Reach for the Stars

The Value of Higher Efficiency Homes in Victoria

renew.

Document information

DOCUMENT VERSION	DATE	PREPARED BY	REVIEWED BY	COMMENTS
Renew 6-10 Star Analysis – FINAL Report v3.0	27th May 2019	Damien Moyse – Policy & Research Manager	Keiran Price – Energy Analyst	
Renew 6-10 Star Analysis – FINAL Report v4.0	10th Sept 2019	Damien Moyse – Policy & Research Manager		For public release

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Prepared for General Release

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Executive Summary

With the rise of rooftop solar photovoltaic (PV) systems, high efficiency electric technology to supply space and water heating loads, and improvements in passive solar building design and construction, there is increasing evidence that substantial energy and financial savings can be achieved in the residential building sector at low cost.

Yet greenfield and infill residential developments of Class 1 buildings in Victoria involve homes built to the minimum 6 Star energy rating requirement and continue to be established as "dual fuel" – i.e. are supplied with both reticulated gas and grid electricity, with the former typically supplying the space heating, water heating and cooking loads.

The purpose of this project has been to undertake an economic analysis of the value of:

- building homes to higher levels of energy efficiency;
- all-electric homes, in comparison with dual fuel homes (given its Victorian focus); and
- solar photovoltaic (PV) technology.

In line with this objective, the project modelled a range of household types, sizes and locations within Victoria.

Approach

The modelling sought to understand the capital and operational costs, and medium to long term value, of higher efficiency, Class 1 dwellings, as compared with typical 6 Star "dual fuel" Class 1 dwellings in Victoria. Appliance mix was a key focus of the modelling, with both dual fuel and all-electric homes being considered. In addition, solar photovoltaic (PV) technology was also considered.

In line with the project objective, the modelling established "Base Case" homes against which all other modelled homes were compared. These were developed based on industry feedback regarding the most common fuel types and appliance mix of new Class 1 dwellings in Victoria. Two main types of Base Case homes were modelled (varying by size, location and thermal efficiency), as follows:

	BASE CASE HOME 1	BASE CASE HOME 2
Name	Dual Fuel: Gas-boosted Solar	Dual Fuel: Gas Instantaneous
Modelling Code:	Gb	Gi
Energy Rating:	6 Stars	6 Stars
Appliance Mix		
Hot Water:	Gas-boosted Solar Thermal	Gas Instantaneous
Space Heating:	Gas Ducted	Gas Ducted
Cooking:	Gas cooktop, electric oven	Gas cooktop, electric oven
All Other Appliances	Electric	Electric

Table 1 Base Case Homes Modelled

To compare against the Base Case homes, alternative higher efficiency homes with different appliance mixes (including solar photovoltaic) were developed:

	ALT HOME 1	ALT HOME 2	ALT HOME 3	ALT HOME 4
Name	Dual Fuel: Gas-boosted Solar	Dual Fuel: Gas Instantaneous	All-Electric: No Solar PV	All-Electric: With Solar PV (5kW)
Modelling Code:	Gb	Gi	Ae	Ae
Energy Rating:	7, 8, 9 & 10 Stars	7, 8, 9 & 10 Stars	6, 7, 8, 9 & 10 Stars	6, 7, 8, 9 & 10 Stars
Appliance Mix				
Hot Water:	Gas-boosted Solar Thermal	Gas Instantaneous	Heat Pump	Heat Pump
Space Heating:	Gas Ducted	Gas Ducted	Reverse Cycle Air Con	Reverse Cycle Air Con
Cooking:	Gas Cooktop, Electric Oven	Gas Cooktop, Electric Oven	Induction cooktop, Electric Oven	Induction cooktop, Electric Oven
All Other Appliances	Electric	Electric	Electric	Electric

Table 2 Alternative Homes Modelled

Location & Household Types

The project team selected five locations for the modelling based on the need to represent:

- urban growth areas – where most of Victoria's new housing over the next decade will be located (i.e. Melbourne's north, south east and west);
- a range of climate zones – including the warmer climate of North-West Victoria (i.e. Mildura) and the colder climate of Gippsland and South Western Victoria; and
- Victoria's highest (Mildura) and lowest (Warrnambool) level of solar irradiance, given the consideration of solar PV in the model.

Three household types were modelled for each location, with the following assumed sizes and occupancy profiles:

HOUSEHOLD TYPE	FLOOR SPACE	OCCUPANTS
Small Home	100 sqm	1-2 persons
Medium Home	166 sqm	3-4 persons
Large Home	230 sqm	4-5 persons

Table 3 Household Types & Descriptions

Payback Periods

The payback charts are defined in years – i.e. the number of years taken for the additional capital associated with higher building efficiency, all-electric appliance mix and solar PV (and any replacement capex that may be incurred), to pay for itself in the form of energy bill savings, as compared with the Base Case, 6 Star dual fuel home.

The charts are presented by location and household size and consider the build cost premium (low, medium, high sensitivities were used) and either a 7% or 4% discount rate (as noted).

Figure 1 shows payback by star rating and additional capital expense (capex) for the Medium-sized, solar all-electric home in Melbourne (7% discount rate). This is compared against a 6-Star dual fuel home with gas-boosted solar hot water. As can be seen, payback times lengthen in line with additional capex incurred. Of note, payback time is:

- less than 10 years for all three build cost premiums associated with a 7 Star build;
- less than 10 years for the low/medium build cost premiums associated with an 8 Star build;
- less than 10 years for the low build cost premium associated with a 9 Star build; and
- longer than 25 years for the:
  - high build cost premium associated with a 9 Star build; and
  - medium and high build cost premiums associated with a 10 Star build.

Significantly, payback time is very short (less than 4.5 years) for all three build cost premiums associated with a 7 Star build, and the low sensitivities for an 8 Star build.

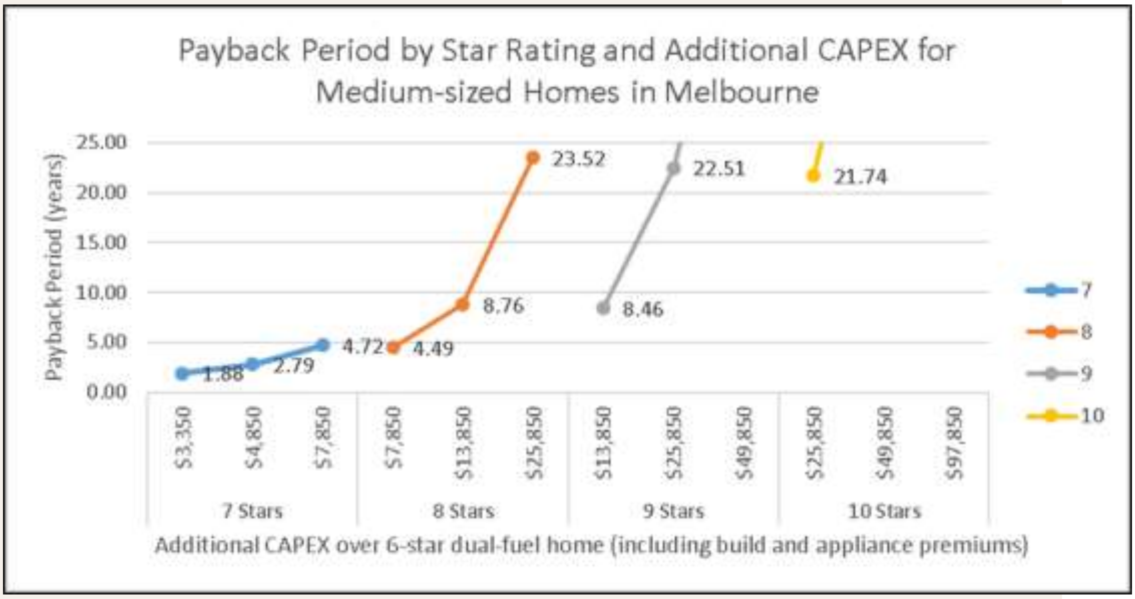

Figure 1: Payback by Star/Capex, Medium Solar All-Electric Melbourne Home (7% Discount)[1]

[1] Compared to 6-Star dual fuel gas-boosted SHW home.

In the four regional locations modelled, payback results were:

- less than 10 years for all three build cost premium sensitivities associated with a 7 Star build;
- less than 10 years for the low and medium build cost premiums associated with an 8 Star build;
- less than 10 years for the low build cost premium associated with a 9 Star build; and
- longer than 25 years for the:
    - high build cost premium associated with a 9 Star build (apart from Warrnambool); and
    - medium and high build cost premiums associated with a 10 Star build.

Obviously, the choice of discount rate has a material impact on payback times. The next chart shows the payback times for the Medium Solar All-Electric Home in Melbourne based on a 4% discount rate:

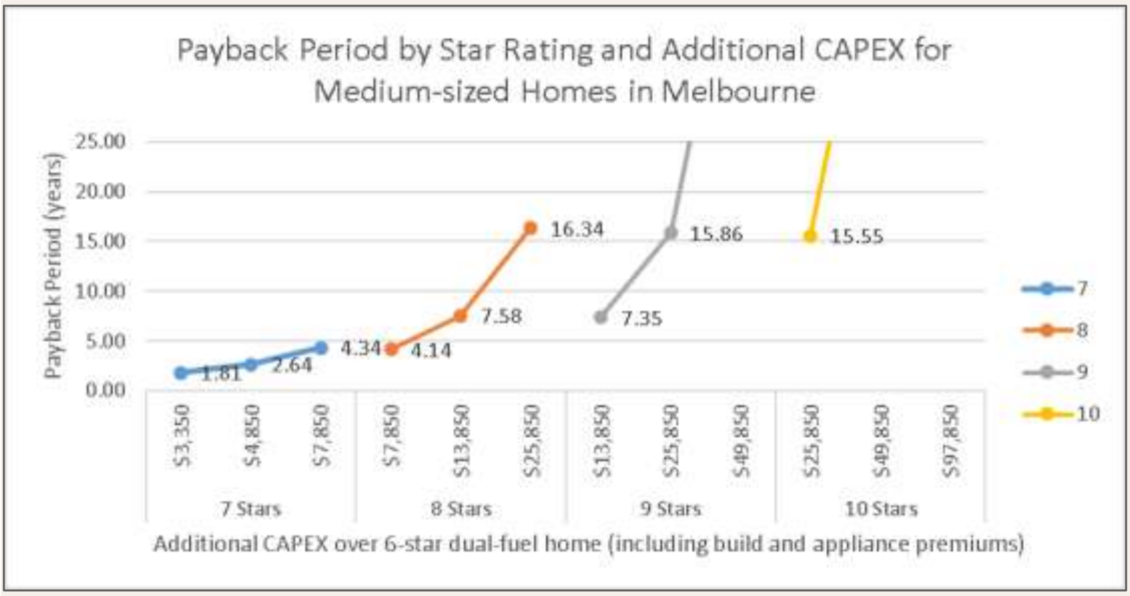

Figure 2: Payback by Star/Capex, Medium Solar All-Electric Home, Melbourne (4% Discount)[2]

The value of solar PV to the payback times can be seen in the next chart – which shows the payback period by star rating and additional capital expense (capex) for the Medium-sized, all-electric home without solar PV in Melbourne, using the 7% discount rate:

[2] Compared to 6-Star gas-boosted SHW home.

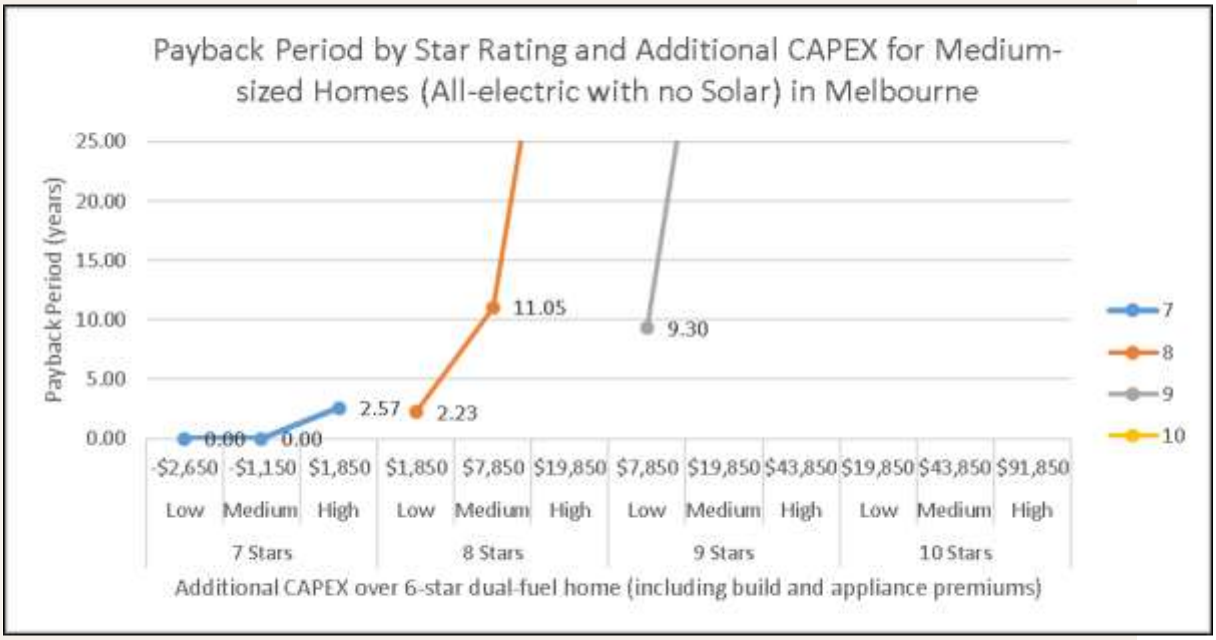

Figure 3: Payback by Star Rating/Capex, Medium All-Electric Melbourne Home (7% Discount)[3]

As can be seen, as compared with the equivalent home with solar PV:

- Payback is reduced for the 7-Star homes, as not having solar reduces the capex:
  - Under the low and medium build-cost premiums, a 7-Star all-electric home without solar is cheaper than a 6-Star dual-fuel home with gas-boosted solar HWS (i.e. payback is negative);
  - Under the high build-cost premium, payback reduces from 4.72 years to 2.57 years, as the total additional capex reduces from $7,850 with solar to $1,850 without solar;
- Payback is reduced for 8-Star homes under low build-cost premium, and is increased under medium and high build-cost premiums:
  - Under the low build-cost premium, additional capex reduces from $7,850 to $1,850, reducing payback from 4.49 years to 2.23 years;
  - Under the high build-cost premium, additional capex reduces from $13,850 to $7,850, however payback time increases due to lower bill savings without solar;
- Payback is increased for all 9- and 10-Star homes without solar:
  - A 9-Star home with low build-cost premiums sees the additional capex reduce from $13,850 to $7,850, however once again this increases the payback, from 8.46 years to 9.3 years;
  - No payback with 25 years for any 10-Star homes without solar.

[3] Compared to 6-Star dual fuel gas-boosted SHW home.

Net present value (25-Year Horizon

Net present values (NPVs) were also defined, on both a 10-year and 25-year, discounted basis (7% and 4% were again used). This section presents the results of the 25-year NPVs for each household type. The charts demonstrate positive or negative values over the relevant time period, considering all capital, operational and replacement costs, bill savings and the discount rates, as compared with the Base Case, 6 Star dual fuel home.

The next chart shows the 25-year NPV of the solar all-electric homes in Melbourne (7% discount rate), considering the different home sizes, build cost premiums and Star ratings. As can be seen:

- The 7 and 8-Star solar all-electric homes retain a positive NPV over 25 years for all build-cost premium sensitivities, with exception of the high build-cost premium at 8-Stars[4];
- The 9-Star solar all-electric homes retain a positive NPV over 25 years for the low and medium build-cost premium sensitivities only;
- The 10-Star solar all-electric homes retain a positive NPV over 25 years for only the low build-cost premium sensitivities, and only for the Small and Medium-sized homes.

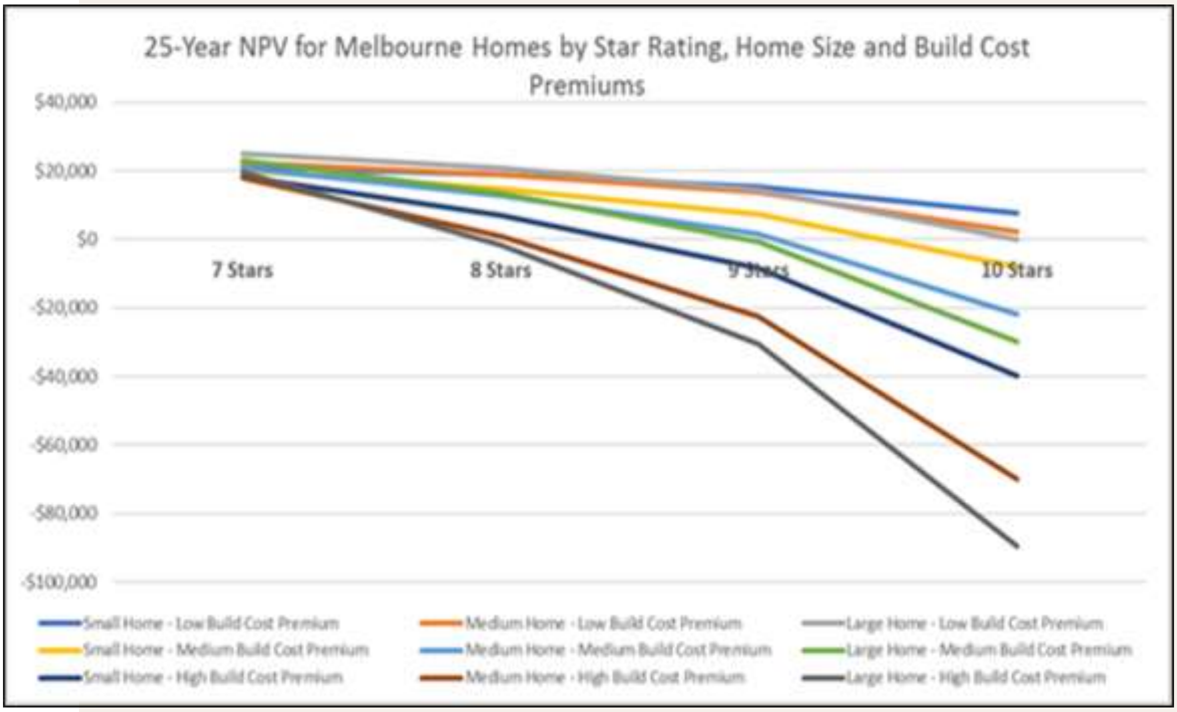

Figure 4: 25-Year NPV by Star Rating/Size, Solar All-Electric Home, Melbourne (7% Discount)[5]

[4] At 7 Stars, the NPVs range between $18,000 and $25,000; whilst at 8 Stars, the NPVs range between $944 and $21,000. The high build-cost premium for 8-Stars led to a 25-year NPV of -$1,509.

[5] Compared to 6-Star gas-boosted SHW home.

The next chart shows the 25-year NPV of the solar all-electric homes in Melbourne (7% discount rate), as compared with 6-Star gas-boosted solar hot water (Gb) and 6-Star gas instantaneous hot water (Gi) homes. Only the medium build-cost premium has been included in this chart.

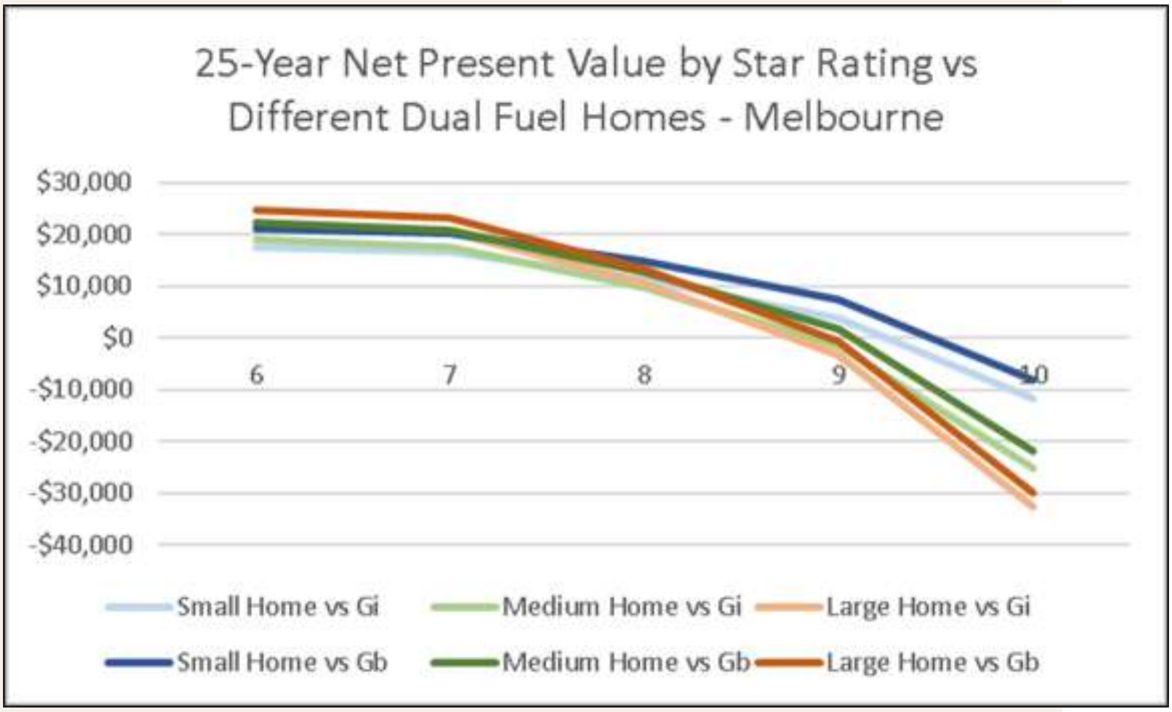

Figure 5: 25-Year NPV by Star/Size, Solar All-Electric Home, Melbourne (7% Discount, Medium Build Cost Premium)

As can be seen, between 6 and 8-Stars, the solar all-electric homes perform marginally better against the 6-Star gas-boosted solar hot water homes, as compared to the 6-Star gas instantaneous hot water homes. The results then become mixed beyond 8-Stars.

Whilst the same trend-line can be seen as compared with the previous chart, the inclusion of the 6-Star solar all-electric home in this chart is of interest. Essentially, the 6-Star and the 7-Star solar all-electric home offers almost the same value over 25 years as compared with their dual fuel counterparts.

In the four regional locations modelled, 25-year NPV results again demonstrated a similar trend to those for Melbourne. For all four locations, the 25-year NPVs were positive for the 6, 7 and 8-Star solar-all electric homes, with Horsham (Small home only), Warranmbool and Mildura being positive for 9-Stars.

Value of Solar PV

Solar PV makes a significant difference to the annual bill savings and therefore NPVs of the all-electric versus the dual fuel homes. The next chart shows the 25-year NPVs all-electric homes in Melbourne, with and without solar PV, when compared to a 6-Star dual fuel home with gas-boosted solar hot water. As can be seen, without solar PV installed, 6 and 7-Star all-electric homes reduce in value by at least $10,000 over 25 years:

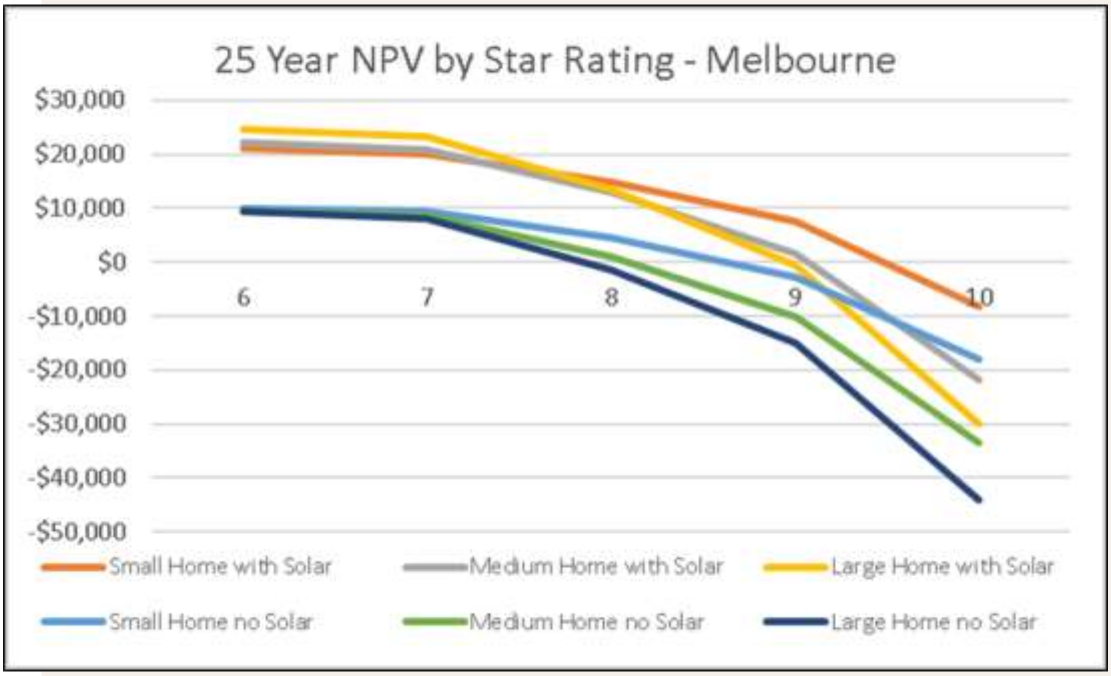

Figure 6: 25-Year NPV by Star/Size, All-Electric Home, Melbourne, with & without Solar PV (7% Discount, Medium Build Cost Premium)[6]

[6] Compared to 6-Star gas-boosted SHW home.

Value of Building Efficiency Upgrades

The following charts isolate the 25-year value of the building efficiency upgrades only – by comparing higher efficiency dual fuel homes (without solar PV) with the Base Case 6-Star dual fuel homes.

As can be seen, the 7-Star dual fuel homes with the medium build-cost premium offer a small amount of value (<$4,000) over 25 years when compared with a 6-Star dual fuel with gas-boosted solar hot water home. This value falls to around zero when the 7-Star home is compared to a 6-Star with gas instantaneous hot water.

For all other higher Star rating levels, the 25-year value is less than zero – dropping to -$40,000 for the Large 10-Star home:

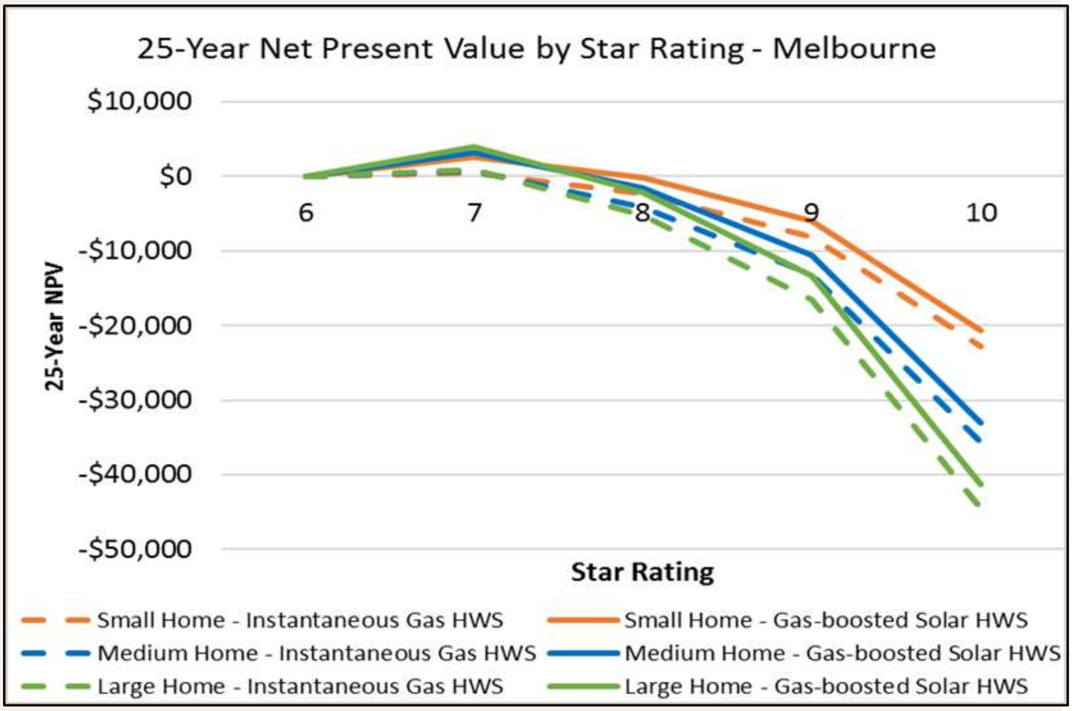

Figure 7: 25-Year NPV by Star Rating/Size, Dual Fuel Home, Melbourne, no Solar PV (7% Discount, Medium Build Cost Premium)

Value of All-Electric versus Dual Fuel Appliance Mix

The chart below shows the 25-year NPV of Medium sized all-electric homes versus dual fuel homes, with no solar PV, in Melbourne by Star rating and build-cost premium.

The purpose of this chart is to demonstrate the value of the appliance mix in isolation from solar or Star rating:

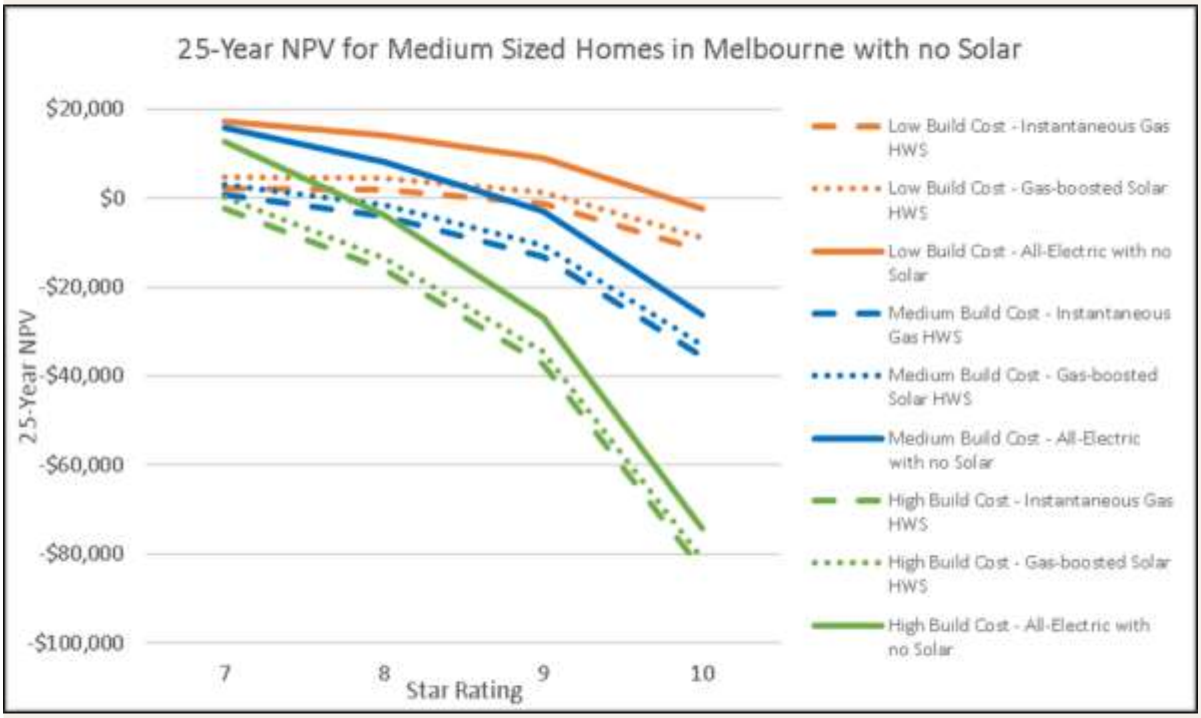

Figure 8: 25-Year NPV of All-Electric versus Dual Fuel Home, Melbourne, no Solar PV (7% Discount, Medium Build Cost Premium)[7]

As can be seen, at each Star rating level, and for each build-cost premium, the all-electric appliance mix delivers a higher 25-year value than the Base Case dual fuel homes. This value reduces in line with the higher the Star rating of the dwelling.

[7] Compared to 6-Star gas-boosted SHW home.

Key Findings

From the analysis undertaken, a few key findings emerge:

1. Whether analysed by payback time or NPV, new 7 to 8-Star all-electric homes with solar PV are highly economically attractive as compared with new 6-Star dual fuel homes in Victoria.

   The main exceptions to this are:

   - 8-Star homes with a high build-cost premium (i.e. above $24,000), as these tended between 14 and 20+ year paybacks and only marginally positive NPVs after 25 years); and

   - 9-Star homes with a low build-cost premium (which achieved less than 10-year paybacks for all scenarios and marginally positive NPVs after 10 years).

2. Solar PV makes a significant difference to the economics of higher efficiency and/or all-electric homes, when compared against dual fuel homes.

   At the more economically attractive Star rating levels (i.e. 7 and 8-Stars), all-electric homes with solar PV:

   - had energy bills between $1,300 and $1,600 per year lower than their 6-Star dual fuel counterparts; and

   - added in the order of $10,000 to the 25-year NPVs.

   Solar PV also has the ability to significantly reduce the annual energy bills of dual fuel homes. However, these cannot be as significant as the same sized solar PV system on an all-electric home, due to:

   - the lower energy bills of all-electric homes (without solar PV) as compared to dual fuel homes (without solar PV); and

   - the ability of an all-electric home to directly consume more solar PV generation on-site than a duel fuel home (offsetting a higher consumption tariff than would be otherwise earned under a lower feed-in tariff).

   Ultimately the benefit of solar PV to a duel fuel Victorian home, when compared to an all-electric home, is a slightly smaller saving off a slightly higher bill.

3. The value of higher building efficiency (in isolation from solar PV or appliance mix) is of less significance than solar PV, and also reduces in line with greater efficiency/higher Star ratings.

   Figure 45 shows the annual energy bill savings between each Star rating level. As can be seen:

   - material savings are achieved for the 7-Star dual fuel home versus the 6-Star Base Case homes (~$400 per year):
     - this reduces to around $275 per year between 7 and 8-Stars; just under $200 between 8 and 9-Stars; and just over $100 between 9 and 10-Stars;
   - 6 to 7-Star savings are considerably less for the all-electric (no solar PV) home (~$180) as these homes use significantly less input energy with their more efficient appliance mix at all Star rating levels:
     - this trend again reduces to around $140 per year between 7 and 8-Stars; $85 between 8 and 9-Stars; and $60 between 9 and 10-Stars;

   These results suggest that building to at least 7-Stars (and potentially 8-) is of greater importance for dual fuel homes where solar PV cannot be installed due to technical reasons.

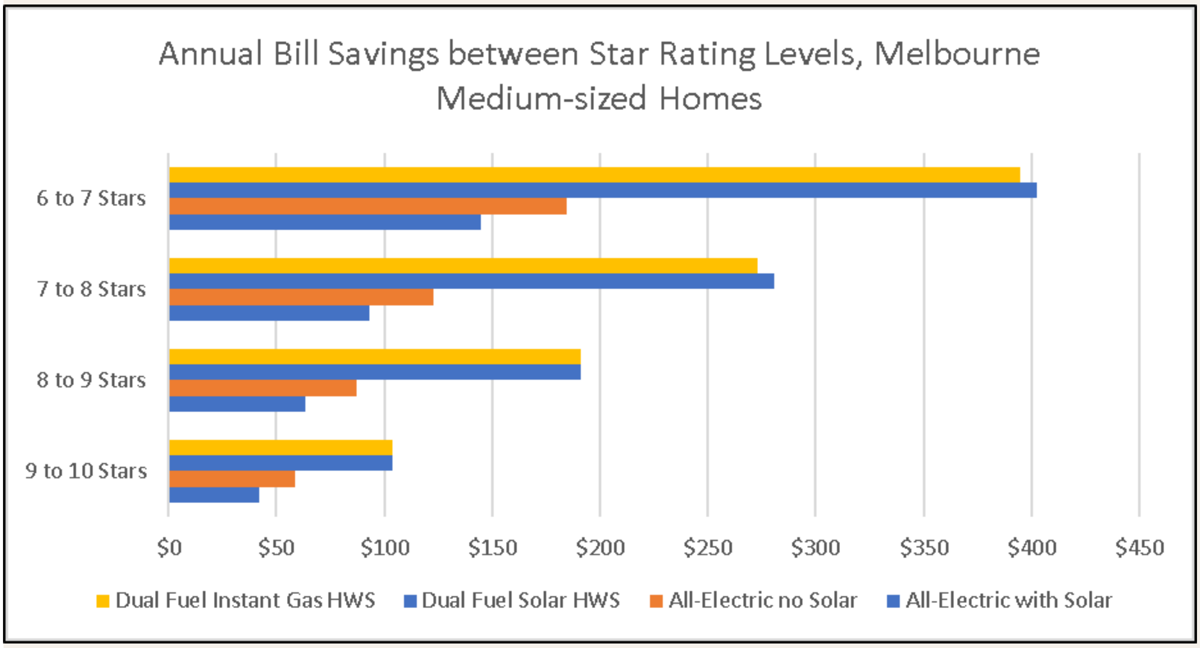

Figure 9 Annual Bill Savings between Star Rating Levels, Medium Home, Melbourne

4. An efficient all-electric appliance mix will provide materially higher economic value over time than a dual fuel appliance mix (in isolation from higher building efficiency or solar PV) for 6 to 10 Star homes.

Contents

1. Introduction

With the rise of rooftop solar photovoltaic (PV) systems, high efficiency electric technology to supply space and water heating loads, and improvements in passive solar building design and construction, there is increasing evidence that substantial energy and financial savings can be achieved in the residential building sector at low cost.

Greenfield and infill residential developments of Class 1 buildings[8] in Victoria involve homes built to the minimum 6 Star energy rating requirement, which continue to be established as "dual fuel" – i.e. are supplied with both reticulated gas and grid electricity, with the former typically supplying the space heating, water heating and cooking loads.

This approach may lock new home occupiers into higher stationary energy costs over time; whilst also ignoring the potential economic opportunity to build to a higher level of building efficiency.

On average, Victorian households now pay in the order of $2,500 per year for stationary energy[9]. Individual new home case studies previously undertaken by Renew have found that this can be cost-effectively reduced to less than $1,000 per year and often to zero – by taking advantage of low-cost efficiency improvements along with solar PV and efficient heating/cooling, hot water and appliances. Such annual bill savings do not require household investment in battery storage or premium (i.e. high) feed-in tariffs.

1.1. Project Objective

The purpose of this project has been to undertake an economic analysis of the value of:

- building homes to higher levels of energy efficiency;
- all-electric homes, in comparison with dual fuel homes (given its Victorian focus); and
- solar photovoltaic (PV) technology.

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[8] Class 1: A detached house or one of a group of two or more dwellings separated by a fire resisting wall, including a row house, terrace house, town house or villa unit: https://www.moretonbay.qld.gov.au/uploadedFiles/common/forms/building-plumbing/Classification-buildings-structures-fact%20sheet.pdf
[9] https://www.dhhs.vic.gov.au/victorian-utility-consumption-household-survey: (2015 Final Report, Tables 4.2.2.1 & 4.3.2.3)

In line with this objective, the project modelled a range of household types, sizes and locations within Victoria.

It should be noted that the economic benefits assessed pertain exclusively to homeowners/occupiers (i.e. private benefits) – and not broader benefits that may be realised throughout the economy or society from a move to higher efficiency homes. These broader benefits include:

- achieving Australia's carbon reduction targets;
- reducing the health and safety risk of sub-standard or non-compliant homes;
- reducing peak demand in our energy grid
- industry jobs.

1.2. Approach

The modelling sought to understand the capital and operational costs, and medium to long term value, of higher efficiency, Class 1 dwellings, as compared with typical 6 Star "dual fuel" Class 1 dwellings in Victoria. Appliance mix was a key focus of the modelling, with both dual fuel and all-electric homes being considered. In addition, solar photovoltaic (PV) technology was also considered.

In line with the project objective, the modelling established "Base Case" homes against which all other modelled homes were compared. These were developed based on industry feedback regarding the most common fuel types and appliance mix of new Class 1 dwellings in Victoria. Two main types of Base Case homes were modelled (varying by size, location and thermal efficiency), as follows:

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Space Heating:	Gas Ducted	Gas Ducted
Cooking:	Gas cooktop, electric oven	Gas cooktop, electric oven
All Other Appliances	Electric	Electric

Table 4 Base Case Homes Modelled

To compare against the Base Case homes, alternative higher efficiency homes with different appliance mixes (including solar photovoltaic) were developed:

	ALT HOME 1	ALT HOME 2	ALT HOME 3	ALT HOME 4
Name	Dual Fuel: Gas-boosted Solar	Dual Fuel: Gas Instantaneous	All-Electric: No Solar PV	All-Electric: With Solar PV (5kW)
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Appliance Mix				
Hot Water:	Gas-boosted Solar Thermal	Gas Instantaneous	Heat Pump	Heat Pump
Space Heating:	Gas Ducted	Gas Ducted	Reverse Cycle Air Con	Reverse Cycle Air Con
Cooking:	Gas Cooktop, Electric Oven	Gas Cooktop, Electric Oven	Induction cooktop, Electric Oven	Induction cooktop, Electric Oven
All Other Appliances	Electric	Electric	Electric	Electric

Table 5 Alternative Homes Modelled

The process brought together three over-arching models, to calculate the energy loads, energy bills and subsequent economic value of the alternative home types versus the base case homes.

These models, and the input assumptions used, are explained in detail in the following chapters. However, Figure 10 gives a diagrammatic overview of the analysis process and the role of each overarching model:

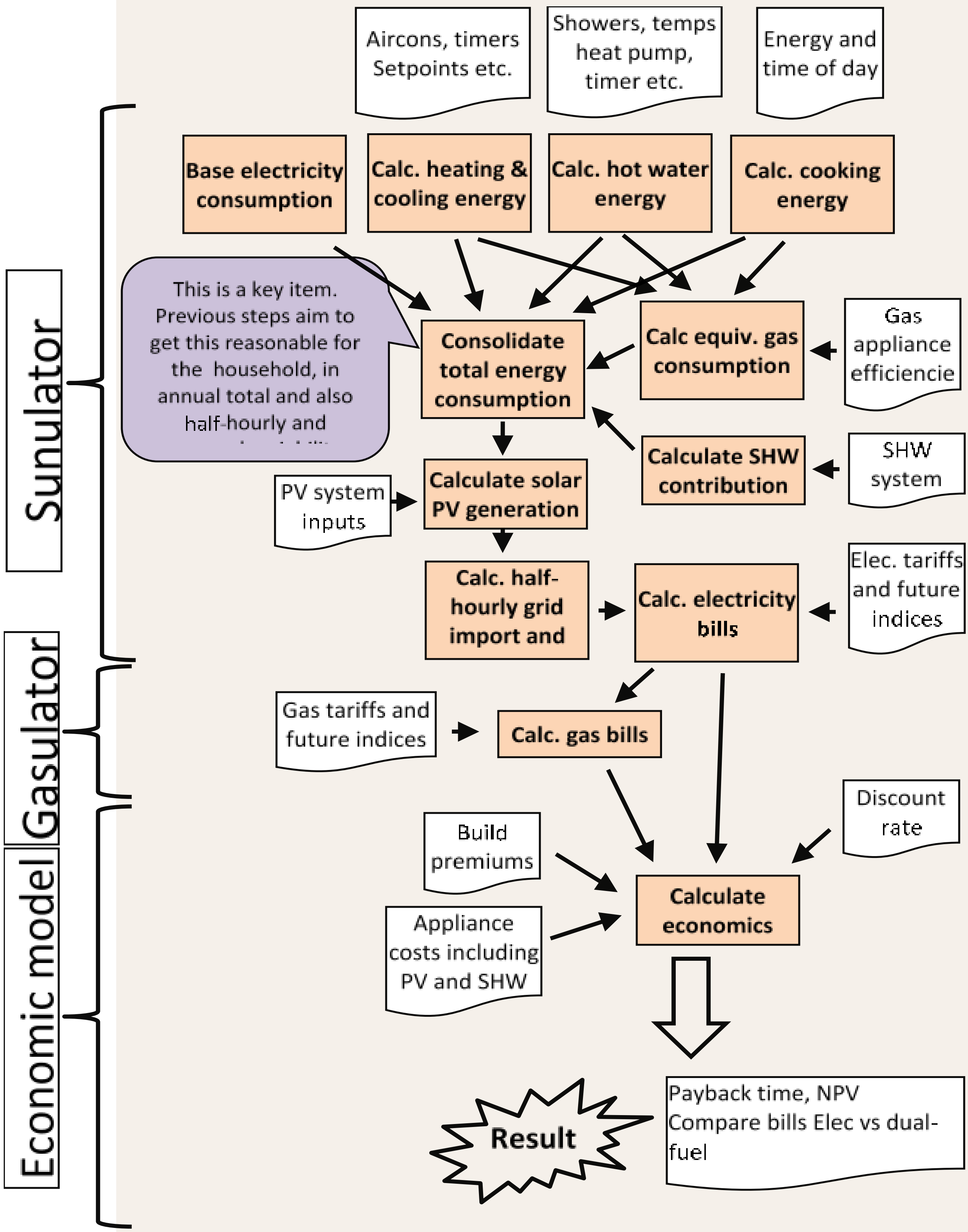

Figure 10 Analysis Process & Role of Each Model Used

2. Energy Loads

The calculation of annual energy loads and annual energy bills required the following inputs:

- A household location;
- Home size & occupancy levels;
- A specific consumption profile for each household in each location, including:
  - a specific heating and cooling load (supplied by either gas or electricity);
  - a specific hot water load (supplied by either gas or electric appliance);
  - a specific cooking load (supplied by either gas or electric appliance); and
  - a "residual" (or remaining) load (supplied by electric appliances only).

It should be noted that the calculation of input electrical loads assumes the use of higher efficiency electric technology for heating/cooling, hot water and cooking. It excludes the use of traditional, low efficiency technologies for these end uses[10].

2.1. Locations

The project team selected five locations based on the need to represent:

- urban growth areas – where most of Victoria's new housing over the next decade will be located (i.e. Melbourne's north, south east and west);
- a range of climate zones – including the warmer North-West Victoria (i.e. Mildura) and the colder South Western Victoria (Gippsland)[11]; and
- Victoria's highest (Mildura) and lowest (Warrnambool) solar irradiance.

The following five locations were used in the modelling:

NO.	LOCATION
1	Melbourne
2	Mildura
3	Warrnambool
4	Bairnsdale
5	Horsham

Table 6 Modelled Locations

[10] e.g. resistive electric technologies.
[11] Victoria's alpine region was not included due to its low level of new housing forecasted.

2.2. Household Types

Three household types were selected for modelling. Designs for the household types were based on the single reference home, previously modelled by Energy Efficient Strategies (EES) for Beyond Zero Emissions (BZE) as part of their *Zero Carbon Australia Buildings Plan*[12].

The reference home is a three-bedroom, single-storey detached dwelling. The floor plan for the Medium home modelled is shown below (the floor plan was broadly scaled for the Small and Large home sizes):

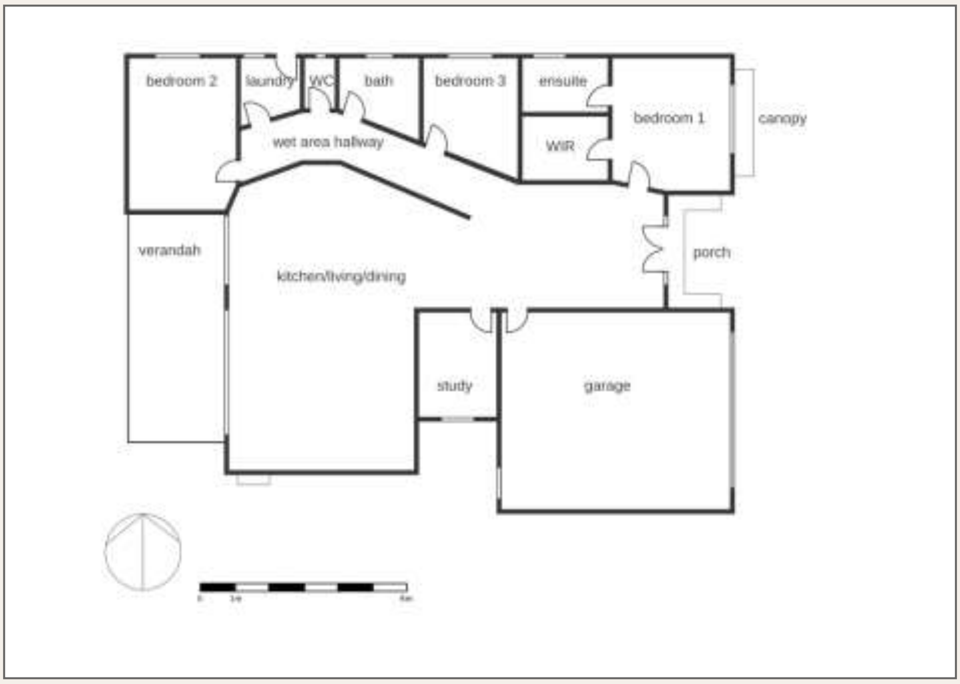

Figure 11 Floor Plan, BZE Reference Home (Medium Home Size Modelled)

Three variants of the household type were modelled for each location, with the following assumed sizes and occupancy profiles:

HOUSEHOLD TYPE	FLOOR SPACE	OCCUPANTS
Small Home	100 sqm	1-2 persons
Medium Home	166 sqm	3-4 persons
Large Home	230 sqm	4-5 persons

Table 7 Household Types & Descriptions

[12] http://media.bze.org.au/bp/bp_appendix_7.pdf

2.3. Reference Energy Loads

Most studies that have attempted to understand the costs and benefits associated with higher efficiency homes in Australia have taken an "elemental" approach to:

- costing the various efficiency upgrades; and
- modelling the heating and cooling loads of various house designs considering design improvements and thermal upgrades.

These projects typically end up with either:

- unit costs for individual energy efficiency measures (e.g. $ per sqm for additional ceiling or wall insulation); and/or
- build costs to reach higher levels of overall energy rating; and/or
- reductions in energy usage associated with heating and cooling, with commensurate savings to that component of the energy bill associated with heating and cooling.

This project is different in that it seeks to:

- calculate the total stationary energy load from all appliances and fuel types for each household type; and
- calculate total (annual) stationary energy bills (and bill savings) from different consumer choices regarding building efficiency, fuel types, appliance mix and on-site solar PV.

As such, the heating and cooling load is only one component of the overall stationary energy load for each household type. Whilst it remains the largest end-use energy activity (given typical space heating requirements throughout most of Victoria), changes in the heating and cooling load do not have as substantial an impact on overall stationary energy costs under this project, once other appliances are accounted for.

On this basis, it was determined that the "elemental" approach of modelling and costing specific energy efficiency measures in First Rate 5[13] or Accurate[14] under the NatHERS framework was not appropriate for this project.

Of greater importance, is the need for this project to define annual energy loads for each household type that are reflective of publicly available data on total stationary energy usage in Victorian homes.

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[13] https://www.fr5.com.au/
[14] https://www.csiro.au/en/Research/EF/Areas/Electricity-grids-and-systems/Intelligent-systems/AccuRate

The best reference currently available on the stationary energy usage of Victorian homes is the Victorian Utility Consumption Household Survey (2015)[15]. Prepared for the Victorian Department of Health and Human Services, this survey publishes detailed data on energy usage, consumption and expenditure by region (as well as for a range of other household utilities).

Annual and average daily electricity consumption from the DHHS locations of the most relevance to this project were:

RENEW PROJECT LOCATION	DHHS LOCATION	ANNUAL ELECTRICITY USAGE (MWH)	AVERAGE DAILY USAGE (KWH)
Melbourne	Melbourne	4.31	11.8
Mildura	N/A	N/A	N/A
Warrnambool	Barwon	4.12	11.29
Bairnsdale	Outer Gippsland	5.58	15.28
Horsham	Western District	4.20	11.5

Table 8 Household Electricity Consumption, DHHS Utility Survey 2015

Annual mains gas consumption from the DHHS locations of the most relevance to this project were:

RENEW PROJECT LOCATION	DHHS LOCATION	ANNUAL GAS USAGE (GJ)	AVERAGE DAILY USAGE (MJ)
Melbourne	Melbourne	48.23	132.1
Mildura	N/A	N/A	N/A
Warrnambool	Barwon	35.20	96.4
Bairnsdale	Outer Gippsland	34.75	95.2
Horsham	Western District	32.50	89.0

Table 9 Household Mains Gas Consumption, DHHS Utility Survey 2015

As can be seen, main gas usage in the regional areas (Warranmbool, Bairnsdale, Horsham) is significantly (~30%) lower than in metropolitan Melbourne.

[15] https://dhhs.vic.gov.au/victorian-utility-consumption-household-survey

DHHS also surveyed the proportion of homes in each location connected to mains gas, as follows:

RENEW PROJECT LOCATION	DHHS LOCATION	USE MAINS GAS
Melbourne	Melbourne	94%
Mildura	N/A	N/A
Warrnambool	Barwon	81%
Bairnsdale	Outer Gippsland	34%
Horsham	Western District	88%

Table 10 Use of Mains Gas in Household by Region, DHHS Utility Survey 2015

As can be seen, Outer Gippsland has a very low penetration of mains gas connections (34%) relative to Melbourne, Barwon (Warrnambool) and the Western District (Horsham). Barwon (Warrnambool) is also some 15% lower than Melbourne.

Outer Gippsland also had the highest reported use of bottled LPG gas (26%) of all DHHS regions surveyed, and higher (~25%) usage of electricity as compared with Melbourne, Barwon (Warrnambool) and the Western District (Horsham).

Given their cool to mild temperate conditions[16] and high winter heating loads, the lower reticulated gas usage in Outer Gippsland, Barwon and the Western District is likely associated with higher usage of other energy sources such as:

- bottled (LPG or cylinder) gas – particularly for hot water and cooking;
- wood – particularly for space heating; and
- electricity – for various other loads.

Anecdotally, the prevalence of all three end uses (cooking, hot water and space heating) supplied by mains gas is more common in Melbourne than in regional Victoria. In Victoria's regions, having only one or two of those end-uses supplied by mains gas may be more common, and possibly associated with the lower annual gas usage reported by DHHS above.

The DHHS data also pertains to existing homes – which on average:

- will be significantly less efficient (thermal) than a new 6 Star build; and
- utilise older gas (and electrical) technology with a lower energy efficiency performance.

These factors suggest that a new, 6 Star dual fuel home in these locations should have lower annual gas use than reported by DHHS.

[16] http://www.yourhome.gov.au/introduction/australian-climate-zones

Countering this:

- The modelling is representing only gas ducted heating systems for all household types – as these are reflective of the most common heating system being installed across new homes in Victoria;

  A significant number of the mains gas connected homes (particularly in the regions) will either not space heat with mains gas or will have wall furnaces – both of which lead to lower gas usage (even where the wall furnace is of a lower efficiency) than a new 5 Star gas ducted system; and

- The Base Case dual fuel homes in the modelling have all three end-uses (cooking, hot water and space heating) supplied by mains gas. Even with new efficient gas appliances, this may lead to higher annual gas usage than reported in the regions by DHHS.

Considering all of the above, Renew's approach was to ensure that the Medium, 6 Star dual fuel home in Melbourne was relatively close to what was reported by DHHS (i.e. 48 gigajoules of mains gas and 4.31 megawatt hours of electricity per annum).

Small and Large home loads, in different locations, were then adjusted from there in accordance with Renew's specific methodologies for calculating heating/cooling, hot water, cooking and the remaining ("residual") loads, for each household type.

These specific methodologies are contained in Appendix A to D.

2.4. Annual Loads Modelled

Considering the heating/cooling, hot water, cooking and residual load calculations above, and with reference to the annual DHHS loads, the following consumption profiles were developed for each modelled household type in each location:

	6 STARS		7 STARS		8 STARS		9 STARS		10 STARS	
Energy Use p.a.	MWh	GJ	MWh	GJ	MWh	GJ	MWh	GJ	MWh	GJ
Large Home										
Ae	8.42	0.00	7.73	0.00	7.28	0.00	6.95	0.00	6.73	0.00
Gb	5.03	63.12	5.00	40.92	4.99	26.11	4.99	16.34	4.99	11.04
Gi	5.03	71.54	5.00	49.34	4.99	34.52	4.99	24.75	4.99	19.45
Medium Home										
Ae	5.37	0.00	4.83	0.00	4.47	0.00	4.21	0.00	4.03	0.00
Gb	2.68	47.89	2.66	30.44	2.66	18.80	2.65	11.12	2.65	6.95
Gi	2.68	54.66	2.66	37.21	2.66	25.57	2.65	17.89	2.65	13.72
Small Home										
Ae	3.73	0.00	3.33	0.00	3.06	0.00	2.87	0.00	2.74	0.00
Gb	1.58	35.01	1.56	22.32	1.55	13.85	1.55	8.26	1.55	5.22
Gi	1.58	40.83	1.56	28.14	1.55	19.66	1.55	14.07	1.55	11.03

Table 11 Annual Loads, Melbourne Homes

	6 STARS		7 STARS		8 STARS		9 STARS		10 STARS	
Energy Use p.a.	MWh	GJ	MWh	GJ	MWh	GJ	MWh	GJ	MWh	GJ
Large Home										
Ae	8.17	0.00	7.54	0.00	7.14	0.00	6.84	0.00	6.63	0.00
Gb	5.11	47.36	5.04	30.30	5.01	19.03	4.99	11.64	4.99	7.63
Gi	5.11	57.49	5.04	40.43	5.01	29.17	4.99	21.77	4.99	17.76
Medium Home										
Ae	5.19	0.00	4.69	0.00	4.37	0.00	4.14	0.00	3.98	0.00
Gb	2.75	36.10	2.70	22.72	2.67	13.88	2.66	8.08	2.65	4.92
Gi	2.75	43.82	2.70	30.44	2.67	21.60	2.66	15.79	2.65	12.64
Small Home										
Ae	3.59	0.00	3.22	0.00	2.99	0.00	2.82	0.00	2.70	0.00
Gb	1.63	26.46	1.58	16.76	1.56	10.35	1.56	6.13	1.55	3.83
Gi	1.63	32.89	1.58	23.19	1.56	16.78	1.56	12.55	1.55	10.26

Table 12 Annual Loads, Mildura Homes

	6 STARS		7 STARS		8 STARS		9 STARS		10 STARS	
Energy Use p.a.	MWh	GJ	MWh	GJ	MWh	GJ	MWh	GJ	MWh	GJ
Large Home										
Ae	9.29	0.00	8.28	0.00	7.59	0.00	7.10	0.00	6.78	0.00
Gb	5.00	85.65	4.99	53.72	4.99	32.40	4.99	18.49	4.99	11.10
Gi	5.00	94.86	4.99	62.93	4.99	41.61	4.99	27.70	4.99	20.32
Medium Home										
Ae	6.06	0.00	5.26	0.00	4.71	0.00	4.32	0.00	4.07	0.00
Gb	2.66	65.54	2.65	40.47	2.65	23.73	2.65	12.80	2.65	6.99
Gi	2.66	72.85	2.65	47.77	2.65	31.03	2.65	20.10	2.65	14.29
Small Home										
Ae	4.23	0.00	3.64	0.00	3.24	0.00	2.95	0.00	2.76	0.00
Gb	1.56	47.82	1.55	29.60	1.55	17.44	1.55	9.49	1.55	5.26
Gi	1.56	54.00	1.55	35.78	1.55	23.62	1.55	15.67	1.55	11.44

Table 13 Annual Loads, Bairnsdale Homes

	6 STARS		7 STARS		8 STARS		9 STARS		10 STARS	
Energy Use p.a.	MWh	GJ	MWh	GJ	MWh	GJ	MWh	GJ	MWh	GJ
Large Home										
Ae	9.58	0.00	8.46	0.00	7.69	0.00	7.15	0.00	6.80	0.00
Gb	5.00	100.31	4.99	62.07	4.99	36.94	4.99	20.36	4.99	11.49
Gi	5.00	109.44	4.99	71.20	4.99	46.07	4.99	29.49	4.99	20.62
Medium Home										
Ae	6.28	0.00	5.40	0.00	4.79	0.00	4.36	0.00	4.08	0.00
Gb	2.67	76.77	2.66	46.70	2.65	26.95	2.65	13.90	2.65	6.92
Gi	2.67	84.32	2.66	54.26	2.65	34.50	2.65	21.46	2.65	14.48
Small Home										
Ae	4.40	0.00	3.75	0.00	3.30	0.00	2.98	0.00	2.77	0.00
Gb	1.56	56.07	1.55	34.19	1.55	19.80	1.55	10.30	1.55	5.20
Gi	1.56	62.45	1.55	40.57	1.55	26.18	1.55	16.68	1.55	11.58

Table 14 Annual Loads, Warrnambool Homes

	6 STARS		7 STARS		8 STARS		9 STARS		10 STARS	
Energy Use p.a.	MWh	GJ	MWh	GJ	MWh	GJ	MWh	GJ	MWh	GJ
Large Home										
Ae	8.62	0.00	7.87	0.00	7.37	0.00	7.01	0.00	6.76	0.00
Gb	5.06	62.21	5.02	40.66	5.00	25.85	4.99	16.02	4.99	10.52
Gi	5.06	71.57	5.02	50.02	5.00	35.22	4.99	25.39	4.99	19.89
Medium Home										
Ae	5.53	0.00	4.94	0.00	4.54	0.00	4.25	0.00	4.06	0.00
Gb	2.71	47.27	2.68	30.36	2.66	18.75	2.65	11.02	2.65	6.70
Gi	2.71	54.64	2.68	37.74	2.66	26.12	2.65	18.40	2.65	14.07
Small Home										
Ae	3.84	0.00	3.41	0.00	3.11	0.00	2.90	0.00	2.76	0.00
Gb	1.60	34.46	1.57	22.19	1.56	13.76	1.55	8.15	1.55	5.00
Gi	1.60	40.74	1.57	28.47	1.56	20.04	1.55	14.43	1.55	11.28

Table 15 Annual Loads, Horsham Homes

The annual loads modelled in Table 11 to Table 15 above should be compared against the DHHS annual loads reported for those locations in Table 8 and Table 9[17]. As can be seen in Table 16, the approach taken resulted in:

- an acceptable annual electricity and gas load for the Medium home in Melbourne when compared against the DHHS survey data; and
- an acceptable annual electricity and gas load for the Small home in Horsham when compared against the DHHS survey data.

	MELBOURNE		HORSHAM (WESTERN DISTRICT	
	Gb	Gi	Gb	Gi
DHHS Survey				
MWh p.a.	4.31	4.31	4.20	4.20
GJ p.a.	48.23	48.23	32.50	32.50
6 Star Small Home Modelled				
MWh p.a.	1.58	1.58	1.60	1.60
GJ p.a.	35.01	40.83	34.46	40.74
6 Star Medium Home Modelled				
MWh p.a.	2.68	2.68	2.71	2.71
GJ p.a.	47.89	54.66	47.27	54.64

Table 16 Load Comparison, Modelled versus DHHS (Melbourne & Horsham)

[17] Noting no DHHS survey results were available for Mildura.

However, the modelled loads for Warrnambool and Bairnsdale resulted in significantly higher annual gas consumption across all household sizes (even the Small Home) than reported by DHHS in those locations:

	DHHS SURVEY		6 STAR MEDIUM HOME MODELLED		6 STAR SMALL HOME MODELLED	
Energy Use p.a.	MWh	GJ	MWh	GJ	MWh	GJ
Warrnambool (Barwon)						
Gb	4.12	35.20	2.67	76.77	1.56	56.07
Gi	4.12	35.20	2.67	84.32	1.56	62.45
Bairnsdale (Outer Gippsland)						
Gb	5.58	34.75	2.66	65.54	1.56	47.82
Gi	5.58	34.75	2.66	72.85	1.56	54.00

Table 17 Load Comparison, Modelled versus DHHS (Warrnambool & Bairnsdale)

As can be seen, even the Small Home modelled loads in Warrnambool and Outer Gippsland are between 38% and 77% higher than the DHHS reference loads. The Medium Home modelled loads were approximately double that of the DHHS reference loads.

Notwithstanding the commentary in Section 2.3[18], it was considered important that the bottom end of the gas usage range (i.e. for the Small Home modelled) reflected the DHHS survey data for these locations.

As such, two additional sensitivity analyses were run, to ensure that the DHHS range was considered for Warrnambool and Bairnsdale. This was done by reducing the number and size of RCACs for the Small home for these two locations.

Table 18 shows the number and sizing of RCACs for the original Small Home and Small Home Sensitivity analysis for Warrnambool and Bairnsdale:

ROOM		SMALL HOME	SMALL HOME SENSITIVITY
Living Space	Heat/Cool Output (kW)	5.0	2.5
Bedroom 1	Heat/Cool Output (kW)	2.5	2.5
Bedroom 2	Heat/Cool Output (kW)	2.5	

Table 18 Load Comparison, Modelled versus DHHS (Melbourne & Horsham)

[18] i.e. that a new 6 Star dual fuel home with gas ducted heating and all three end-uses (cooking, hot water, space heating) supplied by mains gas, would use more gas annually in Warrnambool and Outer Gippsland than reported by the DHHS survey.

This approach resulted in lower annual energy loads for the Small Home Sensitivity analysis for Warrnambool and Bairnsdale as follows:

	6 STARS		7 STARS		8 STARS		9 STARS		10 STARS	
Energy Use p.a.	MWh	GJ	MWh	GJ	MWh	GJ	MWh	GJ	MWh	GJ
Small Home										
Ae	3.39	0.00	3.10	0.00	2.90	0.00	2.75	0.00	2.66	0.00
Gb	1.51	26.30	1.51	17.19	1.51	11.11	1.51	7.13	1.51	5.02
Gi	1.51	32.48	1.51	23.37	1.51	17.29	1.51	13.31	1.51	11.20

Table 19 Annual Loads, Small Homes with Reduced Gas Consumption, Bairnsdale

	6 STARS		7 STARS		8 STARS		9 STARS		10 STARS	
Energy Use p.a.	MWh	GJ	MWh	GJ	MWh	GJ	MWh	GJ	MWh	GJ
Small Home										
Ae	3.47	0.00	3.15	0.00	2.93	0.00	2.77	0.00	2.67	0.00
Gb	1.51	30.36	1.51	19.42	1.51	12.23	1.51	7.48	1.51	4.93
Gi	1.51	36.74	1.51	25.80	1.51	18.61	1.51	13.85	1.51	11.31

Table 20 Annual Loads, Small Homes with Reduced Gas Consumption, Warrn'bool

2.5. Solar

Each scenario considered the installation of a new 5.0-kilowatt solar photovoltaic (PV) system. For each household size, appliance mix and location, scenarios were modelled with and without solar PV. Grid-connected energy storage was not modelled in this project as:

- based on several detailed modelling projects recently undertaken by Renew[19], lithium, flow and other modern storage chemistries are not yet able to pay for themselves in Victoria within a typically accepted battery asset life (i.e. 10 years); and
- this project does not seek to understand the economic case of each scenario in future years[20].

2.5.1. System Size

A range of different solar PV system sizes could be included in the modelling. Renew selected only a 5.0-kilowatt system as:

- 5.0-kilowatt is reflective of the average system size currently being installed in Australia[21];
- 5.0-kilowatt is as close to the optimal economic choice of system size as any other system size, given the now significant economies of scale in solar PV pricing[22];
- 5.0-kilowatt, single phase is the pre-approval limit for grid connection for residential solar across many parts of Victorian distribution networks;
- The modelling will assume that at least some of the electricity required to power the main energy loads (i.e. heating. cooling and hot water, as relevant to the scenario) will come from solar PV, in addition to the remaining daytime electrical load for each household type. For this, a reasonable solar system size is required; and
- Using only one system size reduces the complexity and number of the modelled scenarios.

For the 5.0-kilowatt solar scenarios, installed prices were taken from Solar Choice monthly Solar PV Price Index[23]. For the scenarios with solar PV, the electrical (30-minute) load profile was simulated against the generation from a 5.0-kilowatt solar PV system[24] for a specific household in that location. For a more detailed explanation of the solar methodology used, please refer to Appendix E.

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[19] https://www.ata.org.au/news/grid-connected-batteries-economically-attractive-by-2020-ata-report
[20] Relevant to storage price reductions.
[21] http://reneweconomy.com.au/graph-of-the-day-australias-average-solar-pv-system-size-hits-5 kW-47293/
[22] http://www.solarchoice.net.au/blog/news/residential-solar-pv-system-prices-january-2017
[23] http://www.solarchoice.net.au/blog/news/residential-solar-pv-system-prices-january-2017

[24] True north, 22-degree tilt, 13% panel to socket system losses.

3. Energy Bills

3.1. Tariffs

There are currently 23 licenced electricity retailers, and 15 licenced gas retailers, operating in Victoria. Some commentators have suggested that over 4,000 separate residential tariffs offer exist in Victoria.

To allow for the range of model inputs as described throughout Section 2, a total of 1,350 separate scenarios have been modelled, with over 33,000 rows of energy load/bill data. This includes:

- 5 locations;
- 3 household sizes;
- 5 energy ratings;
- 3 appliance mixes;
- 3 build-cost premiums per energy rating;
- solar PV and non-solar PV homes; and
- 25 individual years for which energy bills are calculated.

On this basis, a relatively simple approach to tariff selection was used for this project, which sought to reflect tariff prices that most energy consumers face in each location.

Renew reviewed electricity and gas offers in each location (by postcode) using the Victorian Government's tariff comparator portal Victorian Energy Compare[25]. Selection criteria within the portal were based on the relevant appliance mix and annual consumption of the various household types modelled.

The tariffs selected were based on average flat/anytime and fixed daily prices (inclusive of GST) of the "big three" retailers[26] (for electricity and gas) in each location. Over 60% of Victorian households remain with one of these three retailers for electricity[27]. Anecdotally this figure is higher in the gas market with lower switching rates and significantly less retailer choice in the regions[28].

The final electricity and gas tariffs used in each location are presented below:

25 https://compare.energy.vic.gov.au/
26 Origin, AGL & Energy Australia
27 https://www.datocms-assets.com/5684/1528864055-2018-retail-energy-competition-reviewfinal15junepublished.pdf

28 Origin is the only gas retailer in Mildura; whilst Energy Australia is the only gas retailer in Horsham.

TARIFF TYPE ($, INC GST)	MELBOURNE	MILDURA	WARRNAMBOOL	BAIRNSDALE	HORSHAM
Fixed Daily	1.19	1.43	1.43	1.42	1.43
Flat/Anytime	0.3227	0.3049	0.3049	0.3265	0.3049

*Table 21 Electricity Tariffs Modelled, by Location**

TARIFF TYPE ($, INC GST)	MELBOURNE	MILDURA	WARRNAMBOOL	BAIRNSDALE	HORSHAM
Fixed Daily	0.95	0.80	0.95	0.82	0.78
Flat – First 50MJ/day	0.0241	0.0396	0.0234	0.0247	0.0221
Flat – Next 50MJ/day	0.0241	0.0264	0.0228	0.0199	0.0221
Flat – Next 50MJ/day	0.0209	0.0264	0.0221	0.0207	0.0216
Flat – Next 50MJ/day	0.0209	0.0264	0.0221	0.0207	0.0216
Flat - Rest	0.0209	0.0264	0.0196	0.0207	0.0210

*Table 22 Gas Tariffs Modelled, by Location**

3.2. Energy Bills Modelled

From the inputs documented in Sections 2.1 to 0 above, annual energy bills could be calculated by household type and location.

The charts below outline the annual energy bill by the four main appliance mixes (i.e. all-electric [with or without solar PV), dual fuel with solar hot water and dual fuel without solar hot water), by Star rating. Annual electricity and gas bills are highlighted separately. The full list of energy bills by location and household type are contained in Appendix F.

Figure 12 displays the annual energy bills for medium sized homes in Melbourne, by Star rating and by appliance mix.

As can be seen, the all-electric home with solar PV has substantially lower energy bills than the all-electric and/or dual-fuel homes without solar PV.

At 6 Stars, the all-electric home's annual bills are approximately $1,800 less than the dual fuel home with gas-boosted solar hot water. Without solar hot water, the dual fuel 6 Star home's annual bill with instant gas HWS is $150 higher and costs almost $2,000 more per year than the all-electric home.

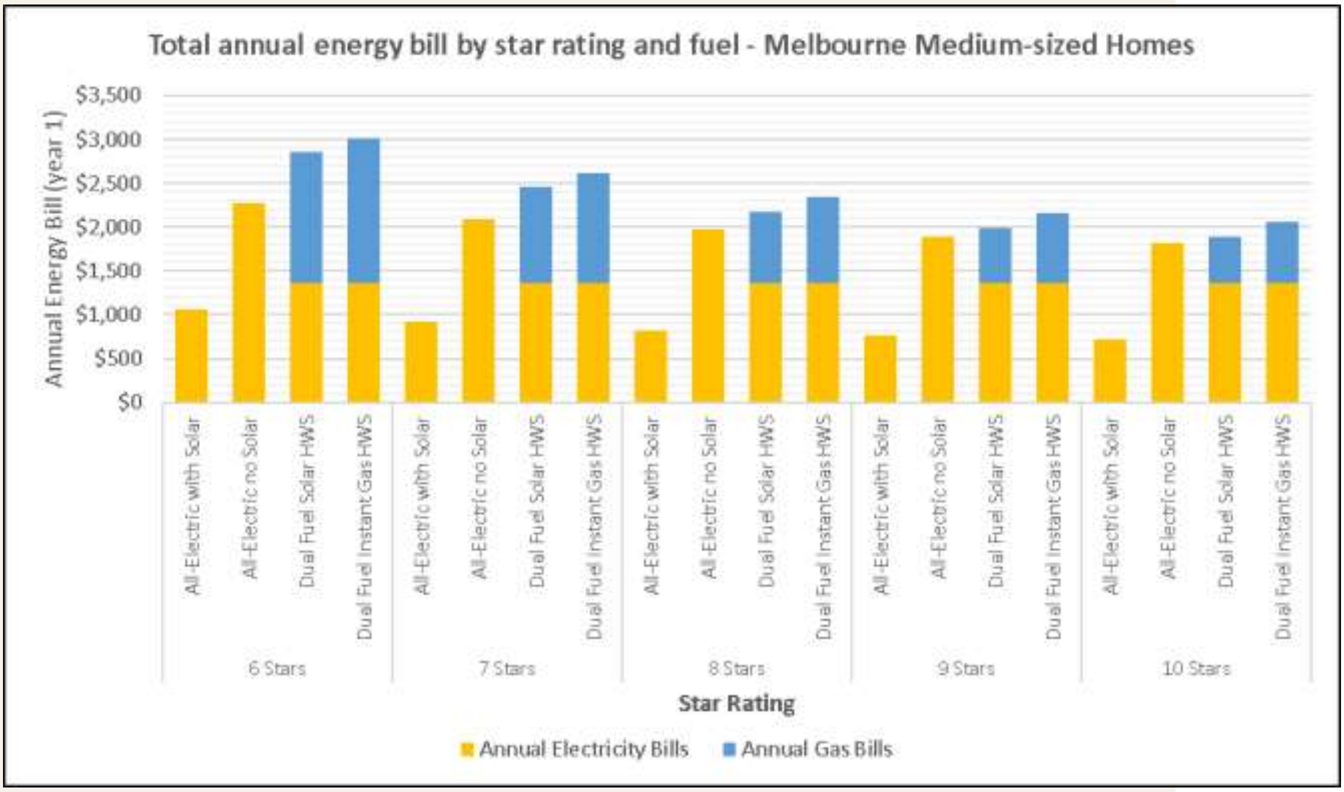

Figure 12: Annual Bills by Star Rating, Medium Home, Melbourne

Total annual bills decrease as higher efficiency homes are built. At 8 Stars, the dual fuel home with gas-boosted solar hot water saves almost $700 per year as compared with its 6 Star equivalent.

However, it should be noted that the magnitude of annual bill savings reduces the higher the efficiency of the building. Between 8 and 10 Stars, only a further $295 is saved for the dual fuel home with gas-boosted solar hot water. This trend is consistent across the household types and appliance mixes.

Interestingly, both the 10 Star dual fuel homes (i.e. with and without solar hot water) save around $1,000 as compared with their 6 Star equivalents. Whereas for the all-electric home, the increased bill savings for a 10 Star home is only $343 as compared with its 6 Star equivalent. This demonstrates the value of solar PV across 6 to 10 stars homes in the overall appliance mix.

As can be seen, not installing solar PV adds over $1,100 per year to the 6 Star all-electric home.

Annual bill savings again increase in line with higher Star rating, however once again, the magnitude of the savings decrease with higher levels of building efficiency:

- The 7 Star all-electric home saves almost $200 per year compared with its 6 Star equivalent; whereas
- The 10 Star all-electric home saves only $59 per year compared with its 9 Star equivalent.

Of note, from all scenarios modelled, there were only three cases where a dual-fuel home has lower annual energy bills than an equivalent all-electric home without solar PV (see Table 23 – the full list of annual energy bills for all-electric and dual fuel homes without solar PV, including the difference in annual bill cost, is included in Appendix G).

All three were 10-Star homes and all had gas-boosted solar hot water systems (i.e. it was never possible to have a lower annual bill as a dual fuel home with a gas instantaneous hot water than an all-electric home without solar PV. The three homes only saved between $3 and $32 per year by choosing the dual fuel without solar PV option:

LOCATION	SIZE	RATING	ALL-ELECTRIC			DUAL FUEL			AE SAVING P.A.
			ELEC	GAS	TOTAL	ELEC	GAS	TOTAL	
Horsham	Medium	10 Stars	$1,848	$0	$1,848	$1,397	$448	$1,845	-$3
Horsham	Large	10 Stars	$2,712	$0	$2,712	$2,145	$535	$2,680	-$32
Bairnsdale	Large	10 Stars	$2,869	$0	$2,869	$2,254	$590	$2,844	-$25

Table 23 Scenarios involving Higher All-Electric than Dual Fuel Bills (No Solar PV)

This is a significant finding as it means that ignoring the potential value of solar PV, it is very unlikely that a new Victorian dual fuel home will result in lower annual energy bills, as compared to an efficient all-electric home.

In addition, whilst solar PV on a dual fuel home would result in significant bill savings, these will not be as significant as the same sized solar PV system on an all-electric home. This is due to:

- the lower energy bills of all-electric homes (without solar PV) as compared to dual fuel homes (without solar PV); and
- the ability of an all-electric home to directly consume more solar PV generation on-site than a duel fuel home (offsetting a higher consumption tariff than would be otherwise earned under a lower feed-in tariff).

Ultimately the benefit of solar PV to a duel fuel Victorian home, when compared to an all-electric home, is a slightly smaller saving off a slightly higher bill.

In all modelled cases, dual-fuel homes with gas-boosted solar hot water have lower energy bills than dual-fuel homes with gas instantaneous hot water systems.

This is most evident in Mildura, where the solar hot water performs the best of any location. As can be seen in Figure 13, large Mildura dual fuel homes save $200-300 per year from having solar hot water. By way of comparison, small homes in Warrnambool save only ~$150 per year.

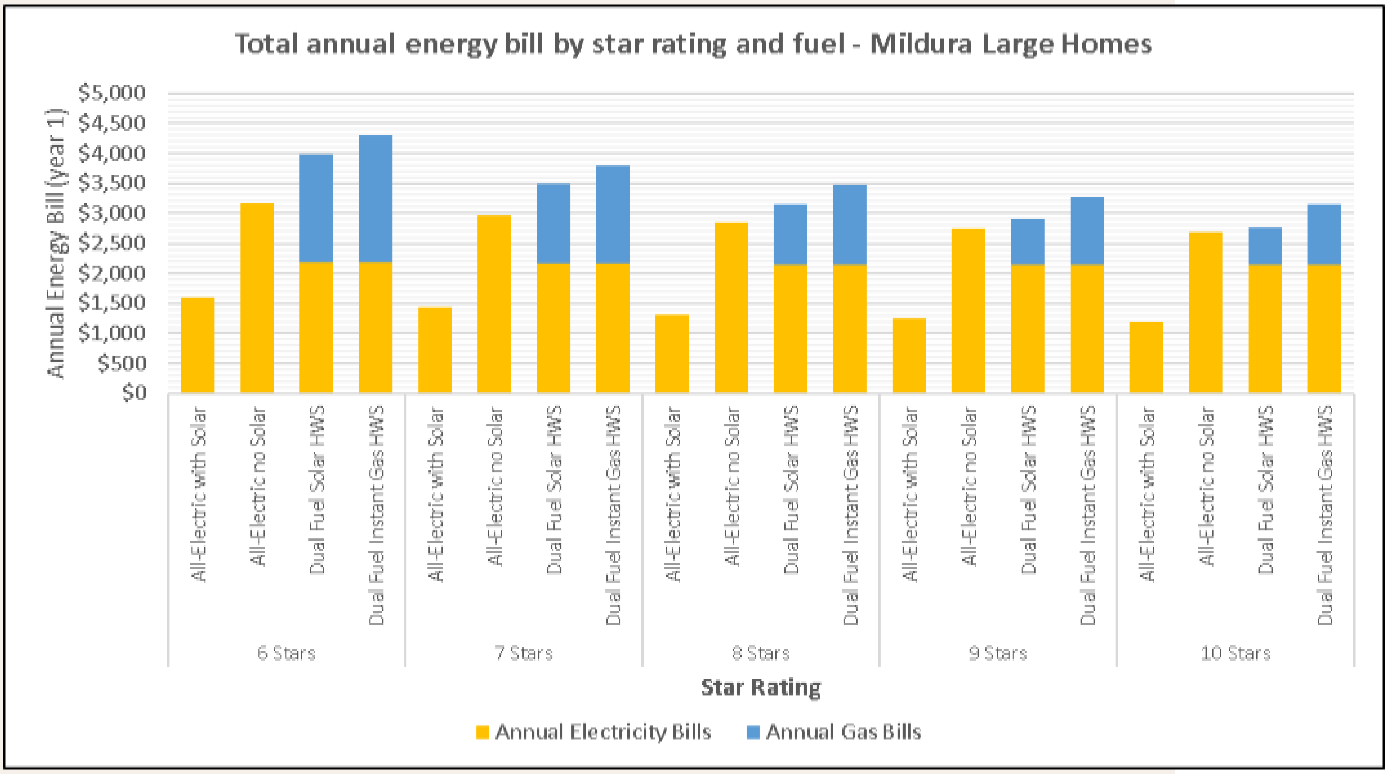

Figure 13: Annual Bills by Star Rating, Large Home, Mildura

4. Economic Model

A separate economic model was then used to capture all the annual electricity and gas bills and input relevant build-cost premiums (by household type, location and Star rating) and appliance capital and replacement costs for each household type and appliance mix.

4.1. Build-Cost Premium

A key objective for the project was to understand the likely cost faced by new home buyers to build to higher levels of thermal efficiency (i.e. the costs associated with achieving an upgrade to the building's "shell" from an energy efficiency perspective).

There currently exists a lack of comprehensive data that reflects industry-wide costs associated with building higher efficiency homes. Renew has worked with several building designers, architects and builders over many years to understand these costs, the result of which is a series of individual case studies and anecdotal data points. As such, Renew developed an industry-wide survey as part of this project, however as outlined below this was not ultimately used.

4.1.1. Industry Survey

To begin with, Renew consulted builders, building designers, academics and architects from the housing industry, to guide the development of the survey.

Several of those consulted indicated two key points at the commencement of this process:

- That obtaining meaningful, industry-wide data on indicative build costs by Star rating is inherently difficult, as costs are influenced by a complex range of factors and can vary considerably; and

- That increasingly, higher energy performance can be achieved without any additional build cost to the project, where passive solar principles can be integrated into the design.

The survey was released in late July 2018 and was open for feedback until late September 2018. Promotion of the survey occurred via the Building Designers Association of Victoria, the Master Builders Association, the Housing Industry Association, ClimateWorks and a range of individual building and design companies[29].

Renew wishes to thank all advisors and participants for their contribution to the project.

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[29] Ultimately, 73 individual professionals were directly contacted through 60 different organisations associated with the housing industry in Victoria.

Despite the broad promotion, the survey response rate was relatively low (23 responses in total). The quality of response data, in particular the questions surrounding building costs, was also low.

On this basis, it was decided by the project team that the survey data was too unreliable to guide the build-cost components of the modelling. As such, Renew relied upon publicly available data from previous work and took a sensitivity approach to capture a range of build-costs for the more efficient homes.

4.1.2. Reference Studies

Two key studies have been relied upon to guide the build cost questions. These were:

- The recent *"Built to Perform"* project (2018)[30] – a collaboration between the Australian Sustainable Built Environment Council (ASBEC) and ClimateWorks Australia. The report outlines a set of energy performance targets for different building types across different climates, based on societal cost-benefit analysis of energy efficiency and on-site renewable energy opportunities.

  CW/ASBEC developed a series of home archetypes to represent simplified versions of typical buildings with a range of surface-area to volume ratios and were designed to characterise the energy performance of typical building types under typical operational conditions. Three archetypes were modelled[31]:

BUILDING TYPE	DESCRIPTION
Standalone detached house	Class 1A, Single Level, Gross floor area = 190 m2, 21.7 x 12.7 m, 2.4 m ceilings, Surface-to-Volume ratio = 1.17
Attached townhouse	Class 1A, Two storey, Gross floor area = 127 m2, 10.1 x 7.3 m, 2.4 m ceilings, Surface-to-Volume ratio = 0.51
Residential apartment	Class 2, Mid-level apartment, Gross floor area = 75 m2, 15.2 x 7.4 m, 2.7 m ceilings, Surface-to-Volume ratio = 0.39

Table 24 Home Archetypes, "Built to Perform"

The CW/ASBEC analysis was specific to Climate Zones 2 (Warm humid), 5 (Warm temperate) and 6 (Mild temperate)[32]. Of these, only Climate Zone 6 is relevant to this project (given the Victorian focus).

For each archetype and climate zone, analysis was undertaken to assess the energy impact and benefit-cost ratio of each building element. This involved graphing benefit cost ratio versus percentage energy saving to assist in the

[30] https://climateworks.com.au/sites/default/files/documents/publications/built_to_perform.pdf

[31] http://www.lowcarbonlivingcrc.com.au/sites/all/files/publications_file_attachments/sp0016_trajectory_interim_technical_report.pdf

[32] As defined by the Australian Building Codes Board.

identification of measures that are both effective (i.e. >2% saving) and economic (i.e. benefit-cost ratio >1).

It should be noted that the benefits included in the CW/ASBEC work were both individual (i.e. energy bill savings) and societal (i.e. network cost savings, carbon savings).

Only a small number of measures (improved air tightness and increased roof insulation) were deemed to be both 'effective' and 'economic' for the detached dwelling and attached townhouse in Climate Zone 6.

Measures were costed using a standard industry cost guide[33] with the following costs documented by house archetype and Star rating achieved:

ARCHETYPE	MEASURE	COST	RATING ACHIEVED
Detached house	Improved air tightness[34]	$800	7.5 Stars
Detached house	Increased roof insulation[35]	$4,401	7.5 Stars
Attached townhouse	Improved air tightness[36]	$800	7.2 Stars
Attached townhouse	Increased roof insulation[37]	$5,140	7.2 Stars

Table 25 Efficiency Costs by Star Rating & Home Archetype, "Built to Perform"

Each house design was modelled to attribute an energy rating under the Nationwide House Energy Rating (NatHERS) scheme[38]. Importantly, air tightness is not captured within the NatHERS framework and does not influence the final rating.

As such, the costs in the table above can be taken as an indication of the cost-premium to achieve a 7.2 / 7.5 Star rating for detached / attached Class 1 dwellings in Victoria.

As has been noted in many previous studies of this nature, once again costing these measures individually, and using a standard industry guide, takes no consideration of any potential economies of scale in pricing by volume builders or learning rates that would likely be achieved were these additional measures mandatory across the industry. As such, these costs can be considered conservatively high.

[33] https://www.rawlhouse.com.au/publications/rawlinsons-construction-cost-guide
[34] To achieve 5.8 air changes per hour @ 50 Pa.
[35] To achieve R6.9 insulation value.
[36] To achieve 5.8 air changes per hour @ 50 Pa.
[37] To achieve R8.7 insulation value.
[38] http://www.nathers.gov.au/

- The *"Changes Associated with Efficient Dwellings"* project (2017)[39] – prepared by the Moreland Energy Foundation (MEFL) in collaboration with Strategic, Policy and Research, WTP partnership and Building Environmental Assessment Company, for the Federal Department of the Environment and Energy (under Measure 31.2 of the National Energy Productivity Plan).

  Amongst other investigations, MEFL undertook quantitative analysis of actual costs incurred by developers across 58 representative dwellings. This was carried out through industry surveys and interviews.

  MEFL noted that above-minimum star ratings represent voluntary decisions, which have the potential to be skewed towards upper-income owners. They also noted that the sample was limited in size and revealed a surprising degree of variability. Whilst it was possible to fit an exponential trend line to the data, MEFL reported a high degree of 'scatter' in the data (indicating lower confidence in results).

  Noting these limitations, MEFL reported an area-adjusted analysis of cost per square metre per star, for Class 1 dwellings, of $18. For a medium-sized, 166 square metre home, this equates to $2,988.

  Separately, MEFL also surveyed industry participants regarding the perceived cost increase from the introduction of minimum 6 Star compliance in the Building Code of Australia in 2010. In the survey:

  - 34% of respondents indicated the initial cost was neutral or less than $2000;
  - 36% of respondents indicated that the initial cost impact was between $2,000 and $5,000; and
  - 30% indicated the increase was more than $5,000.

[39] https://www.energy.gov.au/publications/changes-associated-efficient-dwellings-project

4.1.3. Modelled Build-Cost Premium

Renew used the results in these two studies to inform the build-cost premium at the lower end of the Star rating scale:

REFERENCE	COST	STAR INCREASE	RATING ACHIEVED	COST PER STAR
CW/ASBEC - Detached house	$4,401	1.5 Stars	7.5 Stars	$2,934
CW/ASBEC - Attached house	$5,140	1.2 Stars	7.2 Stars	$4,283
MEFL	$2,988	1.0 Stars	7 Stars	$2,988
Average				$3,366

Table 26 Derived Build-Cost Premium, 6 to 7 Stars

From there, sensitivity analysis was used to capture a broad range of build-cost premiums at each Star rating level, to compensate for the lack of specific data.

Having showcased high efficiency homes for over a decade[40], Renew is able to draw on a range of individual case studies to guide cost information at higher Star rating levels.

Taking all the above into account, the following range of build-cost premiums by Star rating were used for the *Medium Home* case in each location:

STARS	SENSITIVITY		
	Low Cost $	Medium Cost $	High Cost $
7	1,500	3,000	6,000
8	6,000	12,000	24,000
9	12,000	24,000	48,000
10	24,000	48,000	96,000

Table 27 Modelled Build-Cost Premiums above 6 Stars by Star Rating, Medium Home, All Locations

[40] Through *Sanctuary: Modern Green Homes*: https://renew.org.au/sanctuary-magazine/

The build-cost premiums identified above were then adjusted to account for the fact that:

- larger homes are likely to achieve economies of scale in the unit costs to build to higher levels of efficiency (as compared with a medium sized home); whilst
- smaller homes are likely to incur a unit cost-penalty when built to higher levels of efficiency (as compared with a medium sized home).

On this basis, a 10% discount to the build-cost premium was implemented for the Large Homes; whilst a 10% premium was implemented for the Small Homes:

STARS	SENSITIVITY		
	Low Cost $	Medium Cost $	High Cost $
7	1,870	3,741	7,482
8	7,482	14,964	29,928
9	14,964	29,928	59,855
10	29,928	59,855	119,711

Table 28 Modelled Build-Cost Premiums above 6 Stars by Star Rating, Large Home, All Locations

STARS	SENSITIVITY		
	Low Cost $	Medium Cost $	High Cost $
7	994	1,988	3,976
8	3,976	7,952	15,904
9	7,952	15,904	31,807
10	15,904	31,807	63,614

Table 29 Modelled Build-Cost Premiums above 6 Stars by Star Rating, Small Home, All Locations

It should be again noted that higher energy performance can be achieved without any additional build cost to the project, where passive solar principles can be integrated into the design.

4.2. Appliance Capital & Replacement Costs

Capital costs for different appliances within different household types were required to generate typical economic outputs. The following approach was taken when applying appliance capital costs:

- Some of the major fixed appliances will be the same across household types, irrespective of home size and whether the home is dual fuel or all-electric;
- Minor, plug-in appliances are captured in the "residual" load applied in Appendix D. For a given household size, these do not differ by location or fuel type.

On this basis, the most important aspect to capture in the economic model was any "cost-premium" incurred by the new home buyer for selecting appliances associated with:

- a higher efficiency home; and/or
- a dual fuel home with gas-boosted solar hot water instead of gas instantaneous hot water; and/or
- an all-electric instead of a dual fuel home; and/or
- a home with solar PV.

Appliance capital costs were taken from online sourcing of relevant retail appliances prices, including installation.

Appliance replacement costs are also important and taken account of in the model. For simplicity, a standardised approach was taken with regard to the replacement timeframes. Essentially, years 11 and 22 were used across all appliances for either end of asset life or appliance upgrade/partial replacement. Specifically:

- Gas ducted burners were replaced in Years 11 and 22[41], whilst new ducts were only installed in Year 22;
- Gas instantaneous and heat pump hot water units, gas and induction cooktops and reverse cycle air conditioners were replaced in Years 11 and 22[42];
- The gas-boost on solar hot water systems was replaced in Years 11 and 22, whilst the flat plate collectors were only replaced in Year 22[43]; and
- The inverter on the 5.0-kilowatt solar PV system was replaced in Year 11[44], with the solar panels being replaced in Year 22[45].

[41] 10% cost reductions assumed in both Years 11 and 22.
[42] 10% cost reductions assumed in both Years 11 and 22.
[43] 10% cost reductions assumed in both Years 11 and 22.
[44] 10% cost reductions assumed in Year 11.
[45] 50% cost reduction assumed in Year 22.

HOME SIZE	FUEL	TYPE	CAPITAL COST	REPLACE COST		NOTES
				(YEAR 11)	(YEAR 22)	
Large	Gas	Heating	$ 6,400	$ 2,115	$ 2,967	Brivis 5 Star Gas ducted (new ducts Year 22)
Large	Gas	HW	$ 1,980	$ 1,782	$ 1,604	Instantaneous gas hot water
Large	Gas	Cook	$ 988	$ 889	$ 800	Gas cooktop
Large	Elec[46]	Heating	$ 9,205	$ 8,285	$ 7,456	RCAC
Large	Elec	HW	$ 2,683	$ 2,415	$ 2,173	Heat Pump - Quantum, Zone 5 for STCs.
Large	Elec	Cook	$ 1,161	$ 1,045	$ 940	Induction cooktop
Large	Solar	HW	$ 4,000	$ 1,782	$ 3,200	Flat plate split solar thermal HW
Large	Solar	PV	$ 6,000	$ 1,350	$ 3,000	Solar PV: 5 kW
Medium	Gas	Heating	$ 6,050	$ 2,115	$ 2,750	Brivis 5 Star Gas ducted (new ducts Year 22)
Medium	Gas	HW	$ 1,980	$ 1,782	$ 1,604	Instantaneous gas hot water
Medium	Gas	Cook	$ 988	$ 889	$ 800	Gas cooktop
Medium	Elec	Heating	$ 7,487	$ 6,738	$ 6,064	RCAC
Medium	Elec	HW	$ 2,553	$ 2,298	$ 2,068	Heat Pump - Quantum, Zone 5 for STCs.
Medium	Elec	Cook	$ 1,161	$ 1,045	$ 940	Induction cooktop
Medium	Solar	HW	$ 4,000	$ 1,782	$ 3,200	Flat plate split solar thermal HW
Medium	Solar	PV	$ 6,000	$ 1,125	$ 3,000	Solar PV: 5 kW
Small	Gas	Heating	$ 5,755	$ 2,115	$ 2,532	Brivis 5 Star Gas ducted (new ducts Year 22)
Small	Gas	HW	$ 1,980	$ 1,782	$ 1,604	Instantaneous gas hot water
Small	Gas	Cook	$ 988	$ 889	$ 800	Gas cooktop
Small	Elec	Heating	$ 5,769	$ 5,192	$ 4,673	RCAC
Small	Elec	HW	$ 2,230	$ 2,007	$ 1,806	Heat Pump - Quantum, Zone 5 for STCs.
Small	Elec	Cook	$ 1,161	$ 1,045	$ 940	Induction cooktop
Small	Solar	HW	$ 4,000	$ 1,782	$ 3,200	Flat plate split solar thermal HW
Small	Solar	PV	$ 6,000	$ 1,125	$ 3,000	Solar PV: 5 kW

Table 30 Appliance Capital & Replacement Costs by Fuel & Home Size

[46] Applicable to both fuel types as the RCACs are also used for cooling in the dual fuel homes modelled.

5. Results

The economic model presented outputs in both payback period and net present value terms. These are presented and discussed below.

5.1. Payback Period

The payback charts are defined in years – i.e. the number of years taken for the additional capital associated with higher building efficiency, all-electric appliance mix and solar PV (and any replacement capex that may be incurred), to pay for itself in the form of energy bill savings, as compared with the Base Case, 6 Star dual fuel home.

The charts are presented by location and household size and consider the build cost premium sensitivities (low, medium and high) as discussed in Section 4.1. The charts also include either a 7% or 4% discount rate (as noted).

The Victorian Department of Treasury and Finance's *Economic Evaluation Technical Guide* recommends using a discount rate of 4% for traditional core service delivery areas of government such as public health, justice and education, or 7% where the attributable benefits are more easily translated into monetary terms.[47]

For energy efficiency analyses, it is useful to test both 4% and 7%, noting that using the 7% discount rate is likely to undervalue future benefits, given most Victorian home buyers' primary source of finance is a residential mortgage.

Based on current and likely near-term mortgage rates[48], and once adjusted for inflation, a more accurate discount rate for this project might lie somewhere between 2% to 4%. The latter has been used as alternative in presenting these results.

[47] http://www.dtf.vic.gov.au/sites/default/files/2018-03/Economic%20Evaluation%20-%20Technical%20Guide.doc
[48] https://www.rba.gov.au/publications/smp/2018/aug/economic-outlook.html

5.1.1. Melbourne Results (7% Discount Rate)

Figure 14 shows the payback period by star rating and additional capital expense (capex) for the Medium-sized, solar all-electric home in Melbourne (7% discount). The home is compared to a 6-Star dual fuel home with gas-boosted SHW.

As can be seen, payback times lengthen in line with additional capex incurred. Of note, payback time is:

- less than 10 years for all three build cost premium sensitivities associated with a 7 Star build;
- less than 10 years for the low and medium build cost premiums associated with an 8 Star build;
- less than 10 years for the low build cost premium associated with a 9 Star build; and
- longer than 25 years for the:
    - high build cost premium associated with a 9 Star build; and
    - medium and high build cost premiums associated with a 10 Star build.

Significantly, payback time is very short (less than 4.5 years) for all three build cost premiums associated with 7 Stars, and the low sensitivities for 8 Stars. It should be noted that where payback extends above the chart, this is due to the payback for that scenario being longer than the model calculates (i.e. > 30 years).

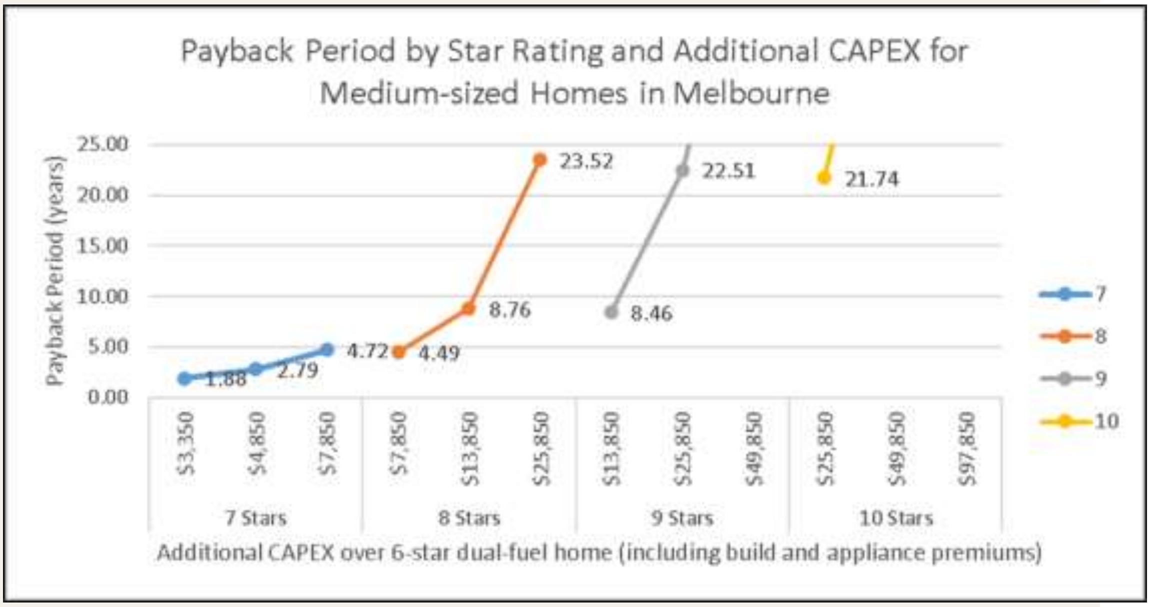

Figure 14: Payback by Star Rating/Capex, Medium Solar All-Electric Melbourne Home (7% Discount)[49]

[49] Compared to 6-Star dual fuel gas-boosted SHW home.

These payback times reduce for the Small, and extend for the Large, solar all-electric home in Melbourne:

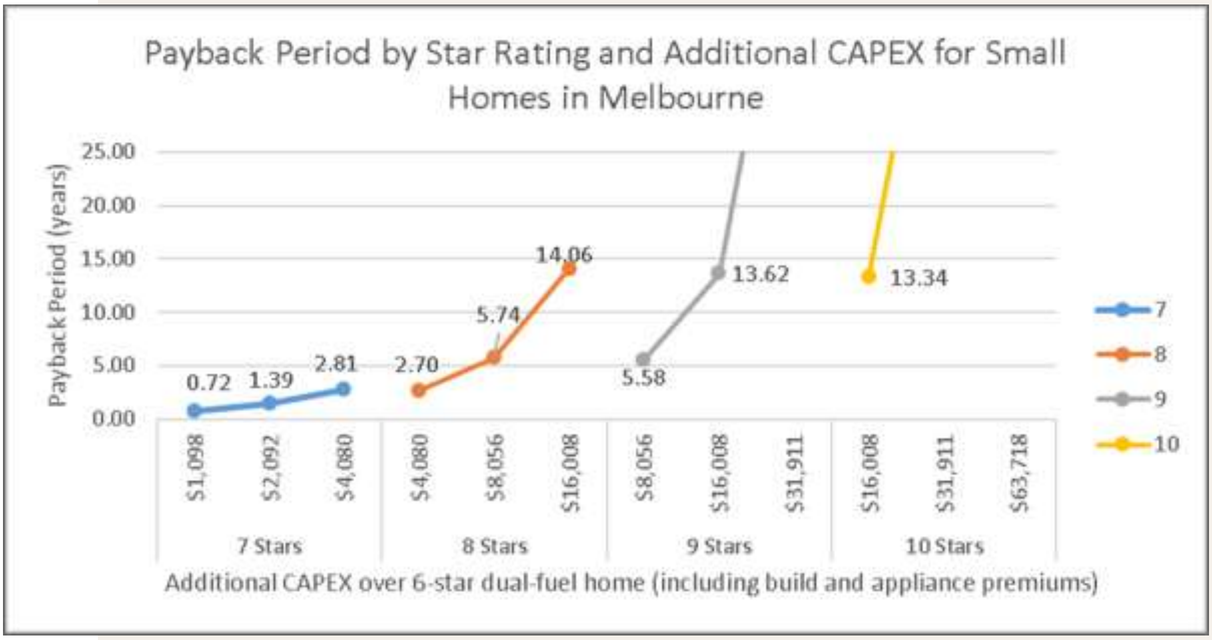

Figure 15: Payback by Star Rating/Capex, Small Solar All-Electric Melbourne Home (7% Discount)[50]

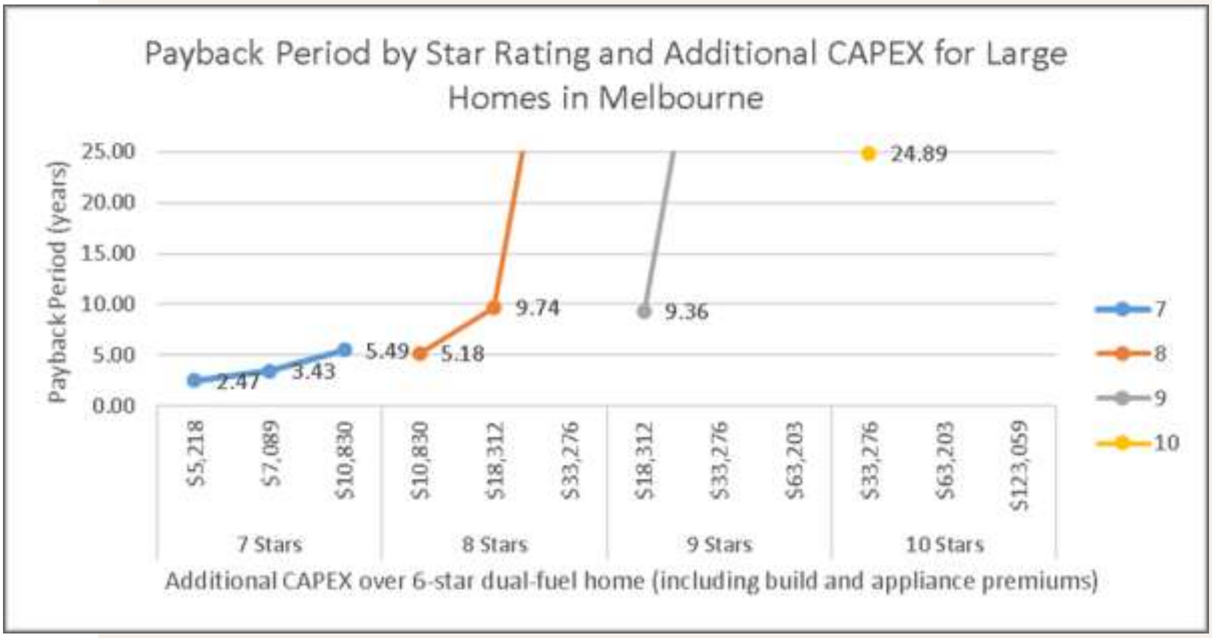

Figure 16: Payback by Star Rating/Capex, Large Solar All-Electric Melbourne Home (7% Discount)[51]

[50] Compared to 6-Star dual fuel gas-boosted SHW home.
[51] Compared to 6-Star dual fuel gas-boosted SHW home.

5.1.2. Regional Locations (7% Discount Rate)

In the four regional locations modelled, payback results were similar to those for Melbourne. For all four locations, payback was again:

- less than 10 years for all three build cost premium sensitivities associated with a 7 Star build;
- less than 10 years for the low and medium build cost premiums associated with an 8 Star build;
- less than 10 years for the low build cost premium associated with a 9 Star build; and
- longer than 25 years for the:
    - high build cost premium associated with a 9 Star build (apart from Warrnambool); and
    - medium and high build cost premiums associated with a 10 Star build.

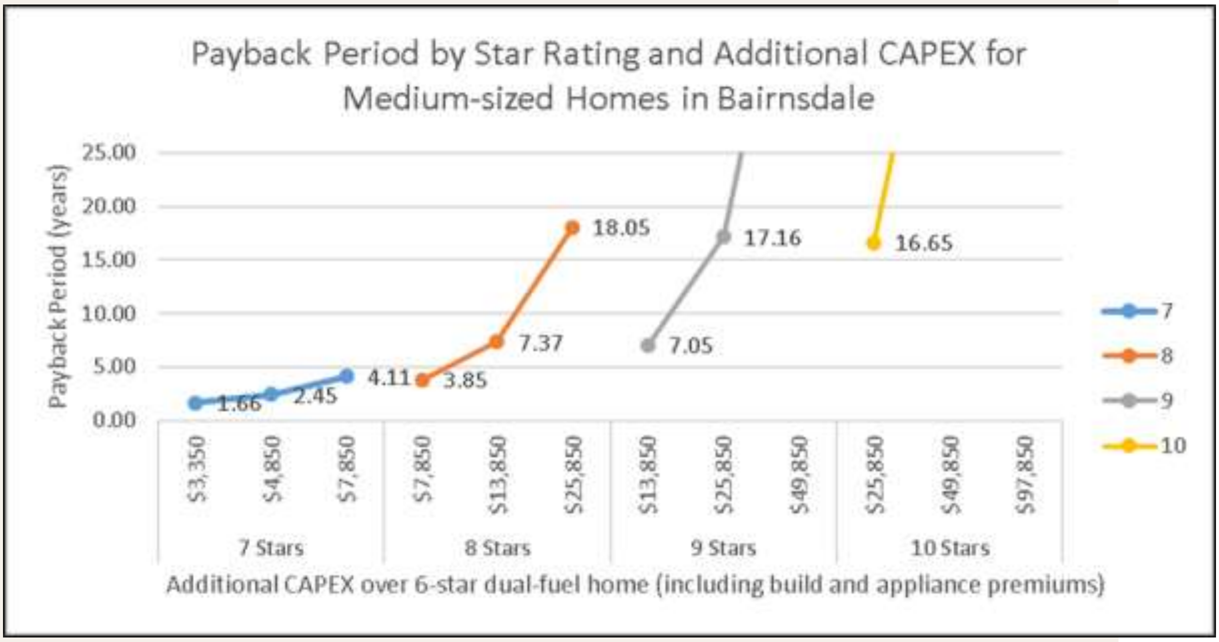

Figure 17: Payback by Star Rating/Capex, Medium Solar All-Electric Home, Bairnsdale (7% Discount)[52]

[52] Compared to 6-Star gas-boosted SHW home.

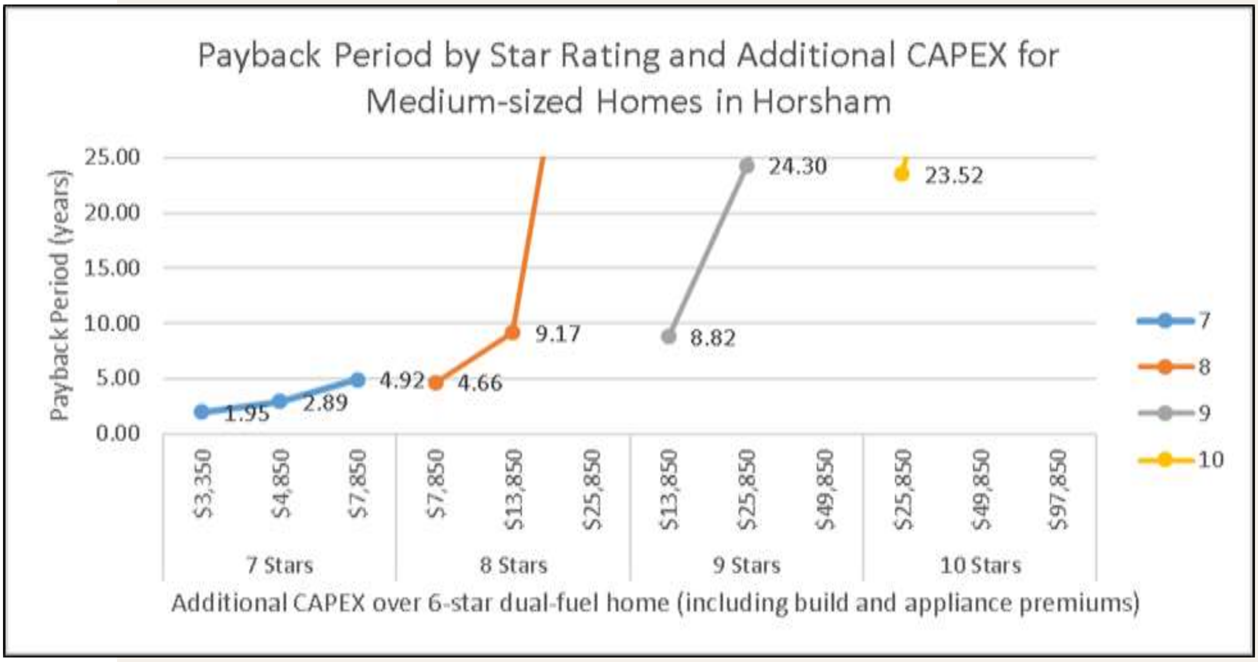

Figure 18: Payback by Star Rating/Capex, Medium Solar All-Electric Home, Horsham (7% Discount)[53]

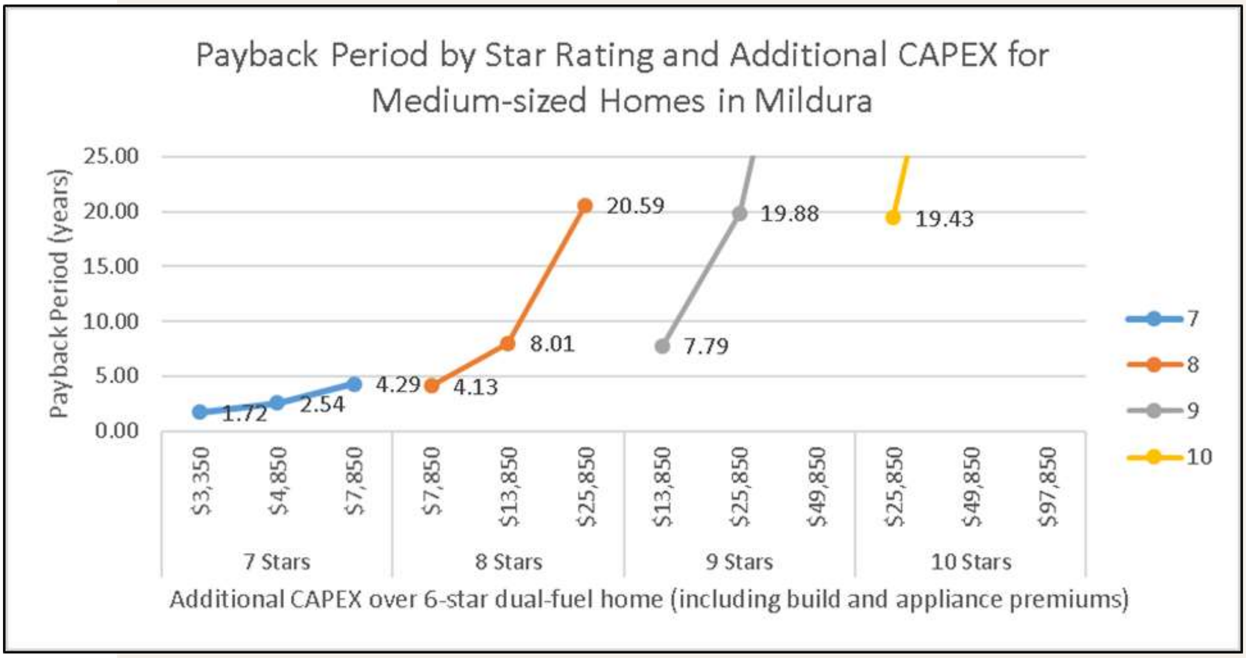

Figure 19: Payback by Star Rating/Capex, Medium Solar All-Electric Home, Mildura (7% Discount)[54]

[53] Compared to 6-Star gas-boosted SHW home.
[54] Compared to 6-Star gas-boosted SHW home.

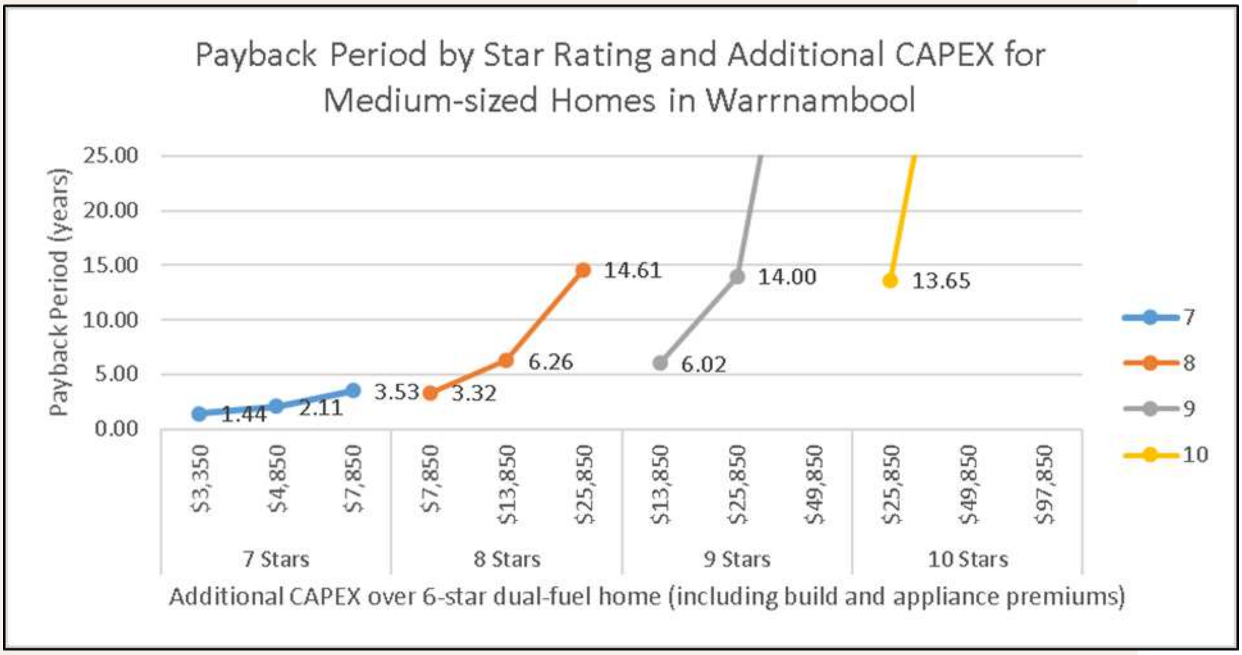

Figure 20: Payback by Star Rating/Capex, Medium Solar All-Electric Home, Warrnambool (7% Discount)[55]

[55] Compared to 6-Star gas-boosted SHW home.

5.1.3. Small Home Sensitivity (Warrnambool & Bairnsdale)

As per Section 2.4, sensitivity analysis was undertaken to consider smaller annual gas loads for Warrnambool and Bairnsdale. Figure 21 and Figure 22 show a difference of less than 12 months in payback times for both locations, as compared with their Medium home counterparts:

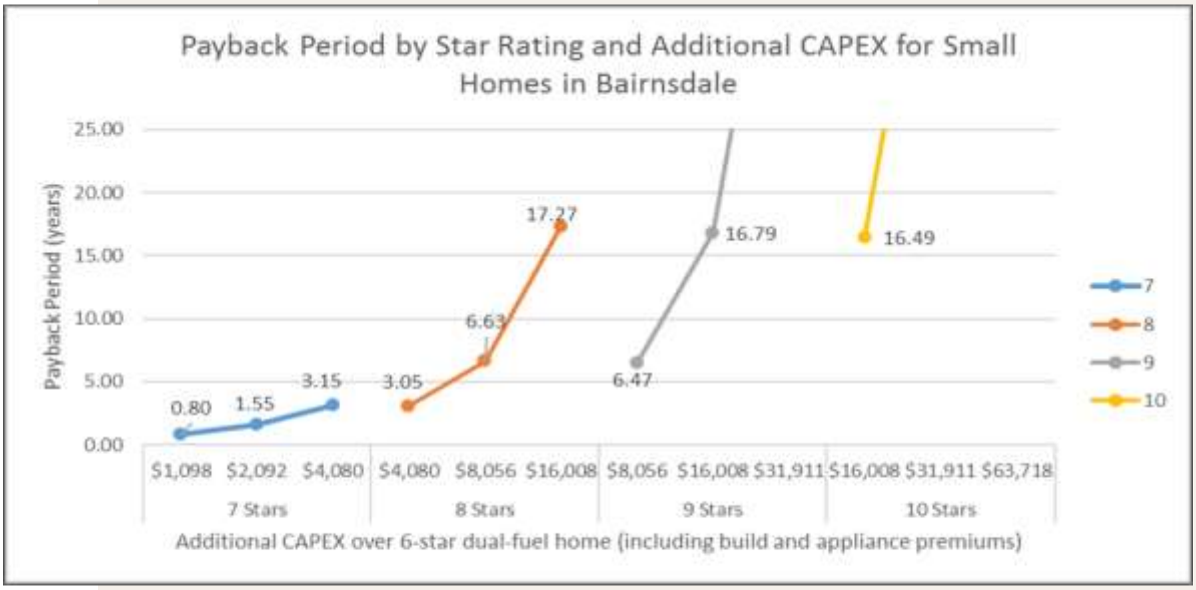

Figure 21: Payback by Star/Capex, Small (Sensitivity) Solar All-Electric, Bairnsdale (7% Discount)[56]

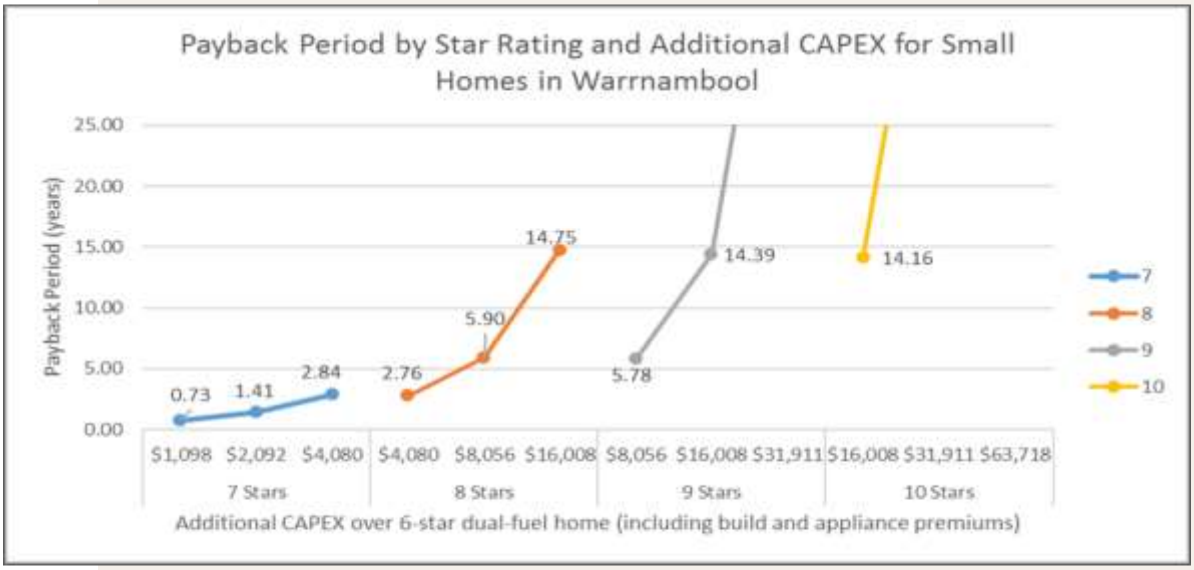

Figure 22: Payback by Star/Capex, Small (Sensitivity) Solar All-Electric, Warrnambool (7% Discount)[57]

[56] Compared to 6-Star gas-boosted SHW home.
[57] Compared to 6-Star gas-boosted SHW home.

5.1.4. Melbourne Results (4% Discount Rate)

Obviously, the choice of discount rate has a material impact on payback times. Figure 23 shows the payback times for the Medium Solar All-Electric Home in Melbourne based on a 4% discount rate.

The 4% rate reduced payback times by no more than 15 months for those scenarios[58] returning payback within 10 years when using the 7% rate.

Obviously, the longer the payback time, the greater the difference between paybacks using the 4% and 7% rate (up to seven years difference for the 9 and 10-Star scenarios that paid for themselves within 25 years):

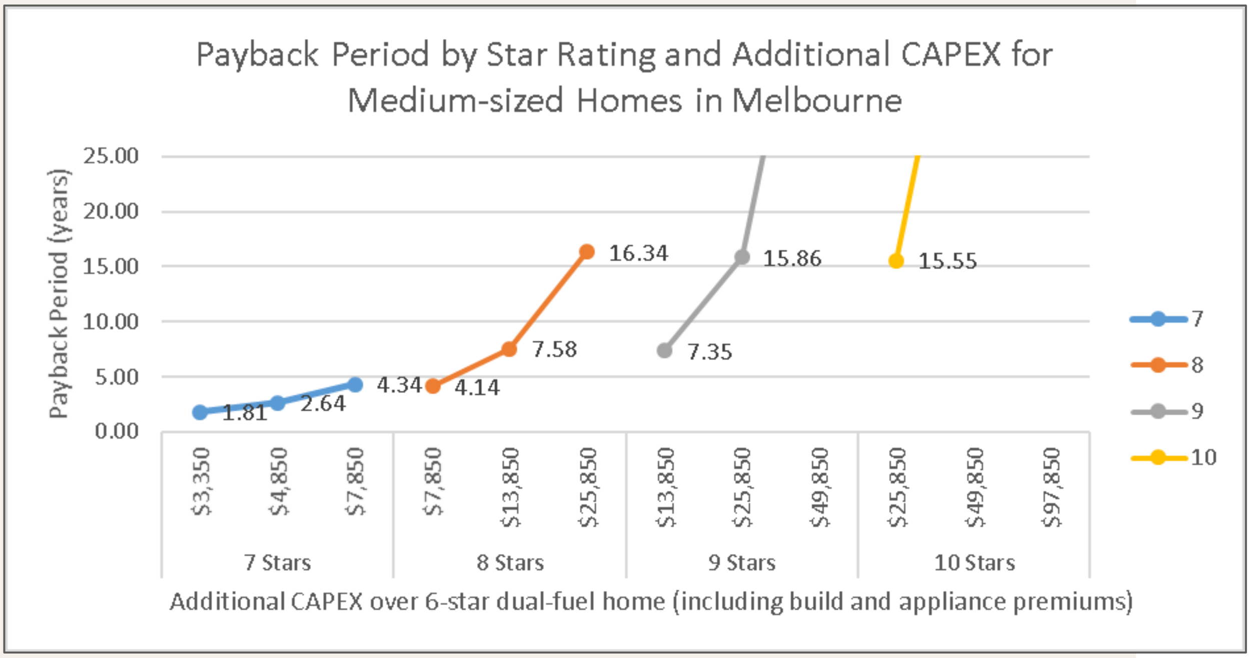

Figure 23: Payback by Star/Capex, Medium Solar All-Electric Home, Melbourne (4% Discount)[59]

[58] i.e. the low, medium and high build-cost premiums for 7 Stars; the low and medium build-cost premiums for 8 Stars; and the low build-cost premiums for 9 Stars.
[59] Compared to 6-Star gas-boosted SHW home.

5.1.5. Value of Solar PV

The value of solar PV to the payback times can be seen below. Figure 24 shows the payback period by star rating and additional capital expense (capex) for the Medium-sized, all-electric home without solar PV in Melbourne, using the 7% discount rate:

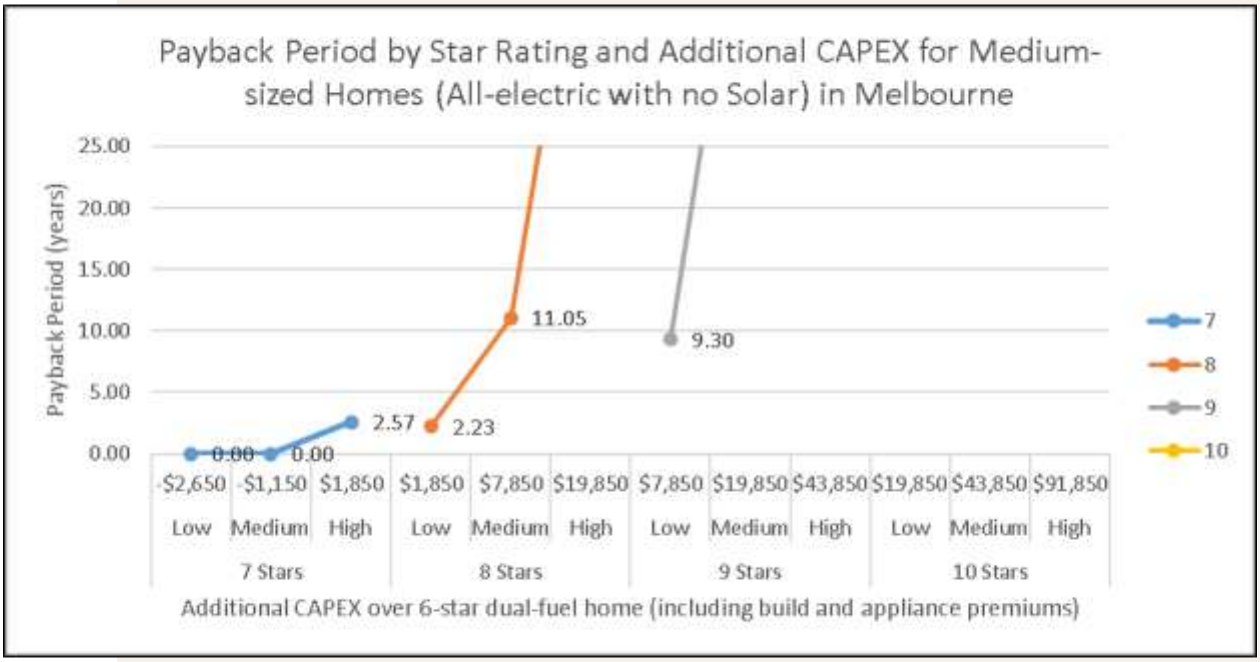

Figure 24: Payback by Star Rating/Capex, Medium All-Electric Melbourne Home (7% Discount)[60]

As can be seen, as compared with the equivalent home with solar PV:

- Payback is reduced for the 7-Star homes, because having no solar significantly reduces the capex:
  - Under the low and medium build-cost premiums, a 7-Star all-electric home without solar is cheaper than a 6-Star dual-fuel home with gas-boost solar HW (i.e. payback is negative);
  - Under the high build-cost premium, payback reduces from 4.72 years to 2.57 years, as the total additional capex reduces from $7,850 with solar to $1,850 without solar;
- Payback is reduced for 8-Star homes under low build-cost premium, and is increased under medium and high build-cost premiums:

[60] Compared to 6-Star dual fuel gas-boosted SHW home.

- Under the low build-cost premium, additional capex reduces from $7,850 to $1,850, reducing payback from 4.49 years to 2.23 years;

- Under the high build-cost premium, additional capex reduces from $13,850 to $7,850, however payback time increases due to lower bill savings without solar;

- Payback is increased for all 9- and 10-Star homes without solar:

    - A 9-Star home with low build-cost premiums sees the additional capex reduce from $13,850 to $7,850, however once again this increases the payback, from 8.46 years to 9.3 years;

    - No payback with 25 years for any 10-Star homes without solar.

5.2. Net Present Values (25-Year Horizon)

Net present values (NPVs) were also defined by the economic model, on both a 10-year and 25-year, discounted basis (7% and 4% were again used). This section presents the results of the 25-year NPVs for each household type.

The charts demonstrate positive or negative values over the relevant time period, considering all capital, operational and replacement costs, bill savings and the discount rates, as compared with the Base Case, 6 Star dual fuel home.

5.2.1. Melbourne Results (7% Discount Rate)

Figure 35 shows the 25-year NPV of the solar all-electric homes in Melbourne (7% discount rate), considering the different home sizes, build cost premiums and Star ratings. As can be seen:

- The 7 and 8-Star solar all-electric homes retain a positive NPV over 25 years for all build-cost premium sensitivities, with exception of the high build-cost premium at 8-Stars[61];
- The 9-Star solar all-electric homes retain a positive NPV over 25 years for the low and medium build-cost premium sensitivities only;
- The 10-Star solar all-electric homes retain a positive NPV over 25 years for only the low build-cost premium sensitivities, and only for the Small and Medium-sized homes.

Figure 26 shows the 25-year NPV of the solar all-electric homes in Melbourne (7% discount rate), as compared with 6-Star gas-boosted solar hot water (Gb) and 6-Star gas instantaneous hot water (Gi) homes. Only the medium build-cost premium has been included in this chart.

As can be seen, between 6 and 8-Stars, the solar all-electric homes perform marginally better against the 6-Star gas-boosted solar hot water homes, as compared to the 6-Star gas instantaneous hot water homes. The results then become mixed beyond 8-Stars.

Whilst the same trend-line can be seen as compared with Figure 35, the inclusion of the 6-Star solar all-electric home in this chart is of interest. Essentially, the 6-Star and the 7-Star solar all-electric home offers almost the same value over 25 years as compared with their dual fuel counterparts:

[61] At 7 Stars, the NPVs range between $18,000 and $25,000; whilst at 8 Stars, the NPVs range between $944 and $21,000. The high build-cost premium for 8-Stars led to a 25-year NPV of -$1,509.

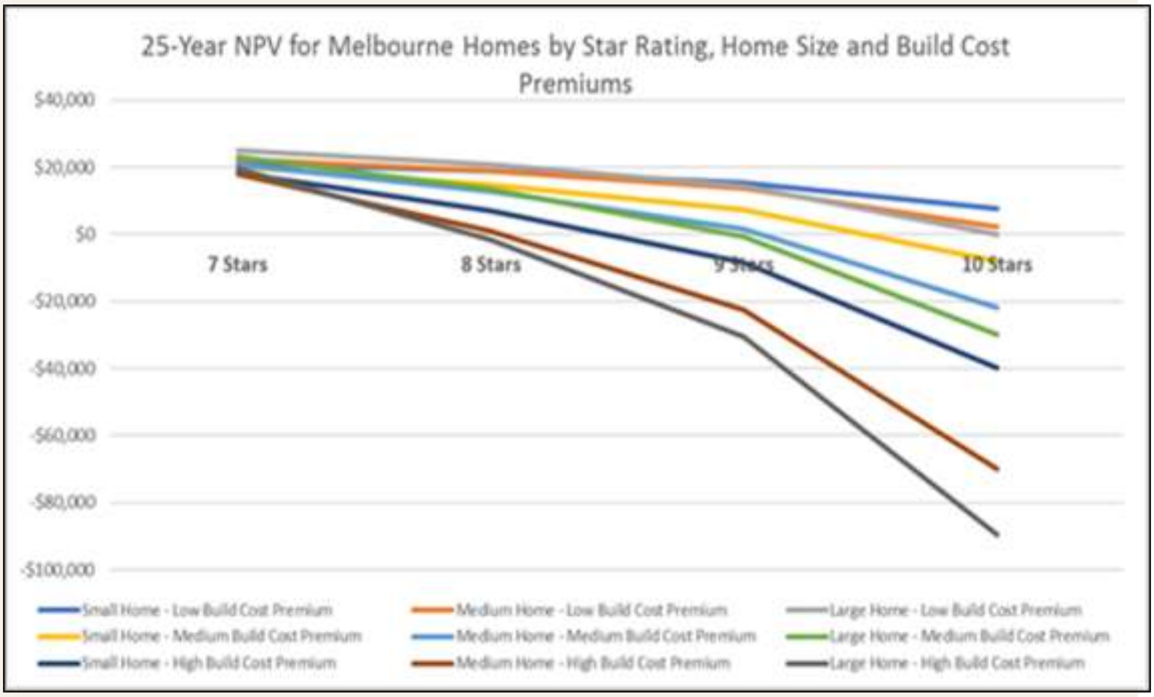

Figure 25: 25-Year NPV by Star Rating/Size, Solar All-Electric Home, Melbourne (7% Discount)[62]

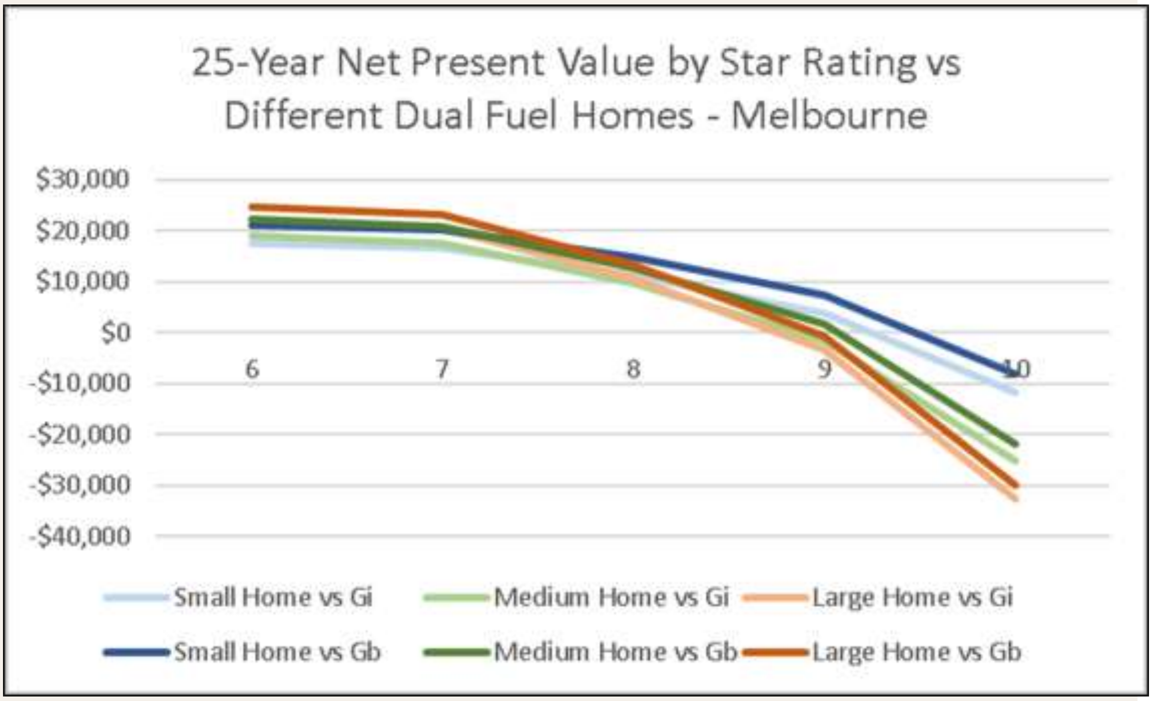

Figure 26: 25-Year NPV by Star/Size, Solar All-Electric Home, Melbourne (7% Discount, Medium Build Cost Premium)

[62] Compared to 6-Star gas-boosted SHW home.

5.2.2. Regional Locations (7% Discount Rate)

In the four regional locations, 25-year NPV results again demonstrated a similar trend to those for Melbourne. For all locations, the 25-year NPVs were positive for the 6, 7 and 8-Star solar-all electric homes, with Horsham (Small home only), Warranmbool and Mildura being positive for 9-Stars:

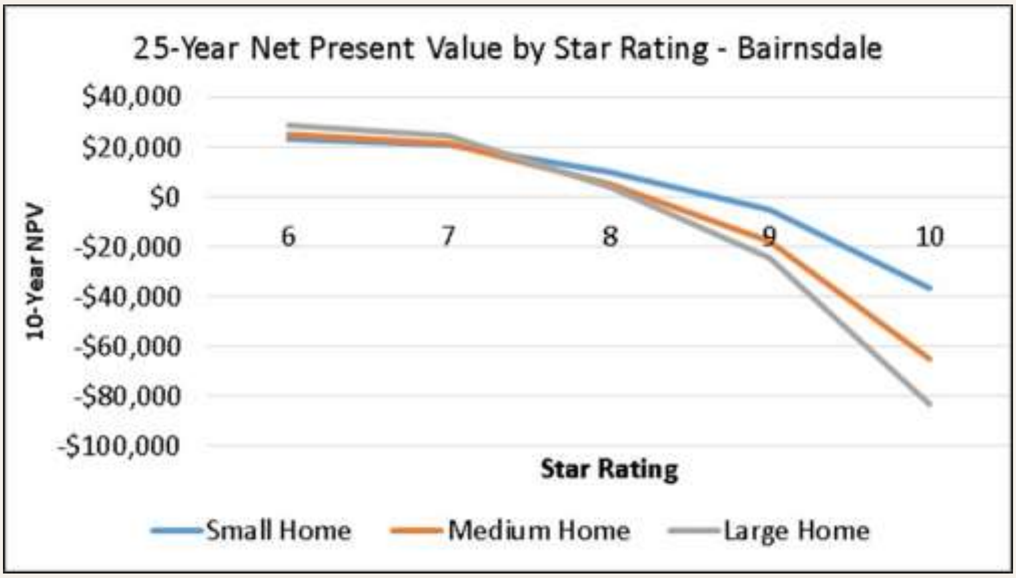

Figure 27: 25-Year NPV by Star/Size, Solar All-Electric, Medium Build Cost, Bairnsdale (7% Discount)[63]

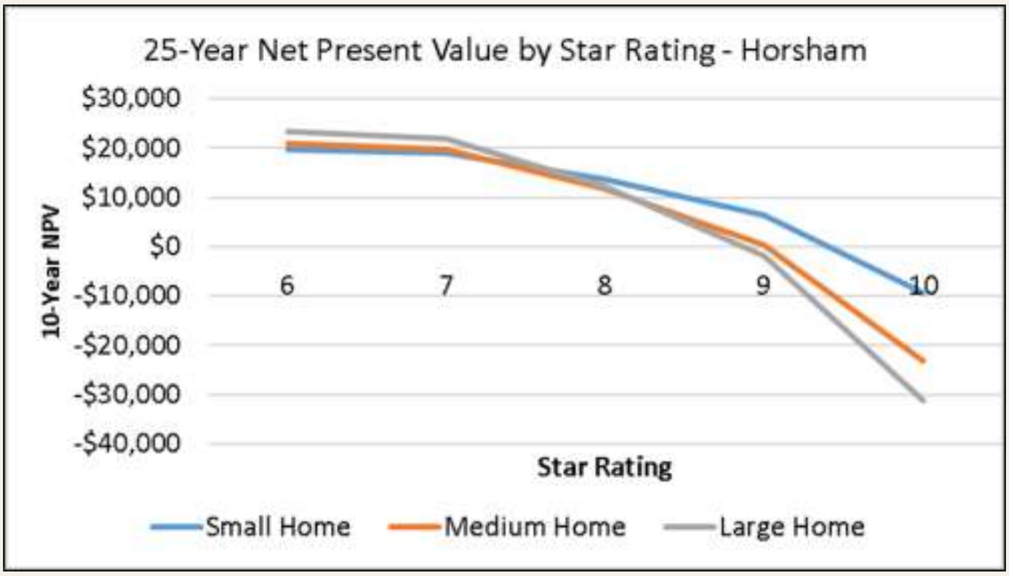

Figure 28: 25-Year NPV by Star /Size, Solar All-Electric, Medium Build Cost, Horsham (7% Discount)[64]

[63] Compared to 6-Star gas-boosted SHW home.
[64] Compared to 6-Star gas-boosted SHW home.

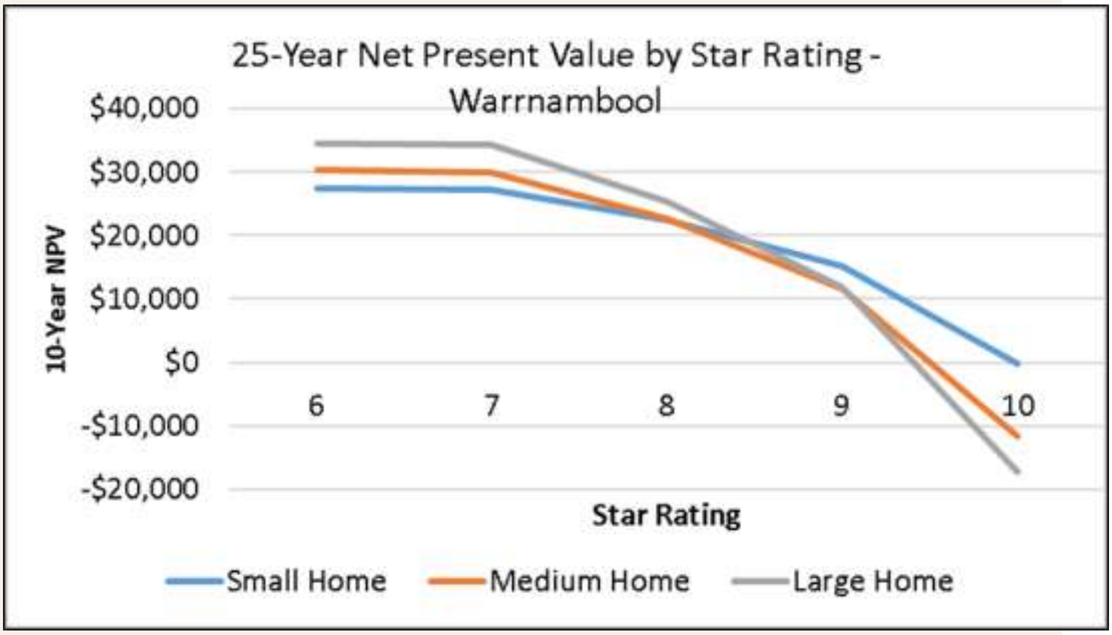

Figure 29: 25-Year NPV by Star /Size, Solar All-Electric, Medium Build Cost, Warrnambool (7% Discount)[65]

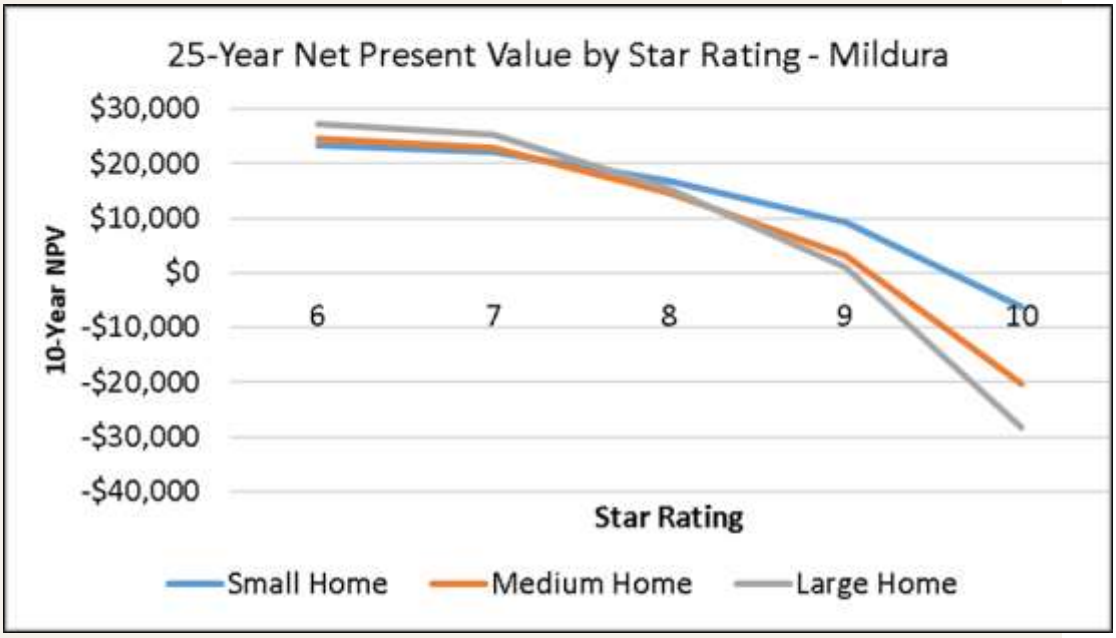

Figure 30: 25-Year NPV by Star/Size, Solar All-Electric, Medium Build Cost, Mildura (7% Discount)[66]

[65] Compared to 6-Star gas-boosted SHW home.
[66] Compared to 6-Star gas-boosted SHW home.

5.2.3. Small Home Sensitivity (Warrnambool & Bairnsdale)

As per the discussion in Section 2.4, sensitivity analysis was undertaken to consider smaller annual gas loads for Warrnambool and Bairnsdale, in line with the DHHS survey data for those regions.

As can be seen from the charts below, the Small home sensitivity analysis lead to:

- still positive 25-year NPVs for all 6-10 Star all-electric homes, using the low build-cost premium;
- positive 25-year NPVs for all homes 6 to 8-Star homes, regardless of build-cost premium;
- 9-Star homes with positive 25-year NPVs under low and medium build cost premiums; and
- 10-Star homes still with positive 25-year NPVs using the low build-cost premium.

Overall, the conclusions were very similar when compared with higher gas consumption for homes in these locations:

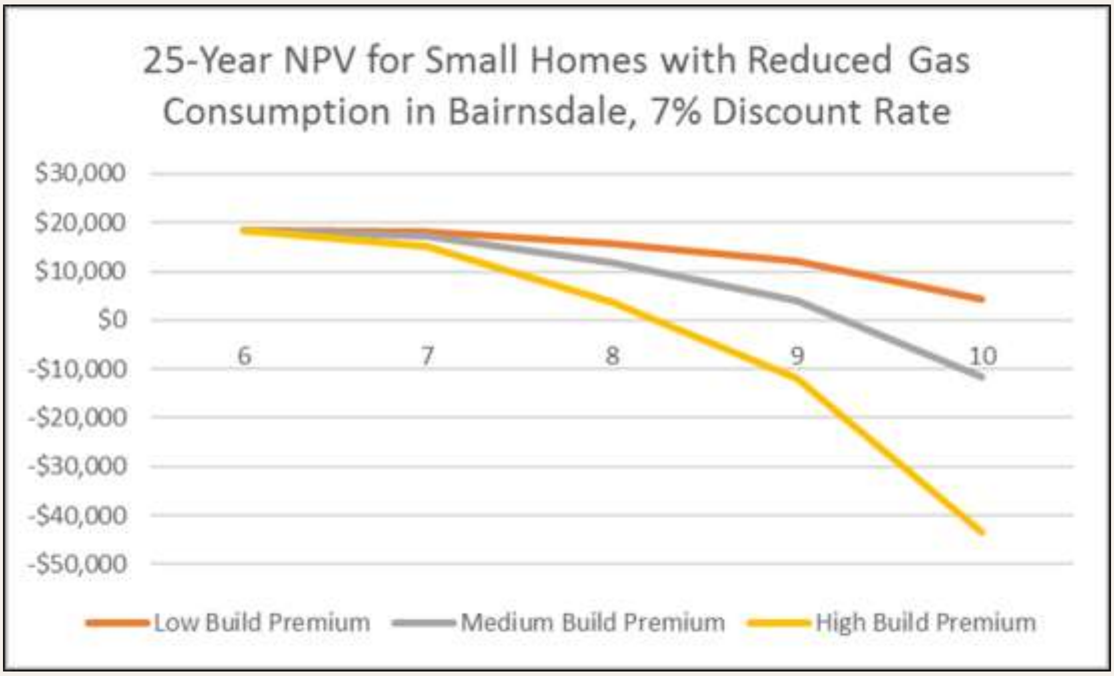

Figure 31: 25-Year NPV by Star Rating/Size, Medium Solar All-Electric Home, Bairnsdale (7% Discount)[67]

[67] Compared to 6-Star gas-boosted SHW home.

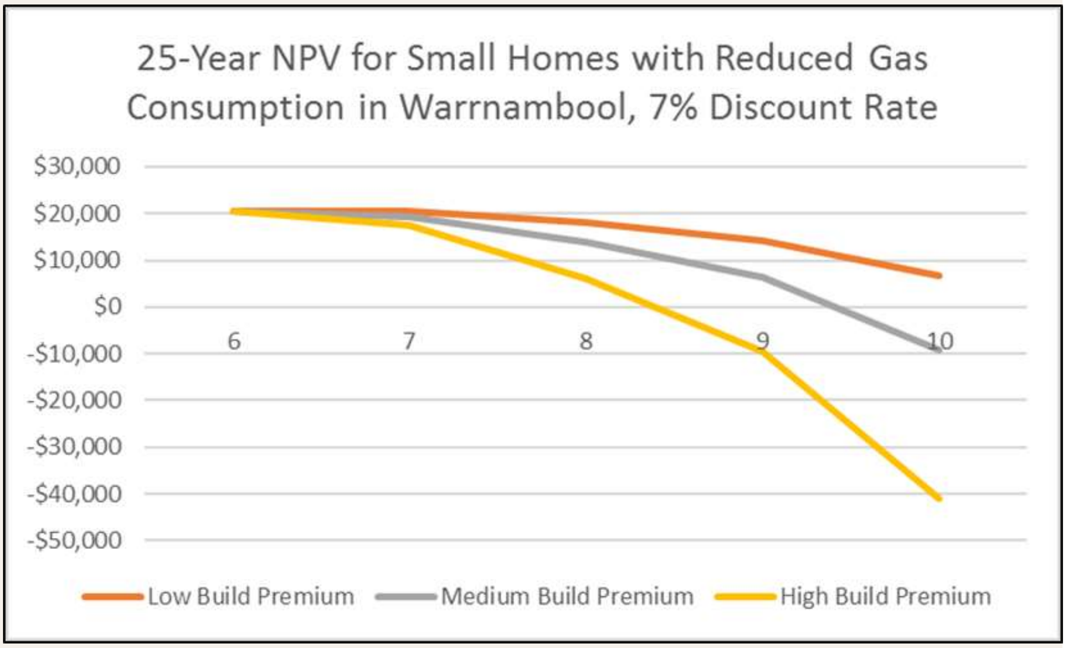

Figure 32: 25-Year NPV by Star Rating/Size, Medium Solar All-Electric Home, Warranmbool (7% Discount)[68]

[68] Compared to 6-Star gas-boosted SHW home.

5.2.4. Melbourne Results (4% Discount Rate)

Once again, using a more realistic cost of household finance (i.e. 4% discount rate), this significantly increased the 25-year NPVs in Melbourne by an average in the order of $10,000 for each Star level:

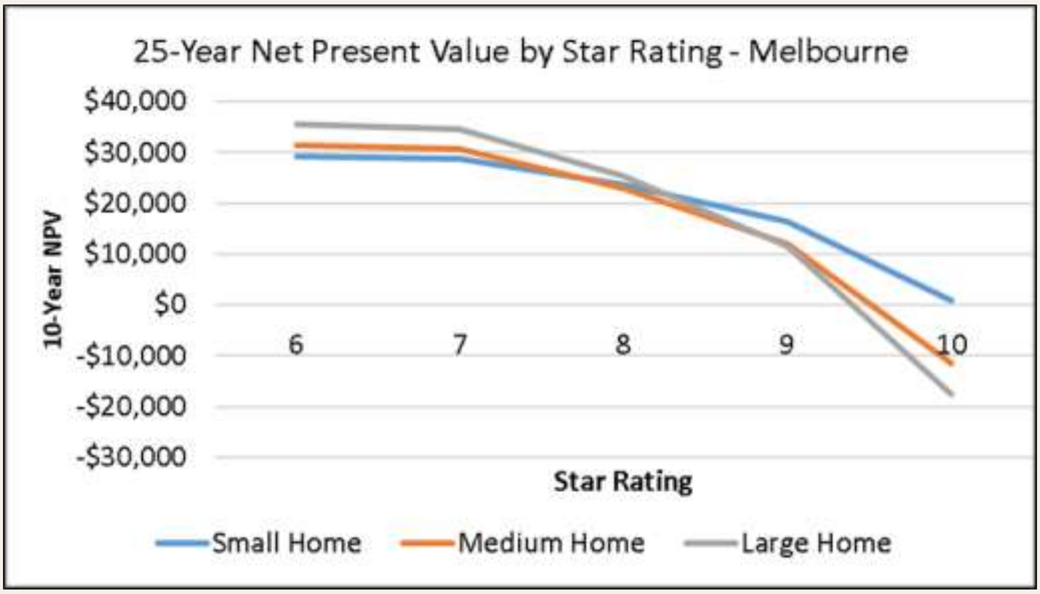

Figure 33: 25-Year NPV by Star Rating/Size, Medium Build Cost Premium, Melbourne (4% Discount)[69]

[69] Compared to 6-Star gas-boosted SHW home.

5.2.5. Value of Solar PV

Solar PV makes a significant difference to the annual bill savings and therefore NPVs of the all-electric versus the dual fuel homes.

Figure 34 shows the 25-year NPVs all-electric homes in Melbourne, with and without solar PV, when compared to a 6-Star dual fuel home with gas-boosted solar hot water. As can be seen, without solar PV installed, 6 and 7-Star all-electric homes reduce in value by at least $10,000 over 25 years:

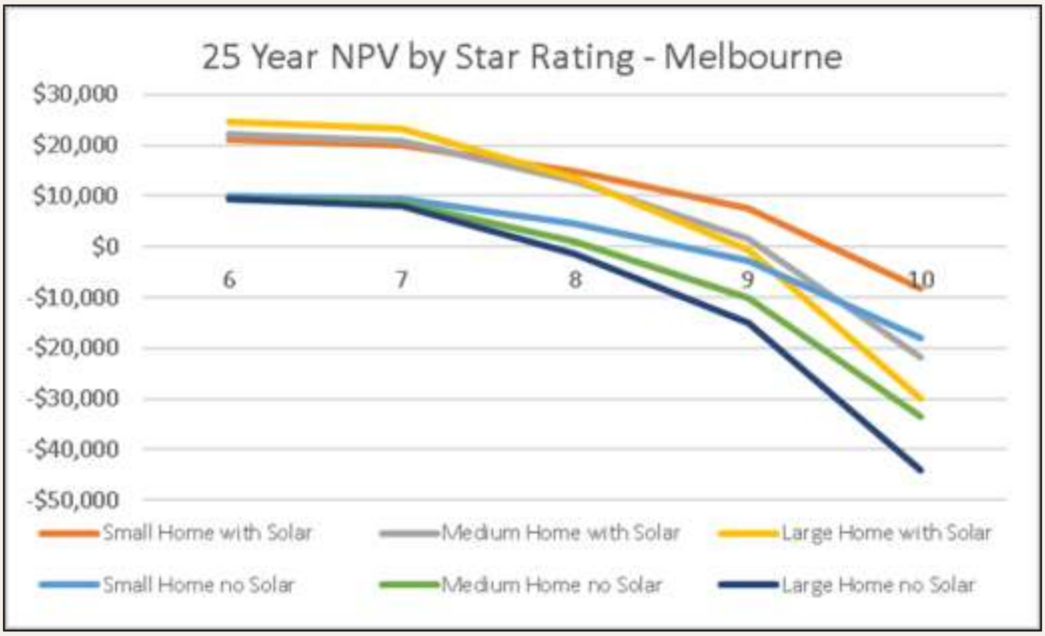

Figure 34: 25-Year NPV by Star/Size, All-Electric Home, Melbourne, with & without Solar PV (7% Discount, Medium Build Cost Premium)[70]

[70] Compared to 6-Star gas-boosted SHW home.

5.2.6. Value of Building Efficiency Upgrades

The following charts isolate the 25-year value of the building efficiency upgrades only – by comparing higher efficiency dual fuel homes (without solar PV) with the Base Case 6-Star dual fuel homes.

As can be seen, the 7-Star dual fuel homes with the medium build-cost premium offer a small amount of value (<$4,000) over 25 years when compared with a 6-Star dual fuel with gas-boosted solar hot water home. This value falls to around zero when the 7-Star home is compared to a 6-Star with gas instantaneous hot water.

For all other higher Star rating levels, the 25-year value is less than zero – dropping to -$40,000 for the Large 10-Star home:

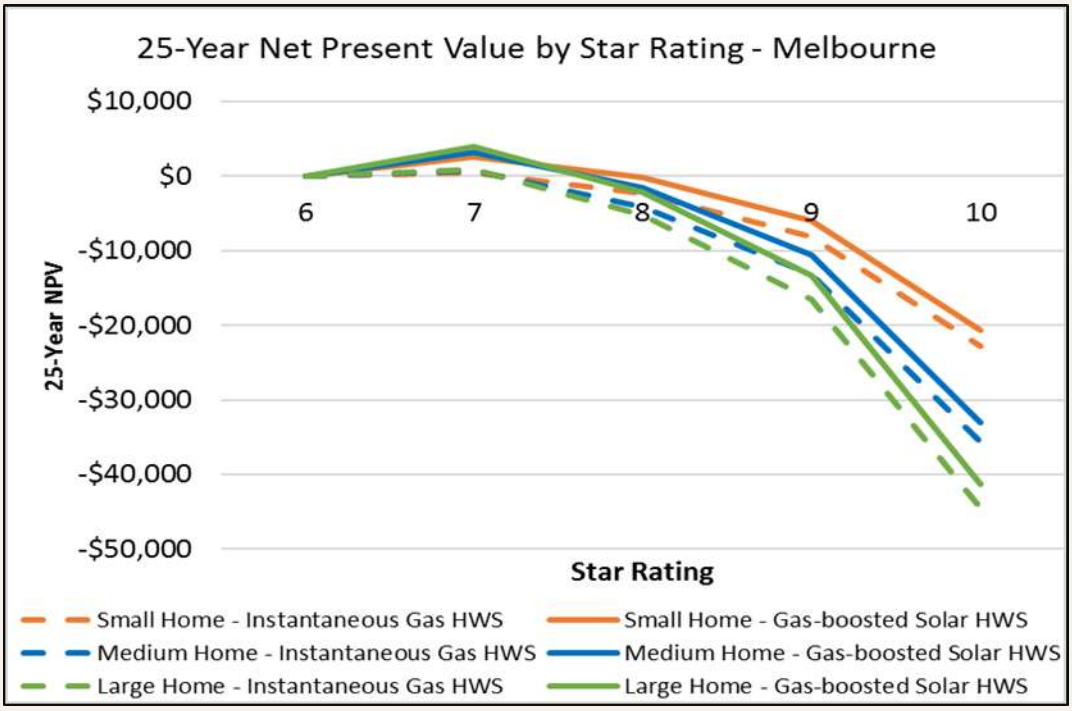

Figure 35: 25-Year NPV by Star Rating/Size, Dual Fuel Home, Melbourne, no Solar PV (7% Discount, Medium Build Cost Premium)

Using the low build-cost premium, between $2,000 and $6,000 of value is offered by the 7 and 8-Star dual fuel homes, when compared with either of the 6-Star Base Case homes.

And unsurprisingly, the high build-cost premium leads to between zero and approximately $100,000 of real cost over the 25 years:

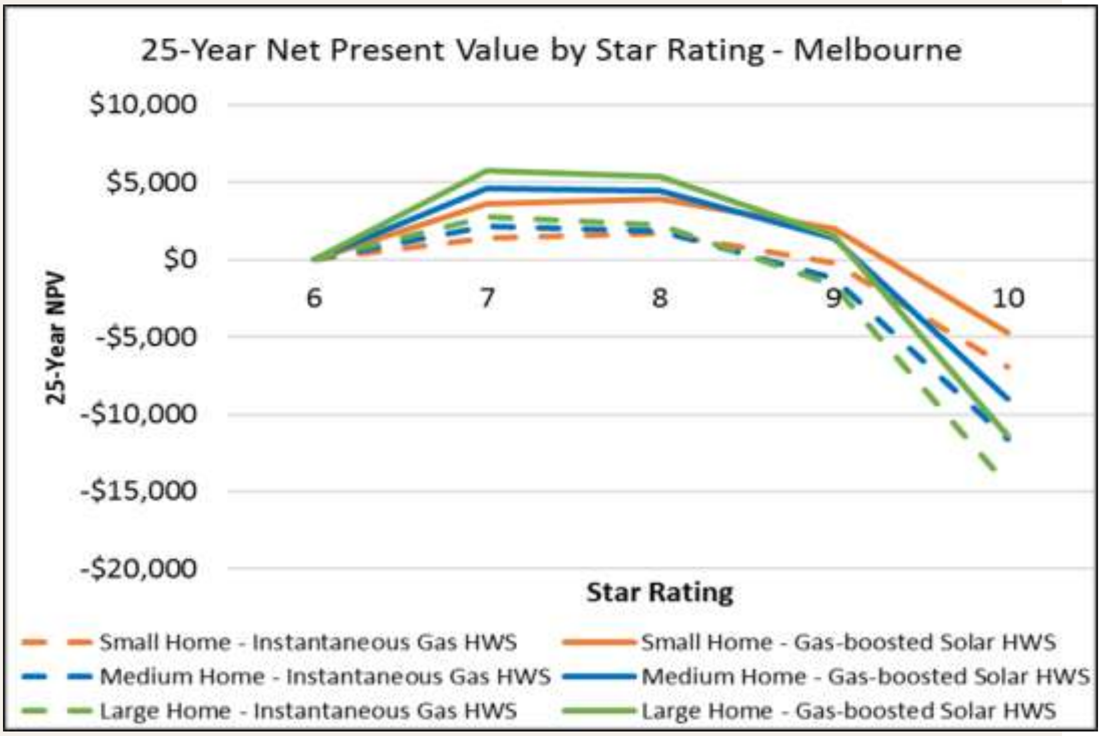

Figure 36: 25-Year NPV by Star Rating/Size, Dual Fuel Home, Melbourne, no Solar PV (7% Discount, Low Build Cost Premium)

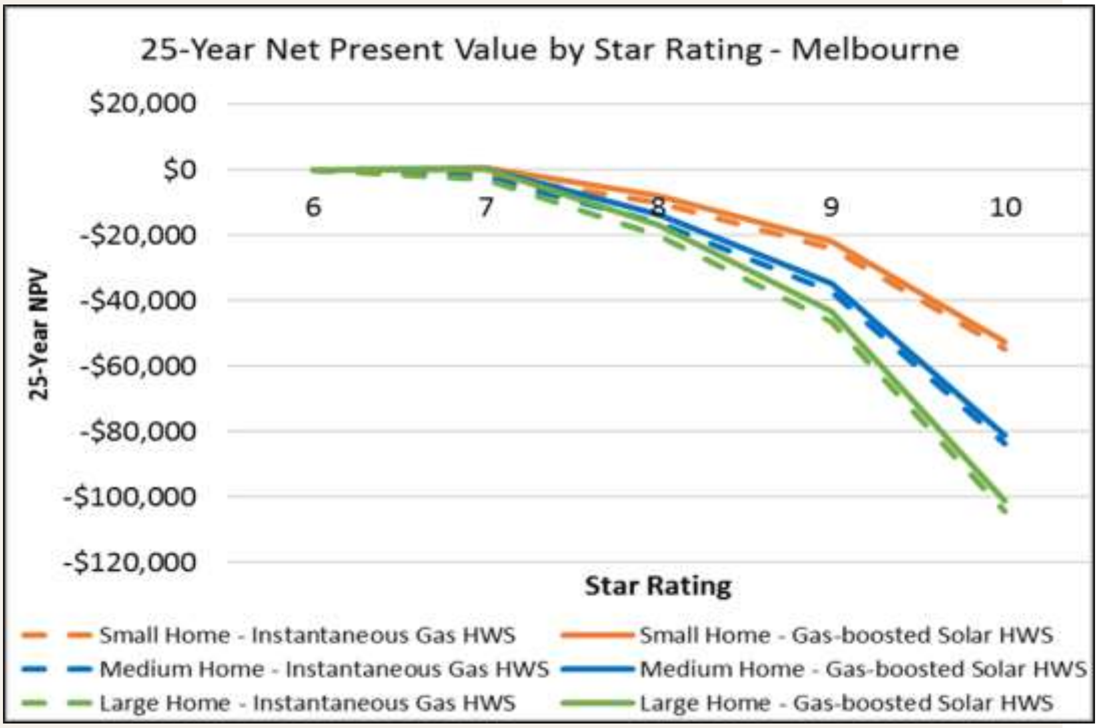

Figure 37: 25-Year NPV by Star Rating/Size, Dual Fuel Home, Melbourne, no Solar PV (7% Discount, High Build Cost Premium)

5.2.7. Value of All-Electric versus Dual Fuel Appliance Mix

Figure 38 shows the 25-year NPV of Medium sized all-electric homes versus dual fuel homes, with no solar PV, in Melbourne by Star rating and build-cost premium.

The purpose of this chart is to demonstrate the value of the appliance mix in isolation from solar or Star rating:

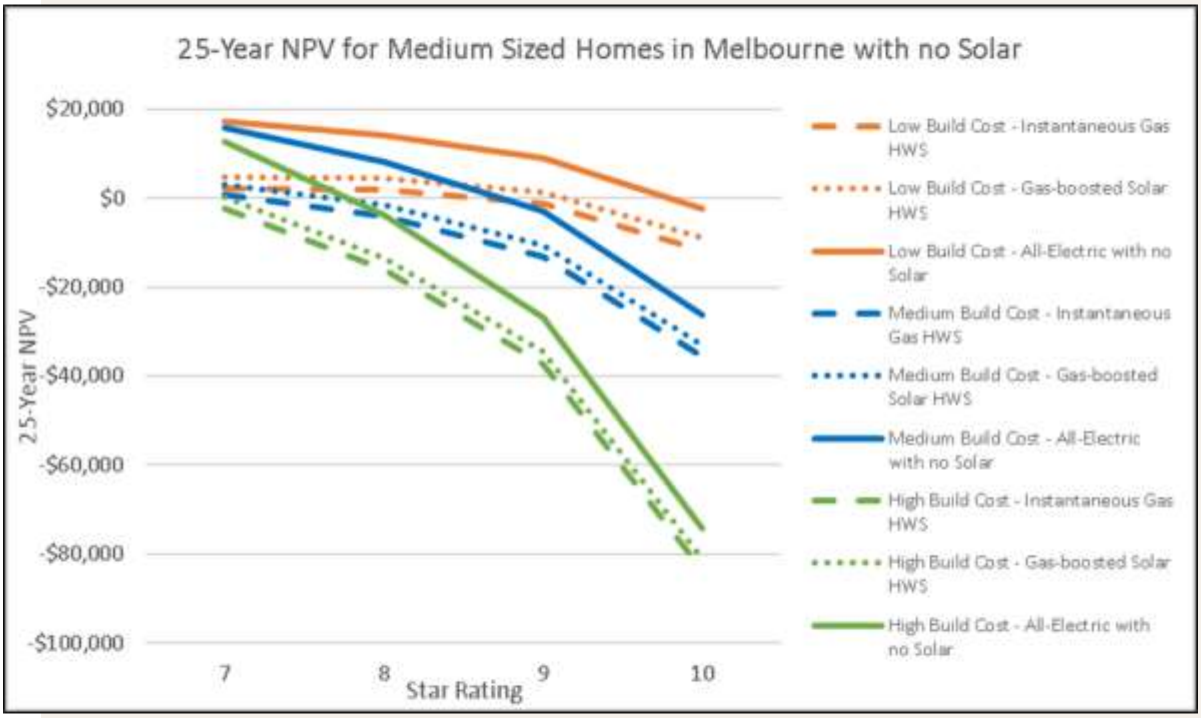

Figure 38: 25-Year NPV of All-Electric versus Dual Fuel Home, Melbourne, no Solar PV (7% Discount, Medium Build Cost Premium)[71]

As can be seen, at each Star rating level, and for each build-cost premium, the all-electric appliance mix delivers a higher 25-year value than the Base Case dual fuel homes. This value reduces in line with the higher the Star rating of the dwelling.

[71] Compared to 6-Star gas-boosted SHW home.

5.3. Net Present Values (10-Year Horizon)

This section presents the results of the 10-year NPVs for each household type. The charts demonstrate positive or negative values over the relevant time period, considering all capital, operational and replacement costs, bill savings and the discount rates, as compared with the Base Case, 6 Star dual fuel home.

The key aspect of the 10-year NPVs in the modelling (as distinct from the 25-year NPVs) is that they are not influenced by any replacement capex (as no appliance is partially or wholly replaced prior to Year 11). The charts are again presented by location and household size and consider the build cost premium sensitivities (low, medium and high).

5.3.1. Melbourne Results

Figure 39 shows the 10-year NPVs of the solar all-electric homes in Melbourne assuming the medium build-cost premium. As can be seen:

- At both 6 and 7 Stars, the Small, Medium and Large homes offer in the order of $10,000 of value over 10 years;
- At 8 Stars, the Small Home offers approximately $5,000 of value; whilst the Medium and Large homes only just pay for themselves within 10 years;
- No 9 or 10-Star homes of any size pay for themselves within 10 years, with all bar the Small 9 Star home costing the owner more than $10,000 over 10 years as compared with their dual fuel counterparts.

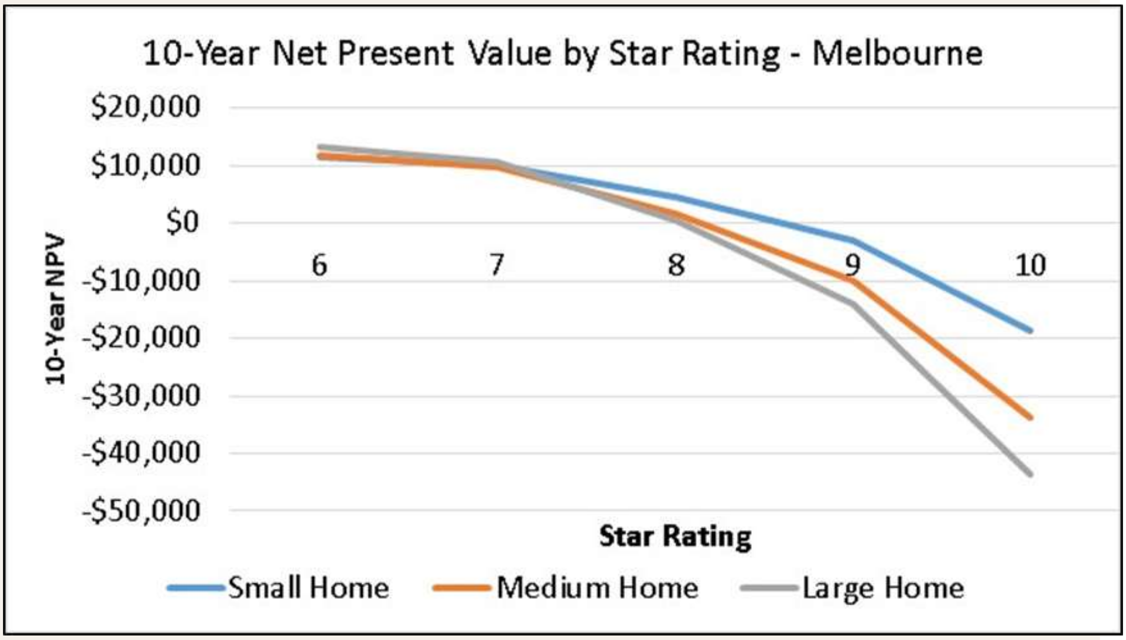

Figure 39: 10-Year NPV by Star Rating/Size, Solar All-Electric Home Melbourne (7% Discount, Medium Build Cost Premium)[72]

[72] Compared to 6-Star gas-boosted SHW home.

Commensurate increases and decreases in the 10-year values can be seen using the low and high build-cost premium for the solar all-electric homes in Melbourne:

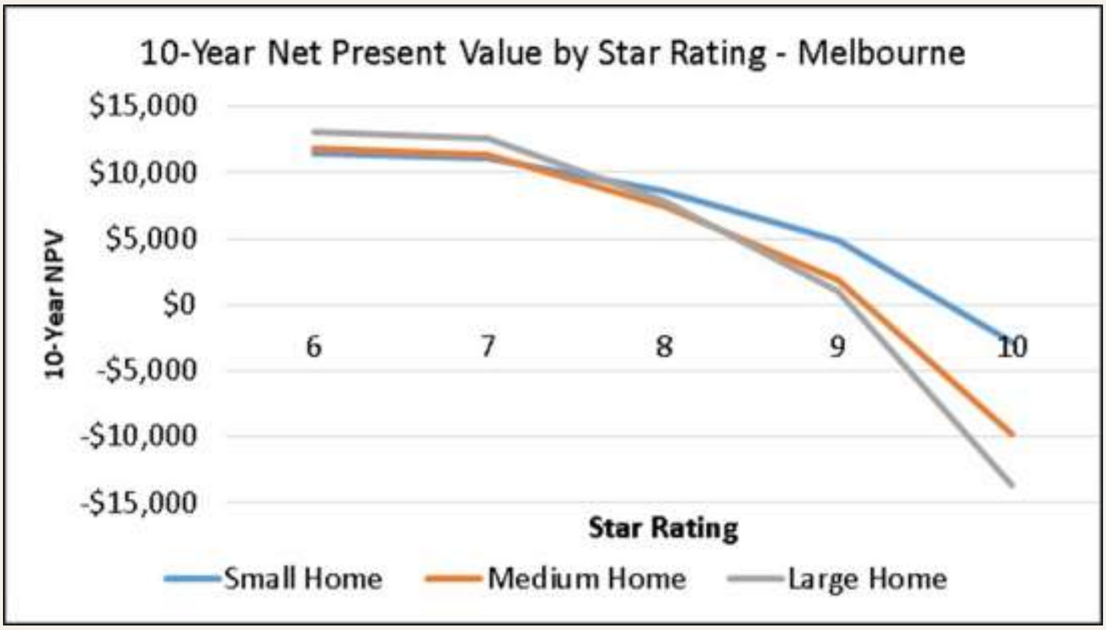

Figure 40: 10-Year NPV by Star Rating/Size, Solar All-Electric Home Melbourne (7% Discount, Low Build Cost Premium)[73]

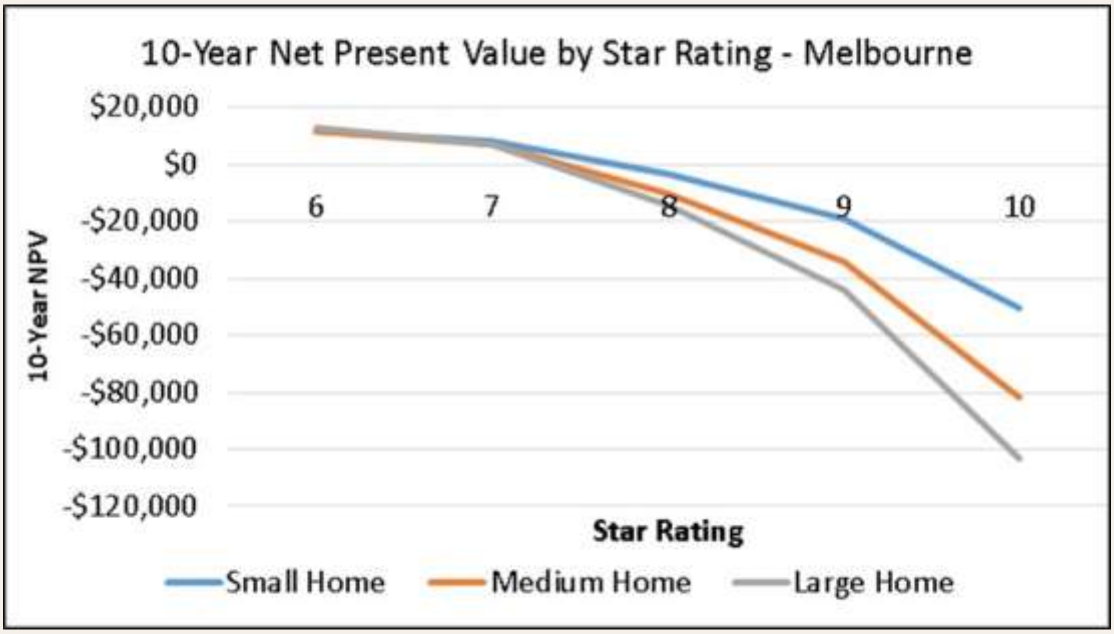

Figure 41: 10-Year NPV by Star Rating/Size, Solar All-Electric Home Melbourne (7% Discount, High Build Cost Premium)[74]

[73] Compared to 6-Star gas-boosted SHW home.
[74] Compared to 6-Star gas-boosted SHW home.

5.3.2. Melbourne Results (4% Discount Rate)

Once again, using a more realistic cost of household finance (i.e. 4%), this materially increased the 10-year NPVs in Melbourne (in the order of $1,000 to $2,000 for each Star level):

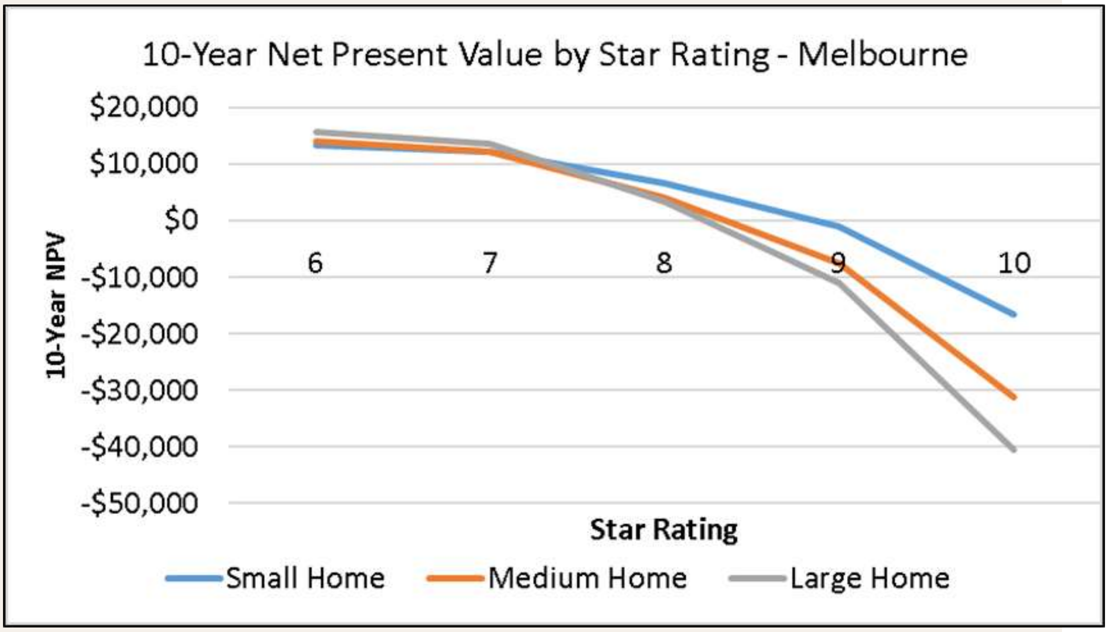

Figure 42: 10-Year NPV by Star/Size, Medium Build Cost Premium, Melbourne (4% Discount)[75]

[75] Compared to 6-Star gas-boosted SHW home.

5.3.3. Value of Solar PV

Once again, the value of solar PV is significant within the 10-year NPV timeframe. Figure 43 shows the 10-year NPVs of the all-electric homes in Melbourne without solar PV, assuming the medium build-cost premium. Not having solar reduces the 10-year NPVs by between $6,200 and $9,700, depending on home size and Star rating, as compared to those homes with solar in Figure 39 above:

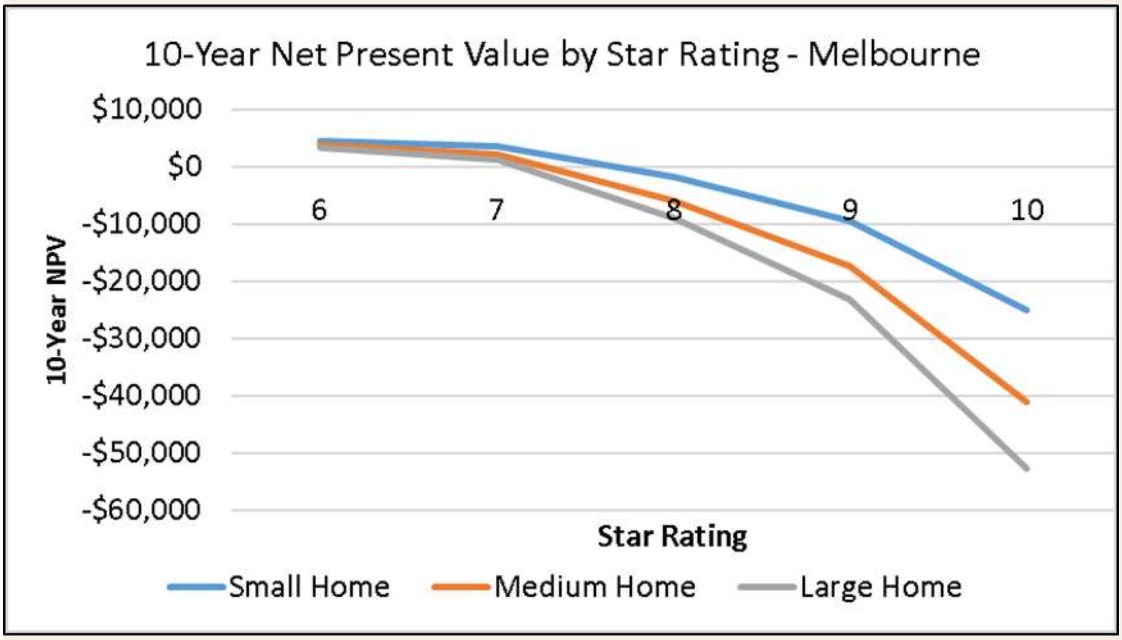

Figure 43: 10-Year NPV by Star Rating/Size, All-Electric Home Melbourne (7% Discount, Medium Build Cost Premium, No Solar)[76]

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[76] Compared to 6-Star gas-boosted SHW home.

5.3.4. Value of Building Efficiency Upgrades

The following charts isolate the 10-year value of the building efficiency upgrades only – by comparing higher efficiency dual fuel homes (without solar PV) with the Base Case 6-Star dual fuel homes.

After 10 years, none of the 7 to 10-Star dual fuel homes offer any meaningful value, as compared with the Base Case 6-Star dual fuel homes[77]. Results are significantly negative above 8-Stars:

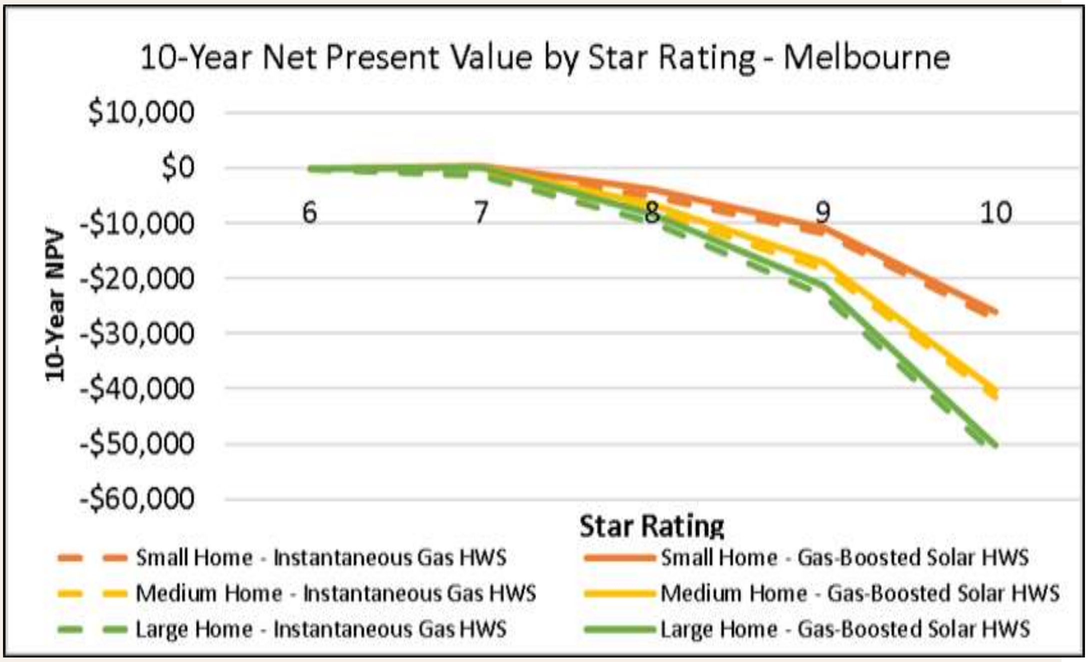


Figure 44: 10-Year NPV by Star Rating/Size, Dual Fuel Home, Melbourne, no Solar PV (7% Discount, Medium Build Cost Premium)[78]

[77] At 7-Stars, there is a slightly positive NPV for all sized homes with gas-boosted SHW; and a slightly negative for all homes with gas instantaneous hot water.
[78] Compared to 6-Star gas-boosted SHW home.

6. Key Findings

From the Results chapter, a few key findings emerge:

1. Whether analysed by payback time or NPV, new 7 to 8-Star all-electric homes with solar PV are highly economically attractive as compared with new 6-Star dual fuel homes in Victoria.

   The main exceptions to this are:

   - 8-Star homes with a high build-cost premium (i.e. above $24,000), as these tended between 14 and 20+ year paybacks and only marginally positive NPVs after 25 years); and

   - 9-Star homes with a low build-cost premium (which achieved less than 10-year paybacks for all scenarios and marginally positive NPVs after 10 years).

2. Solar PV makes a significant difference to the economics of higher efficiency and/or all-electric homes, when compared against dual fuel homes.

   At the more economically attractive Star rating levels (i.e. 7 and 8-Stars), all-electric homes with solar PV:

   - had energy bills between $1,300 and $1,600 per year lower than their 6-Star dual fuel counterparts; and

   - added in the order of $10,000 to the 25-year NPVs.

   Solar PV also has the ability to significantly reduce the annual energy bills of dual fuel homes. However, these cannot be as significant as the same sized solar PV system on an all-electric home, due to:

   - the lower energy bills of all-electric homes (without solar PV) as compared to dual fuel homes (without solar PV); and

   - the ability of an all-electric home to directly consume more solar PV generation on-site than a duel fuel home (offsetting a higher consumption tariff than would be otherwise earned under a lower feed-in tariff).

   Ultimately the benefit of solar PV to a duel fuel Victorian home, when compared to an all-electric home, is a slightly smaller saving off a slightly higher bill.

3. The value of higher building efficiency (in isolation from solar PV or appliance mix) is of less significance than solar PV, and also reduces in line with greater efficiency/higher Star ratings.

   Figure 45 shows the annual energy bill savings between each Star rating level. As can be seen:

   - material savings are achieved for the 7-Star dual fuel home versus the 6-Star Base Case homes (~$400 per year):
     - this reduces to around $275 per year between 7 and 8-Stars; just under $200 between 8 and 9-Stars; and just over $100 between 9 and 10-Stars;
   - 6 to 7-Star savings are considerably less for the all-electric (no solar PV) home (~$180) as these homes use significantly less input energy with their more efficient appliance mix at all Star rating levels:
     - this trend again reduces to around $140 per year between 7 and 8-Stars; $85 between 8 and 9-Stars; and $60 between 9 and 10-Stars;

   These results suggest that building to at least 7-Stars (and potentially 8-) is of greater importance for dual fuel homes where solar PV cannot be installed due to technical reasons.

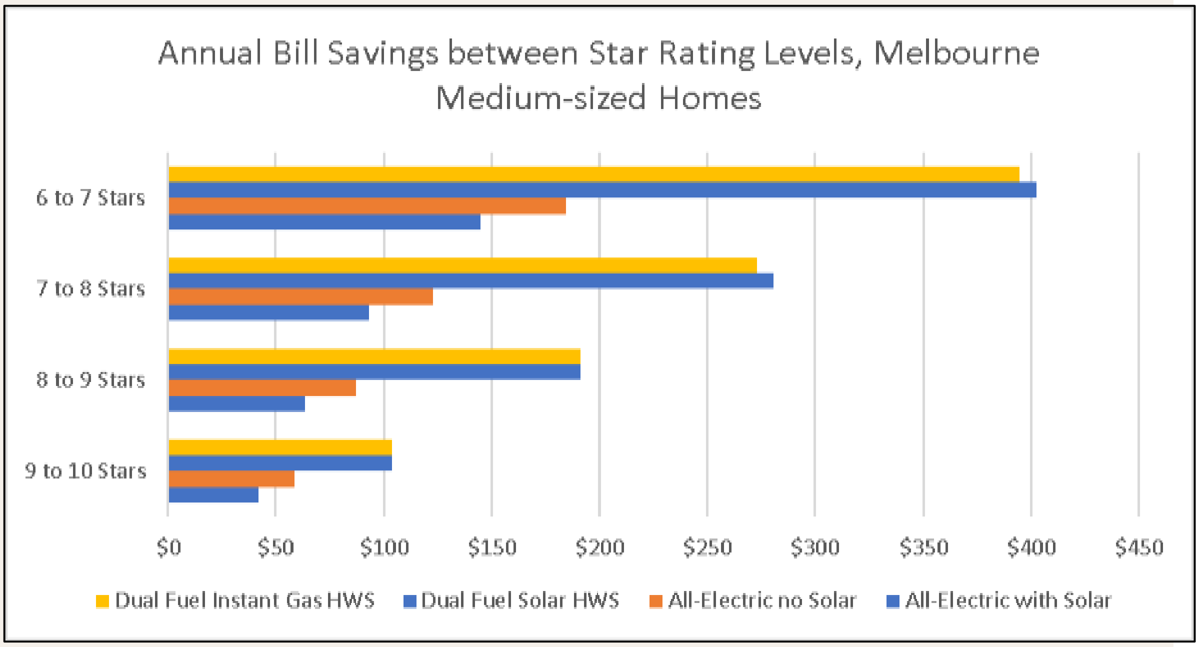


Figure 45 Annual Bill Savings between Star Rating Levels, Medium Home, Melbourne

4. An efficient all-electric appliance mix will provide materially higher economic value over time than a dual fuel appliance mix (in isolation from higher building efficiency or solar PV) for 6 to 10 Star homes.

6.1. Limitations & Further Work

As with all modelling, there are limitations to the analysis undertaken for this project. This section discusses these limitations and further work that would be useful to strengthening the accuracy of the results.

6.1.1. Variability in Household Loads

One of the challenges with this type of analysis is trying to ensure that a majority of household types and loads have been considered.

Currently, there exists no central database or repository of annual household loads for dual fuel or all-electric homes, new or existing, for Victoria or anywhere else in Australia. Whilst retailers and distribution business have this data collectively, they are restricted by both geographic boundary or market share, and do not often publish aggregated load data in useful formats. As such, the DHHS survey was the closest source to representative dataset that Renew could use to inform the annual loads.

The DHHS Survey relied on a combination of a household survey and billing data – provided by energy utilities and Local Councils that was linked to each household in the respondent survey.

DHHS acknowledge a number of limitations of their approach. The most relevant limitations in the context of this project are related to the collection of billing data, as outlined below:

- Whilst survey data was collected in mid-2015, billing data from utilities was obtained for each household for the 2014 calendar year and for councils for the 2013-2014 financial year. As such, there is a time lag between survey data and billing data.

- Data provided by utilities and councils was thoroughly checked to ensure that data was provided for each item collected (in particular, consumption items, charges, retailer discounts and concessions). The agencies were instructed on how to complete these data files.

  Where data files provided had gaps, suppliers were contacted directly to ascertain whether that data item was in fact blank or not for their agency. In some cases, Roy Morgan Research needed to edit the billing data provided to make it consistent with the formats and definitions required. It is also possible that some errors may have occurred in suppliers' data-matching and extraction processes, errors which are not evident by such checking.

- Missing data, either for an entire record (e.g. for a household's entire electricity billing) or for just a small component of a record, was imputed by Roy Morgan Research following a set of imputation rules (detailed later in this report). The imputation process is likely to have slightly reduced the variation in the data, as imputation is based on applying the *mean* result for similar sized households in similar areas.

Despite this, this project has sought to cover a significant range and number of scenarios with regard to household type and annual loads. Overall, 255 individual household loads were modelled (across the three different appliance mixes and five Star rating levels), with the lowest and highest end of the ranges captured in the following table:

	6 STARS – SMALLEST HOME		6 STARS – LARGEST HOME	
Energy Use p.a.	MWh	GJ	MWh	GJ
Ae	3.39	0.00	9.58	0.00
Gb	1.51	26.30	5.00	100.31
Gi	1.51	32.48	5.00	109.44
Energy Use/day	kWh	MJ	kWh	MJ
Ae	9.29	0.00	26.25	0.00
Gb	4.14	72.05	13.70	274.82
Gi	4.14	88.99	13.70	299.84

Table 31: Annual Loads – Smallest & Largest Homes Modelled, 6-Stars, All Locations

Ultimately, a comprehensive repository of annual household loads for dual fuel and all-electric homes, new and existing, Australia-wide, would be invaluable for further analysis of this kind.

6.1.2. Tariffs

As noted in Section 3.1, a relatively simple approach to tariff selection was used for this project, which sought to reflect tariff prices that most energy consumers face in each location.

Retail electricity tariffs for residential customers are becoming increasingly complex – most notably in Victoria, given the existence of smart meters. Two- and three-part time of use tariffs exist on a volume (i.e. kilowatt-hour) basis, in addition to the recent emergence of demand tariffs – that charge based on maximum demand levels (i.e. kilowatts).

Retail tariffs in Victoria are emerging that include a mixture of volume, demand and fixed charges, with differing approaches to volume blocks, demand monthly reset and discounting. It has been noted by some that over 4,000 residential offers currently exist in the Victorian retail electricity market.

A greater range of tariff prices and structures should be included in future modelling, to further understand the impact of different tariffs on economic outcomes.

6.1.3. Build-Cost Premium

One of the key learnings of this work is the lack of useful, publicly available data on:

- the industry-wide costs (actually faced by the home buyer/consumer) to build to higher levels of energy efficiency; and
- the potential of design to alleviate any build-cost premium.

This information gap is considered to be the most significant limitation to the accuracy of the findings of this work.

More work with industry is required to understand the real costs likely to be faced by consumers, including:

- the benefit of volume-purchasing from large builders and across the industry; and
- cost improvements from industry learning rates (e.g. labour time-saving).

6.1.4. Storage

Whilst not yet economically attractive in most situations in Victoria[79], grid connected residential energy storage is falling in cost and will soon become economic for a significant number of households.

In addition, with an all-electric appliance mix, the battery (just as with the solar PV) has the opportunity to supply more of the house load – leading to improved economic outcomes.

Residential energy storage also has the ability to overcome some of the key technical issues[80] that are likely to increase in Victorian distribution networks from the uptake of solar PV in the new few years.

On this basis, energy storage should be assessed in any future modelling work in order to fully understand its value, both to the consumer and potentially to the electricity network, in the context of new efficient residential dwellings.

[79] i.e. it is currently difficult to achieve a payback within the asset life of a residential battery in Victoria for most household types and load profiles.
[80] In particular, voltage rise.

6.2. Peer Review

As part of the development of this work, the analysis and findings were externally "peer" reviewed by Mr Bruce Mountain from Carbon Market Economics (CME).

Bruce is a Melbourne-based energy economist with 26 years' experience in this field. His specialisms are in the economic regulation of networks and in the design of electricity markets and renewable energy policies. He has worked mainly in Australia, Britain and South Africa but has undertaken assignments in numerous other countries.

Bruce has a Bachelor's degree in Electrical Engineering and a Master's degree in Power Systems Engineering from the University of Cape Town, a PhD in Economics from Victoria University and is qualified as a Chartered Management Accountant in England.

The entire feedback from the peer review is contained under a separate letter to this report (dated 10th December 2018). This is outlined, along with suggestions for further work, below.

Specifically, CME addressed the following questions in their peer review:

- Whether the structure of the analysis was reasonable;
- Robustness to tariff assumptions; and
- Reasonableness of the main findings.

CME responded to each of these as follows:

Whether the structure of the analysis is reasonable

We understand that the objective of the analysis is to assess the relative financial position (to households) of:

- Reducing energy consumption by improving a property's energy (star) rating;
- Becoming all-electric); and
- Installing solar photovoltaic (PV) systems.

The analysis is built on a comparison of two different "base cases" (both dual fuel and one with gas-boosted solar hot water) and four different alternatives (with various combinations of technologies for space conditioning, water heating, cooking and with/without PV).

The analysis trades off the capital and operating costs of the various alternatives against the present value of the consequential annual energy costs to work out the net present value and pack-back periods.

While conceptually straight-forward the analysis quickly becomes extremely complex and detailed as different locations, household types and building energy ratings are considered and the ATA's space conditioning, water heating and PV models are applied.

The main advantage of this approach is that fully-worked up cases with different combinations of appliance and house energy rating are compared to the base case. The disadvantage is that the worked-up counter-factuals (and indeed the base cases) needs to be limited to ensure a tractable analysis.

In addition, the complexity and detail of the analysis and the level of subject matter knowledge required in each area means that it is extremely difficult to audit or test. Comprehensiveness therefore inevitably comes at the expense, to some degree, of objectivity.

In further development of this work, other approaches might be considered. Thinking through the technologies and their economics, we identify three largely separable dimensions of the underlying economics in this study:

1. Fuel substitution: this relates mainly to the technology for space heating (split system versus gas ducted) and also, but to a lesser degree, water heating (air source heat pump versus gas boosted solar or gas instantaneous) and cooking (induction versus gas).

2. Decentralised production: the installation of rooftop photovoltaics to substitute for grid supply.

3. Improved energy efficiency: the property's energy rating and the effect this has on the consumption of energy in space conditioning.

The economics, to a household, of some choices here are affected by others. For example, the merits of investing in a fixed size (5 kW) PV system will be worse in more efficient houses than less (because less grid-supplied electricity is replaced). It may nonetheless be attractive to invest in smaller PV systems in more efficient homes. The analysis does not cater for this.

However, some choices are independent (or largely independent) of others. Specifically:

1. The merit of split systems for space conditioning (rather than gas ducted) or induction (rather than gas) for cooking is independent of the installation of PV or the efficiency (energy rating) of the property.

2. The merit of heat pumps for water heating (rather than gas-boosted solar or gas instantaneous) will be affected by the installation of PV (assuming a diverter is installed) but the effect will be second-order and the relative gap between water heating technologies is not big. In addition, the selection of water heating technology will not be affected by the property's energy rating.

Bringing this together, it might be possible to construct a simpler and perhaps more informative analysis along these lines:

1. An analysis of water heater economics independent of building energy rating and perhaps also installation of PV.

2. An analysis of space conditioning economics and cooking economics independent of building energy rating and perhaps also installation of PV.

3. An analysis of building energy rating taking account of the existence (or not) of PV (of various sizes) and assuming the most efficient space conditioning technology (split system)

Such an analysis, we suggest, may deliver more targeted conclusions and would reduce complexity by separating those aspects that are independent of others, from those that depend on each other. It would also allow for a deeper understanding of the economics of improved building energy ratings and how this economics would be affected (and vice versa) by the installation of PV systems of various sizes.

Robustness to tariff assumptions

The electricity and gas prices chosen in this analysis are around the prices that we think are paid, on average. However, we know that price dispersion in Victoria is high and there will be a substantial number of customers who pay prices that are much lower or much higher than the average.

The analysis will be significantly affected by the assumed electricity and gas prices. As such, the analysis might be considered to be representative of the "average" customer. However, considering the sensitivity of the analysis to electricity prices we suggest it will be helpful to consider incorporating electricity and gas price sensitivities.

Reasonableness of the main findings

We understand that the main findings of this report are as follows:

1. With a few exceptions, an all-electric house built to 7 or 8 star energy rating plus PV is likely to cost less to build and operate than a dual-fuel 6 star house. The main gain comes from the PV system.

2. Where PV is not available, it is still advantageous to improve the energy rating to 7 or 8 stars.

3. All-electric homes are cheaper to develop and operate regardless of building energy rating or the installation of PV.

The first finding reflects the large gains to be had in substituting grid-supplied electricity (with a variable charge of around 32 cents per kWh) with PV-supplied electricity with an average price of around 6 cents per kWh. Such a large price difference offers a financial gain as long as there is sufficient volume of grid-supplied electricity to be displaced.

The second finding reflects the cost and efficiency of split system cooling / heating relative to gas heating and it is this factor mainly that underlies the benefit of an all-electric household versus a dual-fuel household in all cases.

The final finding on higher building energy rating reflects the relatively insignificant cost of higher ratings, at least from 6 to 7 or 8 stars.

Considering these economics, the main findings are reasonable and to be expected.

However, we do not think the discount rate is reasonable. The analysis assumes a 7% real discount rate, with a sensitivity of 4%. We think this rate is too high. The analysis is a "financial" analysis from a home-owner's perspective. But homeowners finance their homes (and effectively also related fixed appliances) using mortgages secured against those homes.

This delivers finance that for the last five years costs around 1 to 2% real per annum for a typical homeowner. A 7% rate suggests that homeowners will finance assets that affect the energy consumption of their house using unsecured personal loans. This is not realistic.

Furthermore, the analysis does not value other benefits of home energy rating improvements and PV installation. Such benefits include:

- Longer building life associated with higher quality building construction which is generally associated with houses with higher energy rating.
- The value that many households will associate with reduced greenhouse gas emissions arising from lower grid-sourced electricity volumes.
- The comfort of a home better able to ride through out-door temperature variation without the need to resort to artificial heating or cooling, with its associated noise pollution and forced air movement.

On the basis of our earlier observation and taking these additional benefits into account, we suggest that a real discount rate of 1% (real) would be appropriate, with a sensitivity at zero percent.

Suggestions for future development

In addition to the earlier discussion on approach we suggest consideration might be given in the following three areas.

- Statistical and econometric analysis

Ideally the value of higher building energy ratings, electricity-only homes, different water heating technology and PV can be established through econometric analysis of customers' energy bills. This is not possible now with data in the Victorian Utility Household Consumption Survey. A specific survey will need to be developed for this. The advantage of an econometric analysis over the current approach is that it offers the prospect of stronger objectivity.

- Clarifying the changes from 6 to 7 or 8 star

The costs and benefits associated with PV and split system air-conditioners can be established since the technology and costs are well defined. It would be valuable to define more clearly what the incremental changes might be in raising household energy rating from 6 to 7 to 8 stars.

- Technology change

Technology development in the areas covered in your study is rapid. From the time of an analysis to the establishment of a policy and then its implementation through revised regulations, technology (and costs) are likely to have changed significantly. It would be valuable in the economic assessment to be able to anticipate this in projecting how conclusions might be expected to change over a future five-year period.

7. Appendix A: Heating & Cooling

The objective of the heating and cooling model for this project was to produce plausible daily heating and cooling loads that are sensitive to ambient temperature, household size and occupant behaviour, and are reasonable at the annual aggregate level, for the purposes of modelling energy bills.

Ultimately the same heating and cooling loads on an annual, output megajoule (or “delivered heat”) basis are applied whether the scenario involves gas or electric heating appliances. Relevant gas and electric appliances are then selected to serve that heating load (the cooling load is only supplied by reverse cycle air conditioning in all cases).

7.1. Analysis of Climate/Temperature

The objective of the heating and cooling model for this project was to produce plausible daily heating and cooling loads that are sensitive to ambient temperature, household size and occupant behaviour, and are reasonable at the annual aggregate level, for the purposes of modelling energy bills.

Ultimately the same heating and cooling loads on an annual, output megajoule (or “delivered heat”) basis are applied whether the scenario involves gas or electric heating appliances. Relevant gas and electric appliances are then selected to serve that heating load (the cooling load is only supplied by reverse cycle air conditioning in all cases).

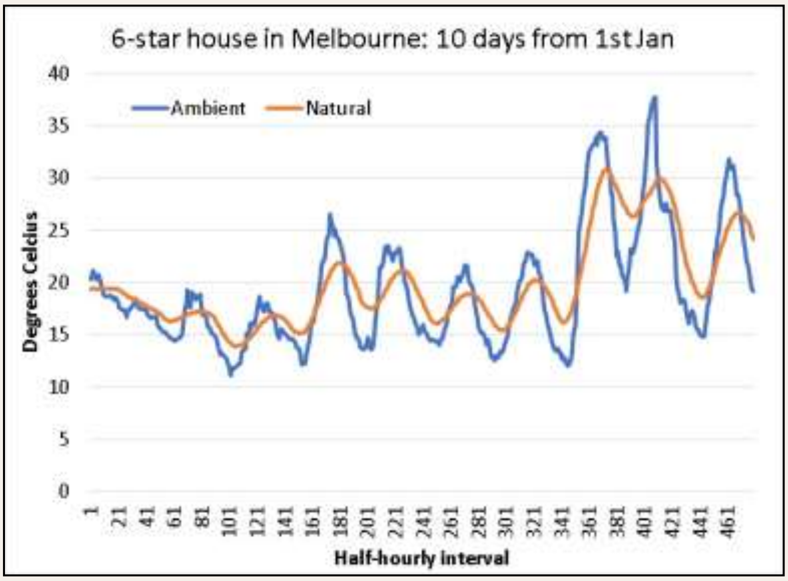


Figure 46 Moving Average of the Ambient versus Natural Indoor Air Temperature

SET POINTS	SETTINGS
Ideal indoor temperature	24.0 degrees C
Degrees tolerated below ideal, before turning on heater	2.0 degrees C
Degrees tolerated above ideal, before turning on cooling	1.5 degrees C
Degrees tolerated before heating during sleeping hours	2.5 degrees C
Degrees tolerated before cooling during sleeping hours	1.0 degrees C
When do occupants go to sleep?	22:00
When do occupants wake up?	07:00
Degrees per Star to decrease natural indoor temp, when above ideal	0.4
No. of half-hour intervals to reach target indoor temperature	4
No. of half-hour intervals to maintain the target temperature	4
No. of half-hour intervals to for indoor temp to revert to base, per star	0.50
Intervals of moving average for natural indoor temperature per star	5

Table 32 Acclimatised Ideal Temperature Settings, Heating & Cooling Model

For each 30-minute interval, the ambient temperature and the simulated indoor air temperature is tracked. The simulated indoor temperature is different to the "natural" indoor temp when the heating is affecting it.

The divergence between the current indoor temperature and the ideal temperature is calculated, allowing for the tolerance ranges.

7.2. Application of Air Conditioners

A heating and cooling load is then generated by the application of specifically sized reverse cycle air conditioners (RCACs) to keep the target indoor temperature within a comfort band. Once generated, the heating load as served by the RCACs is then applied to gas space heaters (in this case, gas ducted systems), considering gas space heater performance, to generate an annual gas load.

The table below shows the number and sizing of RCACs by home type. Essentially, one large RCAC was assumed for the living space in each sized home, whilst each of the bedrooms were supplied by smaller, individual RCAC units. It was assumed that other spaces (e.g. study, bathrooms) were not supplied by individual RCAC units:

ROOM		SMALL	MEDIUM	LARGE
Living Space	Heat/Cool Output (kW)	5.0	6.5	8.0
Bedroom 1	Heat/Cool Output (kW)	2.5	2.5	2.5
Bedroom 2	Heat/Cool Output (kW)	2.5	2.5	2.5
Bedroom 3	Heat/Cool Output (kW)		2.5	2.5
Bedroom 4	Heat/Cool Output (kW)			2.5

Table 33 RCAC Number & Sizing by Home Type

The table below shows the efficiency and standby power consumption of the RCAC units:

	LIVING SPACE	BEDROOM
Heat CoP (Test Conditions)	4.2	4.9
Cool EER (Test Conditions	4.1	6.2
Standby power consumption (watts)	10	5
Efficiency (e.g. ducting losses, excludes COP/EER)	95.0%	95.0%

Table 34 Efficiency & Standby Power Consumption of RCACs

The table below shows the timer settings for each of the RCAC units, whether they are situated in a living space or bedroom:

	LIVING SPACE	BEDROOM
Time the heater can turn on, for weekdays.	07:00	06:00
Time the heater must turn off, for weekdays.	09:00	08:00
Time the heater can turn on, for weekdays. 2nd period.	15:00	20:00
Time the heater must turn off, for weekdays. 2nd period.	22:00	23:00
Time the heater can turn on, for weekends.	07:00	06:00
Time the heater must turn off, for weekends.	22:00	08:00
Time the heater can turn on, for weekends. 2nd period.		20:00
Time the heater must turn off, for weekends. 2nd period.		23:00

Table 35 Timer Settings by Living Space/Bedroom Units

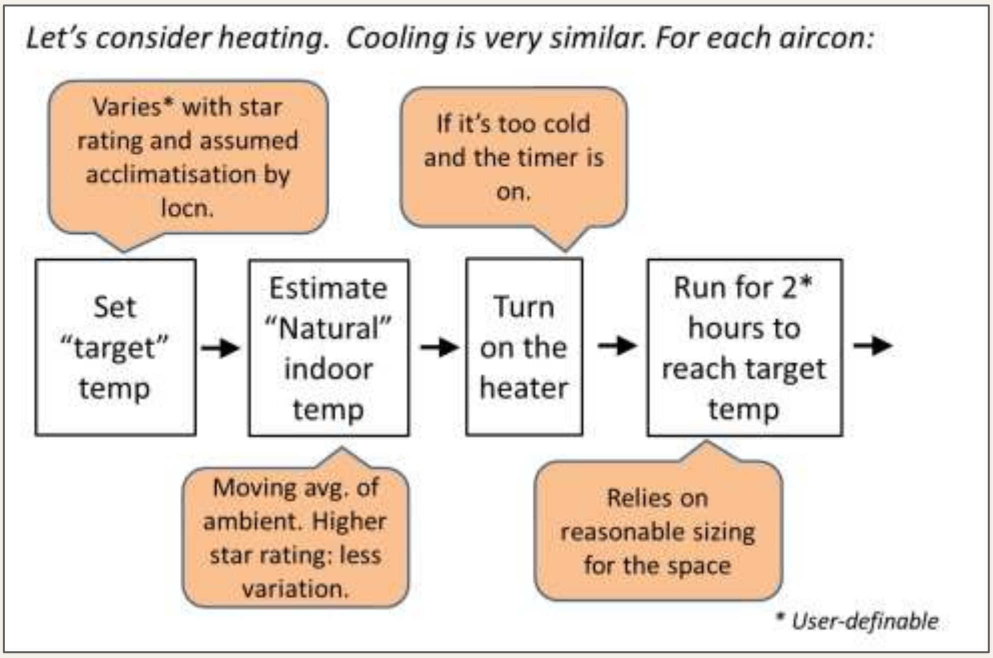
The air conditioner is then turned on if the model is within the timer settings and the indoor temperature is outside the target, considering the tolerance range.

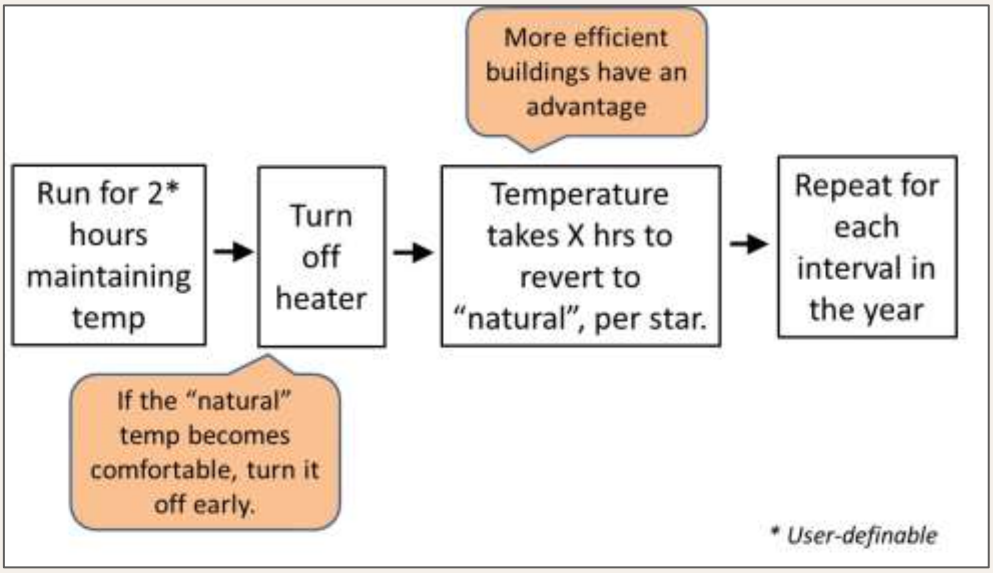
While on, the RCAC aims to bring the internal temperature to the target temperature.

The RCAC is turned off if the natural temperature reaches target. The model assumes it takes 2 hours to reach the target temperature. After that:

- the RCAC will stay on for 2 hours, maintaining the temperature (the "maintenance" phase); and then
- the RCAC will turn off, and the inside temperature will ramp down to the "natural" indoor temperature, taking 0.5 hours per Star rating of the building.

Figure 47 Flow Chart Logic, Air Conditioning Control





The RCAC output power level varies during the heating / cooling cycle. The model assumes that during the "maintenance" phase, it only has to run at "steady state" power:

- this is assumed to be 13% of its rated maximum power level for a 5-star home and 5-degree temp diff inside-outside;
- the power level required varies by star rating and temperature differential.

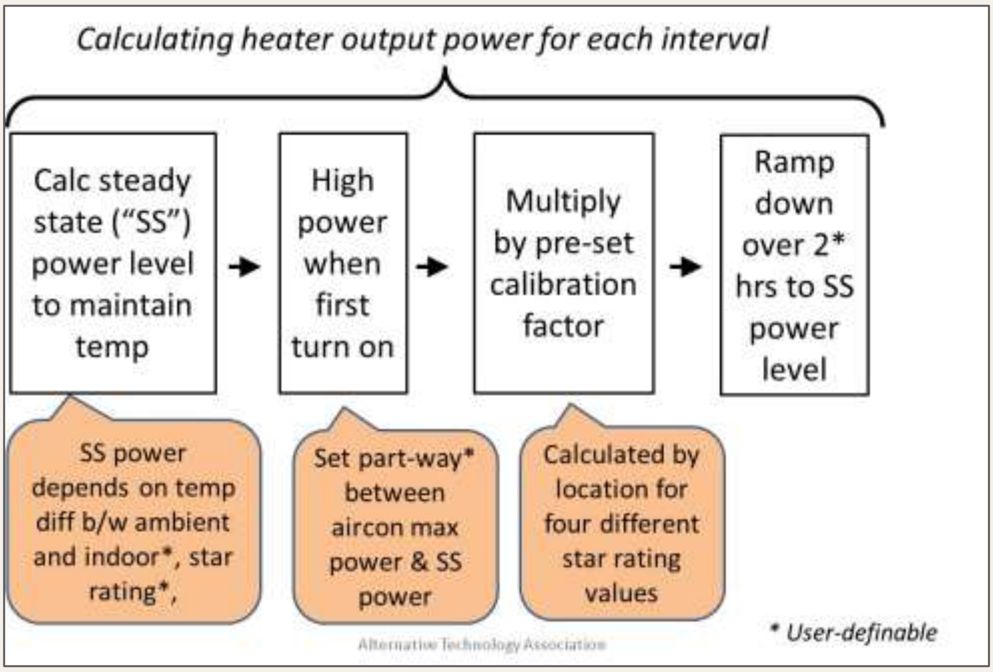


Figure 48 Flow Chart Logic, Air Conditioning Energy Usage (1)

The model assumes that for the first interval when the heater turns on, it runs close to maximum power. It then ramps down to "steady state" power during the temperature ramp-up.

The input power required by the heater is then multiplied by its co-efficient of performance (CoP) and efficiency. The new indoor temperature is then estimated at the end of the interval.

Renew's heating model does not do a full "energy balance" (as compared with heating/cooling software such as FirstRate, AccuRate etc), but mimics that behaviour. It is checked against the NatHERS annual MJ/m2 results by climate zone by comparing them with the Renew model at NatHERS occupancy and set point assumptions and determining a calibration factor (see Section 7.4).

Appropriate specifications for the size and efficiency of relevant gas and electric appliances are then applied and determine the resultant import fuel requirement from the gas or electricity grid (or solar, in the latter case).

Multiple reverse cycle air conditioners (RCACs) are selected, each defined separately for thermostat and timer settings. It is assumed the multiple RCACs serve heating and cooling loads in different parts of the home.

The model also allows for standby power of the RCACs (e.g. the crank-case heater). This is allocated to either the cooling or heating load, whichever is dominant for any scenario.

7.3. Efficiency Calculation

The COP for heating and EER for cooling varies by ambient temperature. To allow for this, the Renew model refers back to the standard test conditions used to state heating/cooling appliance COPs/EERs (e.g. inside 20 degrees, outside 7 degrees for H1 heating).

The difference between the natural and simulated indoor temperature is used to calculate the operation of the units. In the absence of published data by air conditioner model, this is estimated using thermodynamics. First the maximum theoretical COP/EER is calculated for the standard test conditions. Since this is 20 degrees indoors and 7 degrees ambient, the maximum theoretical COP/EER can be calculated as:

- CoP/EER = Tout/(Tin-Tout):
- i.e. 7 + 273.15) / (20-7). This equals 21.55.

From here the rated COP/EER performance percentage is calculated by dividing the COP/EER (user input) by the theoretical COP at standard test conditions.

Next the theoretical maximum COP/EER is calculated based on current conditions for ambient and indoor temperature. Then the actual COP/EER under current conditions is calculated by multiplying the theoretical maximum COP/EER by the rated COP/EER performance percentage. Since this theoretical approach can give unrealistically high results in milder conditions, finally the result is restricted to a maximum COP/EER of 8.

The next step in estimating the COP/EER is to consider the impact of part-loading; air conditioners are more efficient when they're running below full power. The percentage power is calculated by dividing the current running power (estimated as described above) by the unit's rated power.

Then the increase in COP/EER due to the partial loading is calculated by comparing this percentage power against the user-defined increase when the unit is operating at 50% power. For this project this value is 15%. This is converted to a value per percentage point and multiplied by 1 minus the percentage power. Again, the COP/EER is restricted to a maximum of 8.

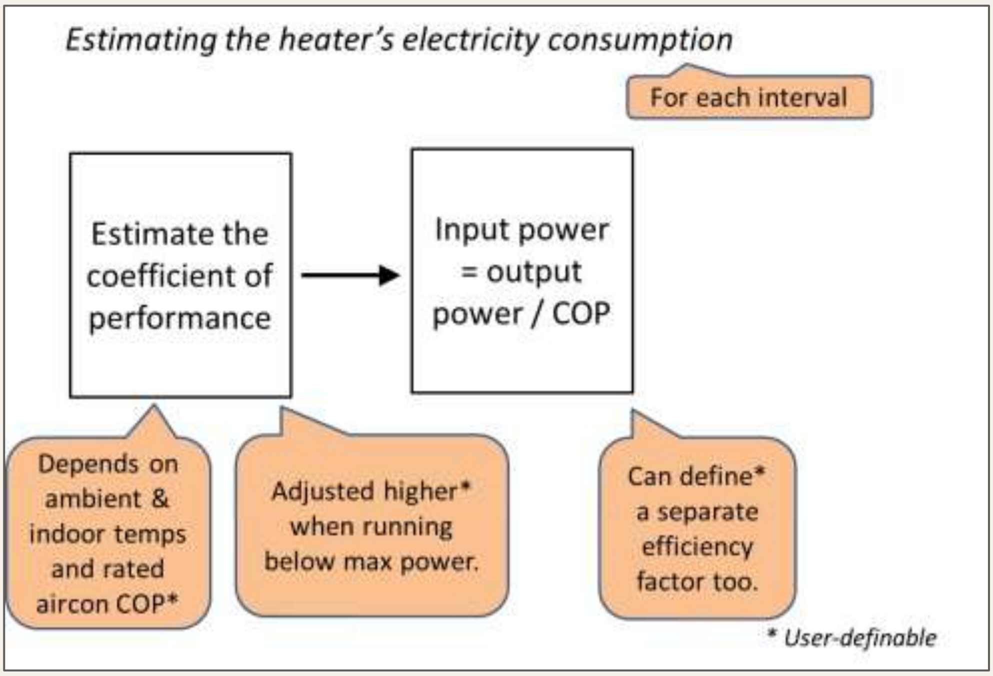


Figure 49 Flow Chart Logic, Air Conditioning Energy Usage (2)

7.4. Calibration

The annual heating and cooling loads predicted by the Renew model are then calibrated back to the NatHERS star rating bands.

The NatHERS bands quantify an annual megajoule per square metre (MJ/m2) heating and cooling load, by building star rating, for 66 locations around Australia[81]. To calibrate, Renew set up the model to mimic the same occupant behaviour as assumed by NatHERS.

Simulations were run for star ratings 0.5, 3.0, 6.0 and 10.0 in 62 NatHERS locations. The results for heating and cooling energy delivery were then compared against the NatHERS star band table, with the ratio for each scenario and location set as a calibration factor.

Each location was assigned one of these 62 locations as a reference. In each interval, the heating/cooling energy delivered was then adjusted by multiplying it by this calibration factor. For buildings with star ratings other than 0.5, 3.0, 6.0 and 10.0, the calibration factor is interpolated.

[81] http://www.nathers.gov.au/files/publications/NatHERS%20Star%20bands.pdf

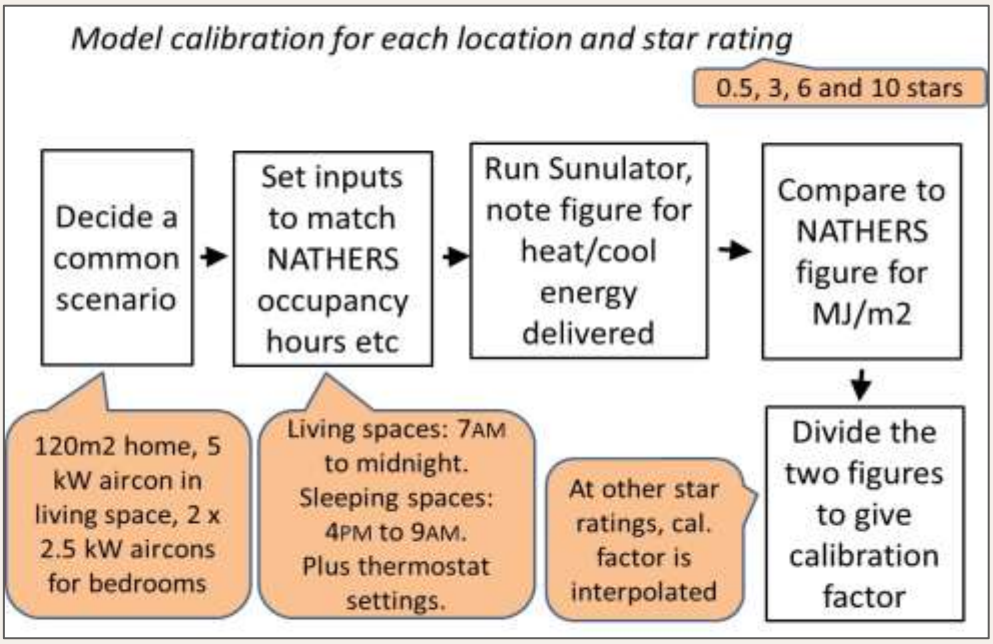


Figure 50 Flow Chart Logic, Calibration against NatHERS

8. Appendix B: Hot Water

A "bottom-up" model of hot water consumption for each household type modelled was developed for the project. A key variable is the temperature of water as it arrives at the home. When this temperature is very cold, hot water energy consumption rises due to several factors, for example:

- When mixing hot and cold water in a shower, a higher volume of hot water is required to achieve a comfortable temperature due to lower cold-water temperature; and
- It takes more energy to produce hot water, as its temperature must be raised further.

Mains water temperature is related to ambient air temperature. In general, on an average annual basis, both temperatures are the same. However, unlike the air, mains water does not vary in temperature on a day-to-day basis. It changes slowly throughout the year, with a lag effect.

Using a methodology documented by the National Renewable Energy Laboratory in the USA[82], Renew modelled mains water temperature for 23 locations around Australia. We used air temperature data previously purchased from the Bureau of Meteorology for the heating and cooling model and already organised into a Typical Meteorological Year (TMY) for each location.

The model's results were validated against measurements of mains water temperature data by the University of Queensland for Melbourne[83]. Some discrepancies were found, but they are expected to be caused by the location and methods by which mains water was sampled. For ease of use, the mains water temperature results were summarised into monthly figures for each location. The following chart summarises the results, showing only capital cities:

[82] Towards development of an algorithm for mains water temperature, NREL, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.515.6885&rep=rep1&type=pdf
[83] Cold Water Temperature in Melbourne 1994-2013, preliminary statistical analysis. University of Queensland, https://www.clearwater.asn.au/user-data/research-projects/swf-files/9tr1---001-grace-2014-cold-water-temperature-in-melbourne-1994-2013-final.pdf

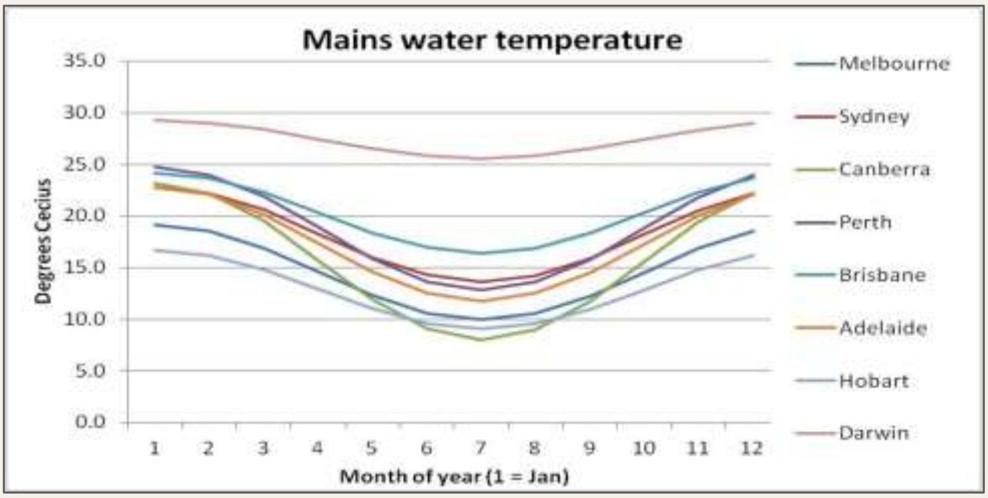


Figure 51 Mains Temperature Water in Australian Capital Cities

8.1. Hot Water Consumption & Energy

For each household type in each location, the household's hot water consumption is estimated in litres per day for four different areas:

- Showers;
- Hand basins;
- Dish washing; and
- Clothes washing.

The energy required to heat water is estimated in megajoules per day for each of these four areas and then summed. Energy consumption is also added for the following items:

- Energy losses in the water heater (e.g. heat escaping up the flue); and
- Heat escaping from the hot water tank (if any).

Water coming from the water heater is assumed to be at 65 degrees Celsius, as 60 degrees is the minimum to kill Legionella bacteria, and anecdotally some systems are set to 70 degrees.

8.1.1. Showers

The volume of hot water used per day in showering is estimated, based on the ratio of hot to cold water required to reach a typical showering temperature. The energy to heat this water is then calculated based on the specific heat of water (4.187 kJ/kg K). The key assumptions are outlined below:

	SMALL HOME	MEDIUM HOME	LARGE HOME
No. of showers per day	2.0	3.0	5.0
Shower duration (mins)	6.7	6.7	6.7
Shower duration - Winter multiplier[84]	1.2	1.2	1.2
Shower flow rate (L/min)[85]	8.0	8.0	8.0
Mixed shower temperature (Deg C)[86]	40.0	40.0	40.0

Table 36 Key Hot Water Input Assumptions, Shower Usage

8.1.2. Hand Basins

Energy calculations are as for showers. Other key assumptions are as follows:

	SMALL HOME	MEDIUM HOME	LARGE HOME
Number of basins uses per day[87]	26	39	52
Volume used each wash (Hot & Cold, Litres)	0.5	0.5	0.5
Mixed Basin Temperature (Deg C)	40.0	40.0	40.0
Mains water threshold (Deg C)[88]	10.0	10.0	10.0

Table 37 Key Hot Water Input Assumptions, Hand Basins

[84] http://www.news.com.au/lifestyle/home/interiors/eggtimer-showers-a-distant-memory-for-queenslanders/news-story/00d4bef8b7b2cdda6577481cea59073c
https://www.clearwater.asn.au/user-data/research-projects/swf-files/10tr5---001-melbourne-residential-water-use_brochure.pdf
http://www.bbc.com/news/science-environment-15836433
[85] http://www.waterrating.gov.au/consumers/water-efficiency
[86] https://forums.whirlpool.net.au/archive/1952143
https://www.reference.com/home-garden/average-shower-water-temperature-e5d7e7ee9f9eef37
[87] https://www.clearwater.asn.au/user-data/research-projects/swf-files/10tr5---001-melbourne-residential-water-use_brochure.pdf, page 21
[88] If the mains water temperature is above 10 degrees, mains water is used. If it's below 10 degrees, hot water is mixed to achieve 20 degrees.

8.1.3. Dish Washing & Clothes Washing

While dish washers and clothes washers can use hot water, modern units are made with built-in heating elements and typically do not use any hot water from the household's hot water system.

Some modern machines can be connected to the household's hot water system, however even in these cases the machine may require a tempering valve to lower the temperature of the input hot water.

Given this study focussed on the establishment of new homes, it has been assumed that all households use dishwashing and clothes washing machines that have internal heating elements and therefore only use a cold-water input.

8.1.4. Energy Losses by Hot Water Appliance

Based upon the hot water consumption outlined above, the volume of hot water needed for each household type, in each location was determined. It takes 4.187 kilojoules of energy to heat one kilogram of water (one litre) by one degree Celsius. On this basis, the amount of energy required to heat the relevant volume of water from the temperature of the mains water to 65°C was then calculated.

To calculate the required amount of input energy requires the efficiency of the hot water system in transferring heat into the water. This allows for heat escaping through the flue, and other inefficiencies in the appliance. (Heat losses from the tank in storage systems are covered in Section 8.1.5 below. The efficiencies of each type of hot water system were used as follows:

HOT WATER SYSTEM TYPE	HEATING EFFICIENCY	HAS TANK?
Gas Instantaneous	86%	N
Heat Pump	98%[89]	Y

Table 38 Efficiencies of Different Hot Water System Technologies

8.1.5. Tank Heat Losses

For the heat pump and solar hot water systems, the energy losses from the hot water as it sits in the tank was also considered. The amount of heat lost from the tank is dependent upon several variables:

- The tank height and diameter, which gives the total internal surface area of the tank;
- The insulation value of the tank walls; and
- The ambient temperature for the location and time of year.

[89] This efficiency does not consider the COP of the heat pump, which is considered later.

From these variables we calculate the continuous power radiated from the heater surface, in Watts per degree of temperature difference between the hot water and the outside air.

TANK LOSS FACTOR	UNIT
Efficiency of hot water delivery (excluding heat pump COP/solar contribution)	98.0%
Hot water tank capacity (Litres)	250
Hot water tank height in metres (m)	1.4
Hot water tank set temperature (Deg C)	60
Hot water tank insulation "R" value (m2K/W)	2.0
Standby power consumption of the water heater (Watts)	30

Table 39 Tank Heat Losses

8.2. Annual Energy Use: Gas Instantaneous Systems

Based on the hot water demand, energy and tank losses outlined above, the total annual energy use for the gas instantaneous (only) water heaters for each household type in each location was then calculated as follows[90]:

LOCATION	SMALL HOME	MEDIUM HOME	LARGE HOME
Bairnsdale	8.33	11.01	16.85
Horsham	7.99	10.54	16.11
Melbourne	7.94	10.46	16.02
Mildura	7.15	9.36	14.30
Warrnambool	8.40	11.10	17.04

Table 40 Annual GJ Consumption, Gas Instant HW by Location/Hhold Type

8.3. Annual Energy Use: Gas-Boosted Solar HW

The gas-boosted solar hot water systems required additional calculations to determine the amount of hot water that would be supplied from the solar collectors, as distinct from the gas instantaneous boost unit.

Renew employed a simple approach to the modelling of solar hot water systems.

As part of its variation to the 6 Star energy provisions of the National Construction Code (NCC), Victoria requires that either a rainwater tank (connected to all sanitary flushing systems) or a solar hot water system is installed for all new Class 1 buildings, in accordance with the Plumbing Regulations 2008[91].

[90] For the gas instantaneous and gas boosted-solar hot water systems, the amount of electricity required for the ignition is also included.
[91] http://www.vba.vic.gov.au/__data/assets/pdf_file/0018/22446/6.13-Hot-Water-Plumbing-Solar-Heated-Water-6-Star-Requirements.pdf

Where a reticulated gas supply is available to the property, the NCC requires that the solar hot water system must be gas boosted[92].

The minimum performance requirement of any new solar hot water system installed is that it must perform to a minimum 60% energy savings relative to a conventional water heater[93].

60% annual energy savings is at the lowest end of the performance range of currently available and approved products. The current list of VEET approved gas boosted solar water heaters range in performance between 60% and 96%[94].

Less efficient solar hot water systems typically involve relatively small, flat plate solar collectors[95]. These are also significantly cheaper to purchase and install than higher efficiency systems[96].

Anecdotal feedback to Renew from Victorian building designers and builders over many years is that the majority of solar hot water systems being installed under the VBA requirement for Class 1 dwellings are small, flat plate collector-based systems with gas instantaneous boosters, with the majority at the cheaper end of the price range for solar water heaters.

On this basis, Renew modelled only flat-plate, solar water heaters with gas instantaneous boost and used the following design elements for each system[97]:

DESIGN ELEMENT	UNIT	VALUE
Absorber area of the collector (not entire area).	m2	3.74
Collector tilt above horizontal	degrees	30
Collector orientation - bearing or description	degrees	N
Conversion factor (basic collector efficiency)	%	79.6%
Collector loss Coefficient A	W/m2K	4.590
Collector loss Coefficient B	W/m2K2	0.0090
Length of pipes from collector to tank	m	10.0
Diameter of pipes from collector to tank	mm	11.7
Thickness of insulation on pipes	mm	10.0
Avg inlet temp as % from mains temp to HW temp.	%	75%
Water temperature rise through the collector	degrees	10
% of tank energy that can be stored for next day.	%	50%

Table 41 Gas-Boosted Solar Hot Water Design Elements

[92] An electric-boosted unit is specifically prohibited.
[93] Calculated in accordance with AS/ NZS 4234:2008.
[94] https://www.veet.vic.gov.au/public/ProductRegistrySearch.aspx
[95] https://renew.org.au/renew-magazine/buyers-guides/hot-water-buyers-guide/
[96] Higher efficiency systems typically involve larger, evacuated tube solar collectors. In Victoria, these systems typically starts at $5,000 installed and can go up to $10,000 in price. Small, flat plate SHW systems can be purchased and installed for $4,000, and possibly less as part of a volume build approach to meet the VBA requirements.
[97] Tank size and performance is as per Section 8.1.5.

Based on the inputs above, the total annual energy use for the gas-boosted solar hot water systems for each household type in each location was then calculated as follows:

LOCATION	SMALL HOME	MEDIUM HOME	LARGE HOME
Bairnsdale	2.15	3.70	7.64
Horsham	1.71	3.17	6.74
Melbourne	2.13	3.69	7.61
Mildura	0.72	1.64	4.17
Warrnambool	2.03	3.54	7.91

Table 42 Annual GJ Consumption, Gas-Boosted Solar HW by Location/Hhold Type

8.4. Annual Energy Use: Heat Pumps

For heat pump hot water systems, the amount of input energy was converted from megajoules to kilowatt hours, and the co-efficient of performance (COP) of the heat pump was then applied to calculate the total annual energy consumption. The COP for the heat pump is dependent on the ambient temperature.

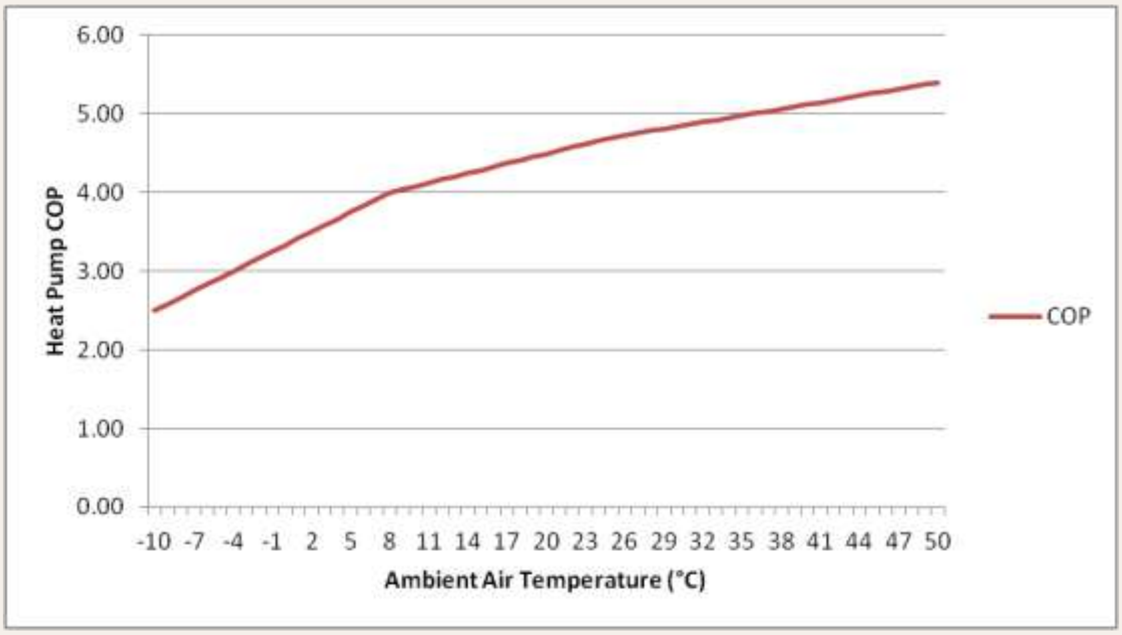


Figure 52 Impact of Ambient Air Temperature on Heat Pump COP

Considering the heat pump COP based on the ambient air temperature for each location, the total annual energy consumption for the electric heat pumps were calculated as follows:

LOCATION	SMALL HOME	MEDIUM HOME	LARGE HOME
Bairnsdale	732	881	1206
Horsham	710	851	1159
Melbourne	709	850	1160
Mildura	657	778	1046
Warrnambool	739	891	1225

Table 43 Annual kwh Consumption, Heat Pump HW by Location/Hhold Type

9. Appendix C: Cooking

Very little data exists on the typical energy consumption of gas or induction cook tops. Of the literature that does exist, it generally agrees that gas use for cooking is a very small proportion of a household's overall annual gas bill.

According to the NSW Independent Pricing and Regulatory Tribunal (IPART)[98], household use of gas for cooking is around 500 megajoules per quarter. This estimate agreed closely with the findings of ClimateWorks[99] that assumed 1552 megajoules per annum throughout Australia. This equates to between 1.18 and 1.52 kilowatt hours per day of electricity usage for the same level of efficiency.

Induction cooktops are approximately twice as efficient as gas cooktops for the same heat output, at the point of use:

TYPE	POWER SOURCE	%	REFERENCE
Cook top	Natural gas	40-45%	Choice 2013[100]
Cook top	Elec - Induction	85-90%	Choice 2013[101]
Cook top	Natural gas	40%	UBC students citing US DoE[102]
Cook top	Elec - Induction	84%	UBC students citing US DoE[103]
Cook top	Elec - Induction	80%	Wuppertal 2013
Cook top	Natural gas	Approx. 30%	US DoC[104]
Cook top	Elec	77-82%	US DoC[105]

Table 44 Point of Use Efficiency Factors of Gas & Induction Cooktops

Given the small annual load, for simplicity, Renew selected a per daily load for the induction cooktop of 1 kilowatt hour. This was then converted to a daily/annual megajoule load using the efficiency factors above[106]. The resultant gas cooktop load for all household types was 2,628 MJ p.a.

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98 http://www.ipart.nsw.gov.au/Home/For_Consumers/Compare_Energy_Offers/Typical_household_energy_use

99 'Low Carbon Lifestyles' report (2012): https://www.climateworksaustralia.org/project/tools-resources/low-carbon-lifestyles

100 https://www.choice.com.au/reviews-and-tests/household/kitchen/ovens-...1

101 https://www.choice.com.au/reviews-and-tests/household/kitchen/ovens-...1

102 Leung, Lin, Mohamed, Lo, 2011: An Investigation into Induction versus Gas Stovetops. University of British Columbia

103 Leung, Lin, Mohamed, Lo, 2011: An Investigation into Induction versus Gas Stovetops. University of British Columbia

104 Aprovecho Research Center, Shell, US EPA, 2002: Test Results of Cook Stove Performance. Partnership for Clean Indoor Air

105 Aprovecho Research Center, Shell, US EPA, 2002: Test Results of Cook Stove Performance. Partnership for Clean Indoor Air

106 i.e. a 50% relative efficiency of gas cooking as compared to electric induction.

10. Appendix D: Residual Load

The "residual load" for the purposes of the modelling is defined as the remaining load, exclusive of heating/cooling, hot water and cooking.

In this project, the residual load is supplied by electricity only, irrespective of whether the modelled home is dual fuel or all-electric. The residual load differed by household size, but not by location.

To generate the residual load for household type, Renew considered the target total annual loads as defined by the DHHS survey data in Section 2.3, as follows:

RENEW PROJECT LOCATION	DHHS LOCATION	ANNUAL ELECTRICITY USAGE (MWH)	AVERAGE DAILY USAGE (KWH)
Melbourne	Melbourne	4.31	11.8
Mildura	N/A	N/A	N/A
Warrnambool	Barwon	4.12	11.29
Bairnsdale	Outer Gippsland	5.58	15.28
Horsham	Western District	4.20	11.5

Table 45 Household Electricity Consumption, DHHS Utility Survey 2015

Given the high proportion of mains gas usage in Melbourne, Warrnambool and Horsham, it was assumed that gas was used for heating, hot water and cooking in those locations.

In addition, the DHHS survey data presents annual energy usage for existing homes – homes with less efficient appliances than would be installed in new homes in 2018. To account for this, Renew used a residual annual load with average daily electricity consumption for the medium home of 7 kWh and adjusted the small and large homes accordingly:

	SMALL HOME	MEDIUM HOME	LARGE HOME
MWh per year	1.463	2.564	4.899
kWh per day (average)	4.01	7.02	13.42

Table 46 Residual Loads by Household Size, Annual & Daily Electricity Usage

11. Appendix E: Solar PV

For the scenarios with solar PV, the electrical (30-minute) load profile is simulated against the generation from a 5.0-kilowatt solar PV system[107] for a specific household in that location.

In each half hour interval, solar generation is calculated (after losses), followed by on-site consumption (considering the load profile in that interval) with any excess exported to the grid. This approach allows an understanding of exactly how much of the total electrical load will be supplied by the solar PV system on an annual basis, and the total annual energy exported.

The solar PV modelling was done in Renew's in-house built Sunulator[108] model. The key characteristics of the model are as follows:

- To inform generation, Renew purchased from the Bureau of Meteorology (BoM) 19 years (1994-2013) of hourly solar insolation data, across five-kilometre grids for Australia. This was filtered to 177 locations (21 in Victoria) and distilled into a Typical Meteorological Year (TMY). Temperature data was also collected for BoM weather stations at those locations, for the same TMY;

- Sunulator considers both insolation data for both diffuse and direct sunlight, obtained from the BoM's *Global Horizontal* (GHI) and *Direct Normal* (DNI) numbers. For each half-hour interval in a full year, Sunulator identifies the position of the sun in the sky, calculates the sunbeams' angle of incidence to the solar array and estimates the array's generation. The effect of temperature on generation is estimated and included;

- Regarding consumption, Sunulator has the capability to directly accommodate 30-minute interval data files of any time period (as Sunulator averages both generation & consumption back to a typical meteorological year and typical consumption year). For this project, 12 months of interval data was used for each scenario;

- Energy calculations and ultimately economic results are based on netting off generation versus consumption data, specific to that location and user profile, for each 30-minute interval over a full year. This takes account of climate variability and gives the most accurate picture of how much solar generation will be consumed on-site (and when) versus exported to the grid.

- Sunulator calculates economic impacts (e.g. electricity bill costs, bill savings, economic returns) annually and projects the results over a 30-year time frame. Financial results include simple and discounted payback, net present value and internal rate of return).

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[107] True north, 22-degree tilt, 13% panel to socket system losses.
[108] https://renew.org.au/resources/sunulator/

12. Appendix F: Annual Bills

Solar + All-Electric versus Base Cases

Medium Homes:

LOCATION	RATING	ALL-ELECTRIC			SOLAR HWS			INSTANT GAS HW		
		Elec	Gas	Total	Elec	Gas	Total	Elec	Gas	Total
Melbourne	6 Stars	$1,061	$0	$1,061	$1,366	$1,498	$2,864	$1,366	$1,651	$3,016
	7 Stars	$916	$0	$916	$1,358	$1,103	$2,461	$1,358	$1,263	$2,621
	8 Stars	$823	$0	$823	$1,356	$824	$2,180	$1,356	$992	$2,348
	9 Stars	$760	$0	$760	$1,355	$634	$1,989	$1,355	$802	$2,157
	10 Stars	$718	$0	$718	$1,355	$530	$1,885	$1,355	$698	$2,053
Horsham	6 Stars	$1,050	$0	$1,050	$1,417	$1,364	$2,781	$1,417	$1,529	$2,946
	7 Stars	$896	$0	$896	$1,405	$986	$2,390	$1,405	$1,152	$2,557
	8 Stars	$799	$0	$799	$1,400	$723	$2,123	$1,400	$891	$2,291
	9 Stars	$733	$0	$733	$1,398	$547	$1,944	$1,398	$715	$2,113
	10 Stars	$688	$0	$688	$1,397	$448	$1,845	$1,397	$616	$2,013
Mildura	6 Stars	$911	$0	$911	$1,429	$1,489	$2,919	$1,429	$1,730	$3,159
	7 Stars	$786	$0	$786	$1,411	$1,109	$2,520	$1,411	$1,353	$2,765
	8 Stars	$709	$0	$709	$1,403	$835	$2,238	$1,403	$1,105	$2,508
	9 Stars	$655	$0	$655	$1,399	$631	$2,031	$1,399	$931	$2,330
	10 Stars	$617	$0	$617	$1,398	$503	$1,900	$1,398	$817	$2,215
Warrnambool	6 Stars	$1,219	$0	$1,219	$1,402	$2,114	$3,516	$1,402	$2,278	$3,680
	7 Stars	$987	$0	$987	$1,399	$1,455	$2,854	$1,399	$1,628	$3,027
	8 Stars	$839	$0	$839	$1,398	$999	$2,397	$1,398	$1,175	$2,573
	9 Stars	$743	$0	$743	$1,397	$690	$2,087	$1,397	$870	$2,268
	10 Stars	$684	$0	$684	$1,397	$522	$1,919	$1,397	$704	$2,101
Bairnsdale	6 Stars	$1,247	$0	$1,247	$1,458	$1,769	$3,227	$1,458	$1,924	$3,382
	7 Stars	$1,026	$0	$1,026	$1,455	$1,233	$2,687	$1,455	$1,390	$2,845
	8 Stars	$884	$0	$884	$1,454	$876	$2,331	$1,454	$1,035	$2,489
	9 Stars	$790	$0	$790	$1,454	$631	$2,085	$1,454	$807	$2,261
	10 Stars	$732	$0	$732	$1,454	$487	$1,941	$1,454	$673	$2,127

Small Homes:

LOCATION	RATING	ALL-ELECTRIC			SOLAR HWS			INSTANT GAS HW		
		Elec	Gas	Total	Elec	Gas	Total	Elec	Gas	Total
Melbourne	6 Stars	$669	$0	$669	$990	$1,208	$2,198	$990	$1,344	$2,334
	7 Stars	$570	$0	$570	$984	$912	$1,896	$984	$1,055	$2,039
	8 Stars	$506	$0	$506	$982	$702	$1,684	$982	$846	$1,828
	9 Stars	$462	$0	$462	$982	$563	$1,545	$982	$707	$1,689
	10 Stars	$433	$0	$433	$981	$487	$1,469	$981	$632	$1,613
Horsham	6 Stars	$668	$0	$668	$1,060	$1,078	$2,137	$1,060	$1,219	$2,279
	7 Stars	$564	$0	$564	$1,050	$801	$1,852	$1,050	$944	$1,994
	8 Stars	$498	$0	$498	$1,046	$609	$1,655	$1,046	$752	$1,799
	9 Stars	$451	$0	$451	$1,045	$481	$1,526	$1,045	$624	$1,669
	10 Stars	$420	$0	$420	$1,045	$409	$1,454	$1,045	$552	$1,597
Mildura	6 Stars	$558	$0	$558	$1,069	$1,219	$2,288	$1,069	$1,419	$2,488
	7 Stars	$472	$0	$472	$1,055	$932	$1,987	$1,055	$1,145	$2,201
	8 Stars	$420	$0	$420	$1,049	$720	$1,769	$1,049	$956	$2,005
	9 Stars	$382	$0	$382	$1,046	$552	$1,598	$1,046	$814	$1,860
	10 Stars	$355	$0	$355	$1,045	$458	$1,503	$1,045	$720	$1,765
Warrnambool	6 Stars	$785	$0	$785	$1,048	$1,669	$2,717	$1,048	$1,812	$2,860
	7 Stars	$627	$0	$627	$1,046	$1,167	$2,213	$1,046	$1,315	$2,361
	8 Stars	$527	$0	$527	$1,045	$830	$1,875	$1,045	$981	$2,026
	9 Stars	$460	$0	$460	$1,044	$603	$1,648	$1,044	$757	$1,801
	10 Stars	$418	$0	$418	$1,044	$481	$1,525	$1,044	$634	$1,679
Bairnsdale	6 Stars	$804	$0	$804	$1,079	$1,390	$2,469	$1,079	$1,523	$2,602
	7 Stars	$653	$0	$653	$1,077	$1,002	$2,079	$1,077	$1,135	$2,212
	8 Stars	$558	$0	$558	$1,077	$739	$1,816	$1,077	$879	$1,956
	9 Stars	$494	$0	$494	$1,076	$551	$1,627	$1,076	$707	$1,783
	10 Stars	$453	$0	$453	$1,076	$443	$1,520	$1,076	$601	$1,677

Large Homes:

LOCATION	RATING	ALL-ELECTRIC			SOLAR HWS			INSTANT GAS HW		
		Elec	Gas	Total	Elec	Gas	Total	Elec	Gas	Total
Melbourne	6 Stars	$1,839	$0	$1,839	$2,159	$1,832	$3,991	$2,159	$2,018	$4,177
	7 Stars	$1,639	$0	$1,639	$2,150	$1,340	$3,490	$2,150	$1,536	$3,686
	8 Stars	$1,511	$0	$1,511	$2,147	$1,001	$3,148	$2,147	$1,205	$3,352
	9 Stars	$1,424	$0	$1,424	$2,146	$763	$2,910	$2,146	$972	$3,119
	10 Stars	$1,367	$0	$1,367	$2,146	$632	$2,778	$2,146	$841	$2,986
Horsham	6 Stars	$1,788	$0	$1,788	$2,169	$1,693	$3,862	$2,169	$1,901	$4,070
	7 Stars	$1,578	$0	$1,578	$2,154	$1,216	$3,370	$2,154	$1,427	$3,581
	8 Stars	$1,444	$0	$1,444	$2,148	$884	$3,031	$2,148	$1,096	$3,244
	9 Stars	$1,351	$0	$1,351	$2,145	$661	$2,806	$2,145	$874	$3,020
	10 Stars	$1,291	$0	$1,291	$2,145	$535	$2,680	$2,145	$749	$2,893
Mildura	6 Stars	$1,602	$0	$1,602	$2,184	$1,805	$3,989	$2,184	$2,112	$4,295
	7 Stars	$1,430	$0	$1,430	$2,162	$1,322	$3,484	$2,162	$1,642	$3,804
	8 Stars	$1,325	$0	$1,325	$2,151	$994	$3,146	$2,151	$1,329	$3,481
	9 Stars	$1,250	$0	$1,250	$2,147	$758	$2,905	$2,147	$1,123	$3,270
	10 Stars	$1,199	$0	$1,199	$2,145	$613	$2,758	$2,145	$1,008	$3,153
Warrnambool	6 Stars	$2,018	$0	$2,018	$2,150	$2,603	$4,753	$2,150	$2,790	$4,940
	7 Stars	$1,703	$0	$1,703	$2,147	$1,797	$3,944	$2,147	$2,000	$4,146
	8 Stars	$1,496	$0	$1,496	$2,145	$1,230	$3,375	$2,145	$1,441	$3,586
	9 Stars	$1,362	$0	$1,362	$2,145	$843	$2,988	$2,145	$1,059	$3,204
	10 Stars	$1,281	$0	$1,281	$2,144	$632	$2,776	$2,144	$851	$2,995
Bairnsdale	6 Stars	$2,080	$0	$2,080	$2,259	$2,197	$4,456	$2,259	$2,392	$4,651
	7 Stars	$1,775	$0	$1,775	$2,255	$1,516	$3,772	$2,255	$1,713	$3,968
	8 Stars	$1,576	$0	$1,576	$2,255	$1,061	$3,316	$2,255	$1,259	$3,514
	9 Stars	$1,445	$0	$1,445	$2,254	$760	$3,014	$2,254	$968	$3,222
	10 Stars	$1,365	$0	$1,365	$2,254	$590	$2,844	$2,254	$814	$3,069

13. Appendix G: Annual Bills

All-Electric & Base Cases (No Solar PV)

Medium Homes:

LOCATION	RATING	ALL-ELECTRIC			DUAL FUEL (SOLAR HWS)			ALL-ELEC SAVING P.A.
		Elec	Gas	Total	Elec	Gas	Total	
Melbourne	6 Stars	$2,277	$0	$2,277	$1,366	$1,498	$2,864	$587
	7 Stars	$2,092	$0	$2,092	$1,358	$1,103	$2,461	$369
	8 Stars	$1,969	$0	$1,969	$1,356	$824	$2,180	$211
	9 Stars	$1,882	$0	$1,882	$1,355	$634	$1,989	$107
	10 Stars	$1,823	$0	$1,823	$1,355	$530	$1,885	$62
Horsham	6 Stars	$2,320	$0	$2,320	$1,417	$1,364	$2,781	$461
	7 Stars	$2,130	$0	$2,130	$1,405	$986	$2,390	$260
	8 Stars	$2,002	$0	$2,002	$1,400	$723	$2,123	$121
	9 Stars	$1,910	$0	$1,910	$1,398	$547	$1,944	$34
	10 Stars	$1,848	$0	$1,848	$1,397	$448	$1,845	-$3
Mildura	6 Stars	$2,210	$0	$2,210	$1,429	$1,489	$2,919	$709
	7 Stars	$2,050	$0	$2,050	$1,411	$1,109	$2,520	$470
	8 Stars	$1,948	$0	$1,948	$1,403	$835	$2,238	$290
	9 Stars	$1,873	$0	$1,873	$1,399	$631	$2,031	$158
	10 Stars	$1,821	$0	$1,821	$1,398	$503	$1,900	$79
Warrnambool	6 Stars	$2,558	$0	$2,558	$1,402	$2,114	$3,516	$958
	7 Stars	$2,276	$0	$2,276	$1,399	$1,455	$2,854	$578
	8 Stars	$2,081	$0	$2,081	$1,398	$999	$2,397	$316
	9 Stars	$1,943	$0	$1,943	$1,397	$690	$2,087	$144
	10 Stars	$1,854	$0	$1,854	$1,397	$522	$1,919	$65
Bairnsdale	6 Stars	$2,622	$0	$2,622	$1,458	$1,769	$3,227	$605
	7 Stars	$2,348	$0	$2,348	$1,455	$1,233	$2,687	$339
	8 Stars	$2,159	$0	$2,159	$1,454	$876	$2,331	$172
	9 Stars	$2,026	$0	$2,026	$1,454	$631	$2,085	$59
	10 Stars	$1,939	$0	$1,939	$1,454	$487	$1,941	$2

Small Homes:

LOCATION	RATING	ALL-ELECTRIC			DUAL FUEL (SOLAR HWS)			ALL-ELEC SAVING P.A.
		Elec	Gas	Total	Elec	Gas	Total	
Melbourne	6 Stars	$1,719	$0	$1,719	$990	$1,208	$2,198	$479
	7 Stars	$1,583	$0	$1,583	$984	$912	$1,896	$313
	8 Stars	$1,492	$0	$1,492	$982	$702	$1,684	$192
	9 Stars	$1,427	$0	$1,427	$982	$563	$1,545	$118
	10 Stars	$1,384	$0	$1,384	$981	$487	$1,469	$85
Horsham	6 Stars	$1,778	$0	$1,778	$1,060	$1,078	$2,137	$359
	7 Stars	$1,639	$0	$1,639	$1,050	$801	$1,852	$213
	8 Stars	$1,545	$0	$1,545	$1,046	$609	$1,655	$110
	9 Stars	$1,477	$0	$1,477	$1,045	$481	$1,526	$49
	10 Stars	$1,431	$0	$1,431	$1,045	$409	$1,454	$23
Mildura	6 Stars	$1,698	$0	$1,698	$1,069	$1,219	$2,288	$590
	7 Stars	$1,580	$0	$1,580	$1,055	$932	$1,987	$407
	8 Stars	$1,505	$0	$1,505	$1,049	$720	$1,769	$264
	9 Stars	$1,449	$0	$1,449	$1,046	$552	$1,598	$149
	10 Stars	$1,411	$0	$1,411	$1,045	$458	$1,503	$92
Warrnambool	6 Stars	$1,955	$0	$1,955	$1,048	$1,669	$2,717	$762
	7 Stars	$1,747	$0	$1,747	$1,046	$1,167	$2,213	$466
	8 Stars	$1,603	$0	$1,603	$1,045	$830	$1,875	$272
	9 Stars	$1,501	$0	$1,501	$1,044	$603	$1,648	$147
	10 Stars	$1,435	$0	$1,435	$1,044	$481	$1,525	$90
Bairnsdale	6 Stars	$1,996	$0	$1,996	$1,079	$1,390	$2,469	$473
	7 Stars	$1,794	$0	$1,794	$1,077	$1,002	$2,079	$285
	8 Stars	$1,655	$0	$1,655	$1,077	$739	$1,816	$161
	9 Stars	$1,556	$0	$1,556	$1,076	$551	$1,627	$71
	10 Stars	$1,492	$0	$1,492	$1,076	$443	$1,520	$28

Large Homes:

LOCATION	RATING	ALL-ELECTRIC			DUAL FUEL (SOLAR HWS)			ALL-ELEC SAVING P.A.
		Elec	Gas	Total	Elec	Gas	Total	
Melbourne	6 Stars	$3,310	$0	$3,310	$2,159	$1,832	$3,991	$681
	7 Stars	$3,077	$0	$3,077	$2,150	$1,340	$3,490	$413
	8 Stars	$2,921	$0	$2,921	$2,147	$1,001	$3,148	$227
	9 Stars	$2,811	$0	$2,811	$2,146	$763	$2,910	$99
	10 Stars	$2,737	$0	$2,737	$2,146	$632	$2,778	$41
Horsham	6 Stars	$3,309	$0	$3,309	$2,169	$1,693	$3,862	$553
	7 Stars	$3,069	$0	$3,069	$2,154	$1,216	$3,370	$301
	8 Stars	$2,907	$0	$2,907	$2,148	$884	$3,031	$124
	9 Stars	$2,791	$0	$2,791	$2,145	$661	$2,806	$15
	10 Stars	$2,712	$0	$2,712	$2,145	$535	$2,680	-$32
Mildura	6 Stars	$3,165	$0	$3,165	$2,184	$1,805	$3,989	$824
	7 Stars	$2,962	$0	$2,962	$2,162	$1,322	$3,484	$522
	8 Stars	$2,833	$0	$2,833	$2,151	$994	$3,146	$313
	9 Stars	$2,738	$0	$2,738	$2,147	$758	$2,905	$167
	10 Stars	$2,672	$0	$2,672	$2,145	$613	$2,758	$86
Warrnambool	6 Stars	$3,615	$0	$3,615	$2,150	$2,603	$4,753	$1,138
	7 Stars	$3,257	$0	$3,257	$2,147	$1,797	$3,944	$687
	8 Stars	$3,011	$0	$3,011	$2,145	$1,230	$3,375	$364
	9 Stars	$2,837	$0	$2,837	$2,145	$843	$2,988	$151
	10 Stars	$2,725	$0	$2,725	$2,144	$632	$2,776	$51
Bairnsdale	6 Stars	$3,731	$0	$3,731	$2,259	$2,197	$4,456	$725
	7 Stars	$3,385	$0	$3,385	$2,255	$1,516	$3,772	$387
	8 Stars	$3,146	$0	$3,146	$2,255	$1,061	$3,316	$170
	9 Stars	$2,978	$0	$2,978	$2,254	$760	$3,014	$36
	10 Stars	$2,869	$0	$2,869	$2,254	$590	$2,844	-$25

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