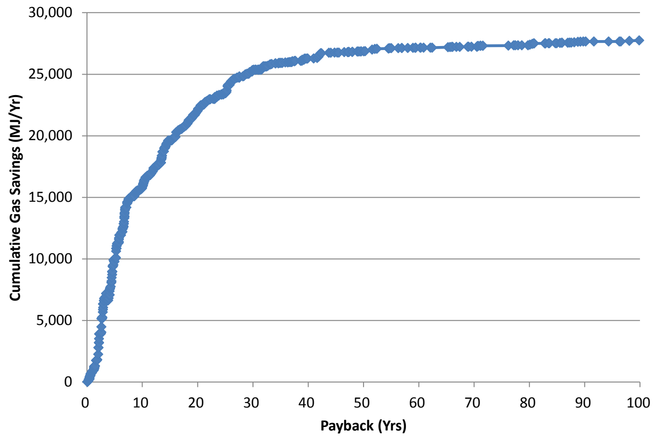


FIGURE A66: NORMALISED CUMULATIVE COST CURVE

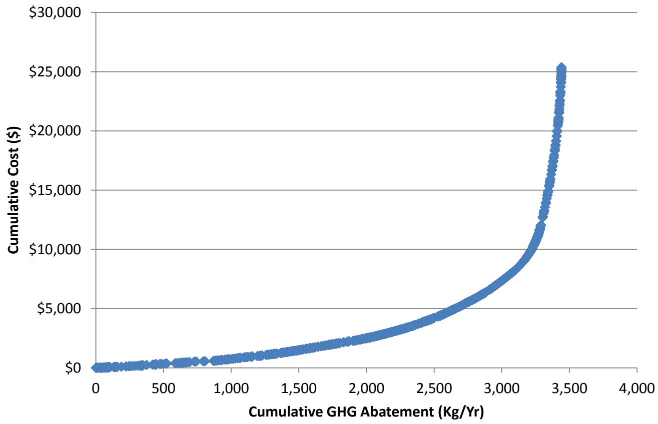


FIGURE A69: NORMALISED CUMULATIVE ELECTRICITY SAVING CURVE

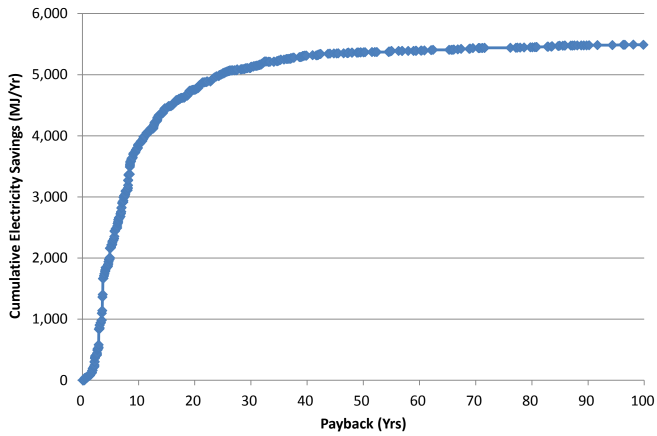
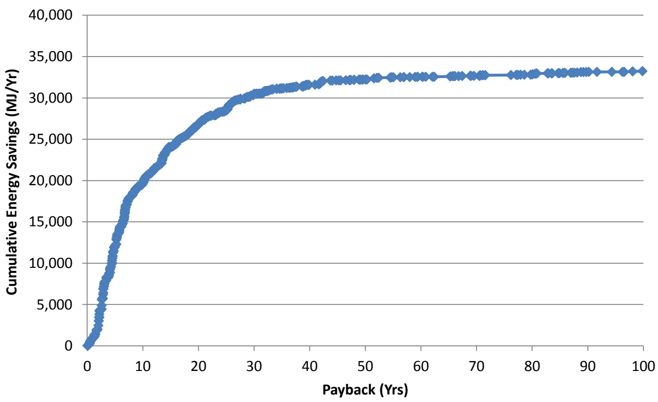


FIGURE A67: NORMALISED CUMULATIVE ENERGY SAVING CURVE



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