Affordable energy choices for WA households

renew.

Prepared for Synergy

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Executive Summary

Cost effective strategies for household energy management are becoming increasingly complex – with a range of opportunities involving the use of grid (electricity and/or gas) and demand side technologies.

More than ever, there is significant confusion among consumers and the energy industry with regard to making optimal fuel and technology choices to manage household stationary energy use.

The objective of this project was to:

- understand the most cost effective choices for residential consumers to access stationary energy in the South West Interconnected System (SWIS) in 2020/21, taking into account different fuel types (mains electricity and mains gas), different household appliances, and the potiential of on-site generation from solar PV; and
- improve WA energy consumers' understanding of the latest trends in cost effective energy management strategies and changing technology for WA households.

Context

Whilst the purchase price of new appliances is highly visible, ongoing ownership costs, in particular when comparing across different fuel types, is largely hidden and/or complex. This problem can be exacerbated by inaccurate or misleading appliance marketing material.

On the demand side, the cost and efficiency of major residential heating and hot water appliances continues to improve; whilst solar PV has become even cheaper and more efficient[1].

On the supply side, retail fixed daily charges for residential consumers to be connected to both mains gas and mains electricity networks in WA are approaching $500 per year.

Space heating/cooling and water heating are typically the two most energy-intensive residential activities. Space heating and hot water can be supplied by electric or gas appliances.

Findings

This report finds that in most cases, when a gas appliance requires replacing, it's economic to install an efficient electric appliance instead. This implies that over time, as appliances reach the end of life, most homes would migrate to become all-electric and disconnect from gas if acting on an economic basis.

- **New Homes**

  Regardless of location or tariff, it's economic for new homes to avoid a gas connection and install efficient electric appliances instead. With efficient electric appliances running costs are lower, and costs are avoided to install gas plumbing pipes and pay ongoing gas supply charges.

[1] A good quality 5 kilowatt solar PV system in Perth now costs as little as $4,000 and provides almost twice the annual electricity demand of the average home. In 2013, a 5 kilowatt system would have required 25 panels; in 2020, this has fallen to 15.

- **Homes where One Gas Appliance needs replacing**

  Where a household's sole gas appliance needs replacing, in almost all cases it's economic to install an efficient electric replacement instead of a gas one. This decision eliminates the gas bill including the gas daily supply charge.

- **Homes where All Gas Appliances need replacing**

  There will be times when a gas appliance fails, and the other existing gas appliances are also approaching end-of-life. In such cases the homeowner might consider replacing all of them at once. In most cases it's economic to install efficient electric appliances.

- **Existing Homes with Solar**

  For homes with a solar electricity system and a battery[2], when a gas appliance requires replacement in almost all cases it's economic to install an efficient electric appliance rather than a new gas one.

- **Resistive electric versus heat pump hot water**

  In the right circumstances, resistive electric water heaters deliver good economics, in some ways rivalling a heat pump. This requires a solar system that generates a large daytime surplus above household consumption.

Recommendations

Renew's general recommendations from this study are as follows:

Recommendation 1:

Educate the building and energy industries, along with new home buyers, of the substantial value of all-electric homes.

A key finding of this work is that by choosing an all-electric home with solar PV , a new home buyer will be in the order of $7,500 to $10,500 better off over 10 years, as compared with establishing that home as dual fuel (i.e. electricity and gas), without solar.

This finding applies to the majority of Class 1 dwellings that will be built across WA over the coming decade.

Recommendation 2:

Review of policy and programs that subsidise/support the expansion of gas networks.

Given the general trend from this study regarding the cost effectiveness of fuel switching from gas to electricity, it is critical that all governments and regulators with an interest in energy infrastructure review policies that seek to promote the expansion of reticulated gas networks to greenfield sites.

To continue to promote reticulated gas to new Class 1 dwelling estates in particular is to lock most of those new home buyers into significantly higher energy costs for the medium to longer term.

[2] Modelling assumed 5 kilowatts of solar panels and 13.5 kilowatt-hours of energy storage capacity.

Recommendation 3:

Provide better information for consumers regarding the cost of owning and operating gas and electric appliances.

This analysis further strengthens similar work undertaken for the NEM by Renew which suggests that gas is no longer the cheapest fuel source for most residential activities in many locations.

As such, consumers need to be better informed of the real cost of purchasing and operating both gas and electric appliances in order that they can confidently make better decisions regarding those appliance choices that are in their long-term interest.

The role of governments and industry here is to assist in the provision of accurate, targeted information and advice, that is easy to understand, and that assists consumers in making these choices.

Recommendation 4:

Strengthen the regulatory oversight of the marketing of gas as cheaper and more efficient than electricity.

Questionable claims about the affordability of gas continue to be communicated by gas appliance sellers, gas retailers and gas networks – often with very little detail as to how individual appliance loads and running costs are calculated, and little regard for appropriate alternatives.

Renew recommends that the ACCC and/or relevant jurisdictional departments of consumer affairs dedicate focus and resources to monitoring relevant marketing material in this area.

Recommendation 5:

Provide support to landlords, and disadvantaged owner-occupiers, to replace less efficient and expensive-to-run appliances with more efficient appliances.

Assistance measures – such as low/no interest loans, rebates, energy efficiency schemes – should be provided to disadvantaged consumers, considering the findings of this report with respect to distributional impacts.

These policies should be technology agnostic and designed in a way that achieves the reduction of the capital cost for the most cost-effective technologies for those consumers who face the strongest capital-cost barriers.

Recommendation 6:

Consider the impact of fuel switching when making energy consumption and demand forecasts.

Energy market institutions and energy businesses use short- and long-range consumption and demand forecasts in planning and decision-making. Since the end result of households basing appliance replacement fuel choice on economic benefit is ultimately for most households to switch away from gas (whether all at once, or one at a time), this trajectory should be considered (along with other observable and predictable trends) when developing such forecasts.

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1. Introduction

Cost effective strategies for household energy management are becoming increasingly complex – with a range of opportunities involving the use of grid (electricity and/or gas) and demand side technologies.

More than ever, there is significant confusion among consumers and the energy industry with regard to making optimal fuel and technology choices to manage household stationary energy use.

In mid-2018, Renew completed its second "Household Fuel Choice in the NEM" project[3], that assessed the economics of "dual fuel" (i.e. gas & electricity) versus all-electric homes in the National Electricity Market (NEM), with and without solar photovoltaic (PV) technology. A range of household types, NEM locations and appliance replacement cases were considered.

Subsequent to the release of that work, Synergy[4] commissioned Renew as independent experts to undertake a similar economic comparison of dual fuel versus all-electric homes (with and without solar PV) for households in the South West Interconnected System of Western Australia (SWIS). The same modelling approach was used for this project as for the 2018 NEM work.

The objective of this project was to:

- understand the most cost effective choices for residential consumers to access stationary energy in the SWIS in 2020/21, taking into account different fuel types (mains electricity and mains gas), different household appliances, and the potiential of on-site generation from solar PV; and
- improve WA energy consumers' understanding of the latest trends in cost effective energy management strategies and changing technology for WA households.

It should be noted that the findings and recommendations contained herein are Renew's and do not necessarily reflect the organisational views or policies of Synergy.

[3] https://renew.org.au/research/all-electric-solar-homes-save-thousands-over-gas-report/
[4] WA's largest energy retailer.

1.1. Context

Whilst the purchase price of new appliances is highly visible, ongoing ownership costs, in particular when comparing across different fuel types, is largely hidden and/or complex. This problem can be exacerbated by inaccurate or misleading appliance marketing material.

On the demand side, the cost and efficiency of major residential heating and hot water appliances continues to improve; whilst solar PV has become even cheaper and more efficient[5].

On the supply side, retail fixed daily charges for residential consumers to be connected to both mains gas and mains electricity networks in WA are approaching $500 per year.

Space heating/cooling and water heating are typically the two most energy-intensive residential activities. Space heating and hot water can be supplied by electric or gas appliances.

Electrical technology used to heat air and water, historically inefficient and high cost, is becoming increasingly efficient. Heat pumps (commonly known as reverse-cycle air conditioners) for space heating have reached coefficients of performance (CoP) of 5.95[6] – meaning that for every 1-kilowatt hour of energy input to the system, 5.95 kilowatt hours are generated to heat air. CoPs for the most efficient electric heat pumps (for water heating) now exceed 4.0.

Gas hot water and space heating systems have also increased in efficiency over recent years, with the most efficient systems on the market now achieving a CoP of up to 0.91[7].

Heat pumps and other electric appliances also have the potential to be powered directly by on-site solar PV. The levelised cost of electricity from rooftop solar PV in Perth in 2020 is around five to six cents per kilowatt hour[8] – around one-fifth of the price of a Perth retail electricity tariff for energy.

Cooking is the third residential activity for which either electricity or gas can be used – albeit with significantly lower overall energy consumption.

Meaningfully comparing fuel and appliance choices is complex due to the variety of economic and other considerations that households are faced with in making such a decision.

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[5] A good quality 5 kilowatt solar PV system in Perth now costs as little as $4,000 and provides almost twice the annual electricity demand of the average home. In 2013, a 5 kilowatt system would have required 25 panels; in 2020, this has fallen to 15.

[6] https://www.daikin.com.au/our-product-range/split-system-air-conditioning/us7#tech-specs

[7] https://www.elgas.com.au/blog/449-star-ratings-for-gas-heaters-gas-wall-furnaces-a-gas-fireplaces

[8] Renew analysis using the Sunulator solar model. LCoE measured over 25 years, inverter replaced at years 10 & 20. Financial discount rate: 2% (real). System prices sourced from Solar Choice benchmarks.

2. Approach

The economics of gas and electric appliance choices are sensitive to a range of factors, including:

- whether or not an appliance is at or near the end of its asset life;
- whether the decision incurs the cost of a new connection or fixed charge (particularly for new builds);
- whether the decision avoids the cost of existing fixed charges;
- current gas and electricity tariffs and tariff structures;
- forecast prices for electricity and gas;
- whether the consumer can generate some of their own electricity with a solar PV system, avoiding paying the retail price for some of the household electricity consumed;
- financial expectation, including cost of capital and return on investment expectations; and
- the annual input energy use of individual gas and/or electric appliances, which is itself influenced by:
    - building type, size and thermal performance;
    - the efficiency of that appliance;
    - climate zone (with particular reference to space and water heating loads).

2.1. Model Structure

For residential consumers, the primary use of mains gas occurs for any combination of the following end-use energy services:

- space heating (warming rooms and buildings);
- water heating; and
- cooking.

Each of these end uses can be supplied by either gas or electric appliances. With regard to consumer choices, any individual consumer may be considering:

- replacing one or two gas appliances with electric appliances (or vice versa), and retaining an existing mains gas connection;
- a complete switch from gas to electric appliances, and disconnection from the gas network; or
- establishing a new connection to the mains gas network, and purchase of new gas appliances, for:
    - an existing home without mains gas; or
    - a newly built home.

2.1.1. Replacing Gas Appliances in Existing Homes

The existing household types consider scenarios where a decision to replace one or more existing gas appliances is made at the point where it has failed or is highly likely to require replacement within five years.

The options are either to:

1. replace the gas appliance/s with a new, efficient gas appliance (this is considered the *Business as Usual* – BAU case); or

2. replace the gas appliance/s with an efficient electric appliance/s.

Under option 2, there is also the case where all gas appliances are replaced with efficient electric alternatives, avoiding the need for an existing mains gas connection. In this case, the consumer avoids the ongoing fixed charge incurred by maintaining the gas connection.

2.1.2. Choosing Appliances for New Homes

For new homes, consideration must be given to the scenario where the home is built and installs efficient electric appliance/s from the outset – thereby not connecting to the gas network. Under this option, the consumer also avoids any ongoing fixed charge incurred by maintaining a gas connection.

3. Methodology

The objective of the methodology was to capture a range of different household types, locations and appliance replacement cases, in order that the results provide useful guidance for a wide number of residential energy consumers in WA.

3.1. Locations

The project team selected two locations for the modelling:

- Perth; and
- Albany.

3.2. Household Types

Five household types were selected for modelling, with the following assumed sizes and occupancy profiles:

HOUSEHOLD TYPE	OCCUPANTS	BUILDING ENERGY RATING	NOTES
Small Home	1-2 Persons	3 Stars	Typical, existing small detached/semi-detached
Medium Home – Stay at Home Family	2-3 Persons	3 Stars	Typical existing detached, moderate usage during working hours
Medium Home –Working Family	2-3 Persons	3 Stars	Typical existing detached, low usage during working hours
Large Home	4-5 Persons	3 Stars	Typical existing large 10+ year old house, urban fringe
New Home	4-5 Persons	6 Stars	New home, urban fringe

Table 1 Characteristics of the Household Types Modelled for this Project

3.3. Appliance Choice

The entire range of available new gas, electric and solar appliances available for space heating, water heating and cooking were considered for inclusion within the model.

In narrowing this down to which appliances to analyse, and to a shorter list of models for detailed economic analysis, we have considered the following questions of each type:

- Is it common and generally accepted by consumers in WA?
- Is it available on the mass market and supported by a mature supply chain?
- Is it energy efficient, relative to other appliances of the same fuel type?
- Is the purchase price in a realistic range for mass-market consumers?
- Is it acceptable for mass-market consumers with respect to quality, convenience and amenity?

- How is it comparable with equivalent appliances of different fuel types with respect to quality, convenience and amenity? In keeping with the context and intent of this research, this analysis considers the consumer experience of gas appliances to be the benchmark against which any electric equivalents should be compared. Appliances considered inferior to gas are therefore excluded.

- Is it widely accepted as safe to use in normal use?

- With respect to cost and performance characteristics, is it materially dissimilar to other appliance types analysed, such that we can't assume that the same conclusions can be drawn as for other appliances?

Given the low prevalence of gas ducted heating in WA, the model assumes that gas heating for all household types is supplied by individual gas heater units.

For electric heating, the model assumed reverse-cycle air conditioners, with an equivalent sized unit in the main living area to provide the same heating output as the gas wall furnace.

Heating was not considered for bedrooms for either gas or electric heating appliances.

For hot water, the model assumes gas hot water is instantaneous for all household types. Electric hot water is heat pump with tank storage for all household types, timed to heat during the day (to take advantage of higher ambient temperatures as well as potential solar generation).

Regarding cooking, the model assumes gas cooktop with gas oven for the dual fuel homes; with induction cooktop and electric oven for the electric alternatives.

The following tables outline the specific appliances chosen for each replacement case by household type:

HOUSEHOLD TYPE	GAS HEATING APPLIANCE	ELECTRIC HEATING APPLIANCE
Small Home	1x Wall Furnace (3kW burner)	1x 5kW RCAC (Living Space only)
Medium Home – Stay at Home Family	1x Wall Furnace (5kW burner)	1x 7kW RCAC (Living Space only)
Medium Home – Working Family	1x Wall Furnace (5kW burner)	1x 7kW RCAC (Living Space only)
Large Home	1x Wall Furnace (5kW burner)	1x 9kW RCAC (Living Space only)
New Home	1x Wall Furnace (5kW burner)	1x 9kW RCAC (Living Space only)

Table 2 Appliance Replacement Selections by Household Type, Space Heating

Renew also considered modern gas log fire-type heaters[9] (as opposed to traditional wall furnaces[10][11]). A review of available products in the market suggested gas log fire heaters had a comparable efficiency and performance but at significantly higher cost (i.e. more than double and for some units, more than triple). This would have skewed the economic results considerably and so these were excluded from the analysis.

[9] https://www.gstore.com.au/rinnai-650-gas-fire-lpg-includes-remote.html
[10] https://www.thegoodguys.com.au/rinnai-spectrum-inbuilt-ng-beige-heater-flued-spein
[11] https://www.thegoodguys.com.au/rinnai-ultima-ii-inbuilt-ng-beige-heater-flued-ult2in

HOUSEHOLD TYPE	WATER HEATING		COOKING	
	DUAL FUEL	ALL-ELECTRIC	DUAL FUEL	ALL-ELECTRIC
Small Home	Instantaneous	Heat Pump (150L Tank)	Gas Cooktop, Gas Oven	Induction Cooktop, Electric Oven
Medium Home – Stay at Home Family	Instantaneous	Heat Pump (270L Tank)	Gas Cooktop, Gas Oven	Induction Cooktop, Electric Oven
Medium Home –Working Family	Instantaneous	Heat Pump (270L Tank)	Gas Cooktop, Gas Oven	Induction Cooktop, Electric Oven
Large Home	Instantaneous	Heat Pump (340L Tank)	Gas Cooktop, Gas Oven	Induction Cooktop, Electric Oven
New Home	Instantaneous	Heat Pump (340L Tank)	Gas Cooktop, Gas Oven	Induction Cooktop, Electric Oven

Table 3 Appliance Replacement Selections by Household Type, Water Heating & Cooking

3.4. Replacement Cases

The following replacement cases were modelled for the project:

EXISTING GAS APPLIANCE	REPLACEMENT CASE	GAS NETWORK STATUS
Hot Water	Replace with new Heat Pump (electric) HW instead of new Gas Instantaneous HW	Stay on gas network
Space Heating	Replace with new RCAC[12] (electric) heating instead of new Gas Wall Furnace heating	Stay on gas network
Cooking	Replace with new Induction Cooktop instead of new Gas Cooktop	Stay on gas network
Hot Water	Replace with new Heat Pump (electric) HW instead of new Gas Instantaneous HW	Disconnect from gas network
Cooking	Replace with new Induction Cooktop instead of new Gas Cooktop	Disconnect from gas network
Hot Water & Space Heating	Replace with new Heat Pump (electric) HW instead of new Gas Instantaneous HW & replace with new RCAC (electric) heating instead of new Gas Wall Furnace heating	Disconnect from gas network
Space Heating & Cooking	Replace with new RCAC (electric) heating instead of new Gas Wall Furnace heating & replace with new Induction Cooktop instead of new Gas Cooktop	Disconnect from gas network
Hot Water & Cooking	Replace with new Heat Pump (electric) HW instead of new Gas Instantaneous HW & replace with new Induction Cooktop instead of new Gas Cooktop	Disconnect from gas network
Hot Water & Space Heating & Cooking	Replace with new Heat Pump (electric) HW instead of new Gas Instantaneous HW & replace with new RCAC (electric) heating instead of new Gas Wall Furnace heating & replace with new Induction Cooktop instead of new Gas Cooktop	Disconnect from gas network
None	New home – establishment of new all-electric home instead of establishment of new dual fuel home at outset	No mains gas connection

Table 4 Replacement Cases Modelled

[12] RCAC – Reverse Cycle Air Conditioner

In order to read the modelling results, the three main appliance types were given a code, as follows:

APPLIANCE	CODE
Gas Space Heating	S
Gas Hot Water	W
Gas Cooking	C
No Gas Space Heating, Hot Water or Cooking	NNN

Table 5 Appliance Type Codes

These codes could then be used to concisely summarise the replacement cases, as follows:

CODE	BAU GAS APPLIANCES	POST-REPLACEMENT GAS APPLIANCES
C - NNN	Cooking only	None
S - NNN	Space Heating only	None
SC —C	Space Heating & Cooking	Cooking only
SC - NNN	Space Heating & Cooking	None
SC - S	Space Heating & Cooking	Space Heating only
SW - S	Space Heating & Hot Water	Space Heating only
SW - W	Space Heating & Hot Water	Hot Water only
SWC - C	Sp Heating & Hot Water & Cooking	Cooking only
SWC - NNN	Sp Heating & Hot Water & Cooking	None
SWC - S	Sp Heating & Hot Water & Cooking	Space Heating only
SWC - SC	Sp Heating & Hot Water & Cooking	Space Heating & Cooking
SWC - SW	Sp Heating & Hot Water & Cooking	Space Heating & Hot Water
SWC - W	Sp Heating & Hot Water & Cooking	Hot Water only
SWC - WC	Sp Heating & Hot Water & Cooking	Hot Water & Cooking
W - NNN	Hot Water only	None
WC - C	Hot Water & Cooking	Cooking only
WC - NNN	Hot Water & Cooking	None
WC - W	Hot Water & Cooking	Hot Water only

Table 6 Replacement Cases Codes

3.5. Solar & Batteries

Each scenario was modelled three separate times for three different solar PV and battery system configurations, as follows:

- No solar or battery installed;
- An existing 5kW solar PV system only (i.e. no battery); and
- An existing 5kW solar PV system with a 13.5kWh battery.

This approach considered the value of existing solar and battery systems but ensured the value of different appliance mixes could still be understood separately in the results.

3.6. Energy Loads

The calculation of annual energy loads 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 load (supplied by either gas or electric appliance);
  - 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[13].

3.6.1. Reference Energy Loads

Whilst Renew is able to individually model separate heating, hot water and cooking loads for individual household types in different climate zones, it is important that the total household load (either the electricity and gas load or the electricity-only load) is reasonable on an annual basis, taking into account the remaining ‘residual’ load.

As such, the project team drew on publicly available data to define ‘reference energy loads’ for both gas and electricity for WA homes. The project team reviewed annual energy usage data for WA homes from a range of sources[14].

[13] e.g. resistive electric technologies.

[14] Including:
https://www.synergy.net.au/Our-energy/Energy-tool/Compare-your-bill
https://www.aemo.com.au/Electricity/Wholesale-Electricity-Market-WEM/Planning-and-forecasting/WEM-Electricity-Statement-of-Opportunities
https://www.energy.gov.au/sites/default/files/gas_price_trends_review_2017.pdf
https://quickstats.censusdata.abs.gov.au/census_services/getproduct/census/2016/quickstat/5?opendocument

3.6.1.1. Electricity

The Australian Energy Market Operator's (AEMO) Electricity Statement of Opportunities for 2020 for the South West Interconnected System (SWIS) suggests:

- just over 4,600 gigawatt hours (GWh) of residential electricity consumption from the grid in 2018/19; and
- an underlying annual consumption of just over **5,200 kilowatt hours** (kWh) per residential connection in 2018/19 (or approximately 14.2 kWh per day).[15] This includes consumption met by rooftop solar as well as the grid.

As such, Renew's electricity consumption datasets for the medium household types were scaled to an annual total of 5,000 kWh.

3.6.1.2. Gas

Since 2013/14, residential gas use in WA has been just over 10 petajoules (PJ) per annum.

2013/14	2015/16	2017/18
10.5[16]	10.9[17]	10.69[18]

Table 7 WA Residential Gas Use

More recent data is not yet available, although forecasts by the regulator suggest a figure of 9.9 PJ for 2020.[19]

Approximately 720,000 WA homes are connected to the mains gas network[20]. Using this and the 2017/18 residential consumption figure, this equates to approximately 14.85 GJ (4.1 MWh) of gas energy consumption per WA home per annum.

Renew understands that it is not typical in WA for homes connected to the mains gas network to use gas for space heating, hot water and cooking. Typically, homes in WA use mains gas for hot water and cooking or space heating and cooking, but not all three.

On this basis, the 14.85 GJ (4.1 MWh) figure above is considered reflective of:

- homes with predominantly two end-uses on gas; and
- older (i.e. less efficient) existing gas appliances.

In order to establish a reference gas load, Renew used a figure of approximately **20 GJ per annum** as the basis for calibrating gas consumption data for the medium household types with all three end-uses on gas (i.e. space heating, hot water and cooking).

This figure took account of the fact that an additional gas end-use needed to be added to the publicly available data (i.e. 14.85 GJ), however that needed to be balanced with the fact that new gas appliances would be in the order of 20% to 25% more efficient.

https://www.aemo.com.au/-/media/Files/Gas/National_Planning_and_Forecasting/WA_GSOO/2018/2018-WA-GSOO.pdf
Energy distributors report, 2017/18, provided by Synergy.

[15] AEMO 2020 WEM ESOO, figure 19 page 36.

[16] https://www.energy.gov.au/sites/default/files/gas_price_trends_review_2017.pdf

[17] https://www.energy.gov.au/sites/default/files/gas_price_trends_review_2017.pdf

[18] Energy distributors report, 2017/18, provided by Synergy

[19] WA Economic Regulation Authority, Final decision on proposed revisions to the Mid-West and South-West Gas Distribution Systems access arrangement for 2020 to 2024, table 5. https://www.erawa.com.au/cproot/20818/2/GDS---ATCO---AA5---Final-Decision---Public-FINAL-Version.PDF

[20] Energy distributors report, 2017/18, provided by Synergy

3.6.2. Calculating Energy Usage

Renew has in-house models for predicting space heating (and cooling), hot water and cooking loads by Household Type and climate zone using parameters such as ambient temperature, number of occupants, thermal performance and dwelling size, to determine granular energy requirements tailored to household characteristics, season and location.

For a detailed overview of how the space heating, hot water, cooking and residual (remaining) loads were modelled for this project, please refer to **Appendices A to F.**

The energy output requirements calculated by these models are then used to determine half-hourly electricity consumption or daily gas consumption profiles for relevant appliances to meet those end use loads.

Calculating energy loads in this way means the results are more tailored to household type and location. It also makes it possible to include the value of home solar PV generation and energy storage.

Using our methodology for building the heating/cooling, hot water, cooking and residual loads, Renew calculated the following annual electricity and gas loads for each of the household types in the two locations[21]:

HOUSEHOLD TYPE	ANNUAL ELECTRICITY USAGE (KWH)	AVERAGE DAILY USAGE (KWH)	ANNUAL GAS USAGE (GJ)	AVERAGE DAILY USAGE (MJ)
Small Home	2,099	5.75	16.8	46.11
Medium Home – Stay at Home Family	3,443	9.43	22.1	60.61
Medium Home – Working Family	3,415	9.35	21.9	60.01
Large Home	5,903	16.17	29.8	81.73
New Home	5,356	14.67	24.8	68.03

Table 8 Annual Loads, Electricity & Gas Usage, Dual Fuel Homes, Perth

[21] Albany resulted in slightly higher annual loads due to higher requirements for heating and cooling.

HOUSEHOLD TYPE	ANNUAL ELECTRICITY USAGE (KWH)	AVERAGE DAILY USAGE (KWH)
Small Home	3,390	9.29
Medium Home – Stay at Home Family	4,991	13.68
Medium Home – Working Family	4,936	13.52
Large Home	7,798	21.36
New Home	7,039	19.28

Table 9 Annual Loads, Electricity Usage, All-Electric Homes, Perth

HOUSEHOLD TYPE	ANNUAL ELECTRICITY USAGE (KWH)	AVERAGE DAILY USAGE (KWH)	ANNUAL GAS USAGE (GJ)	AVERAGE DAILY USAGE (MJ)
Small Home	2,110	5.78	22,166	60.73
Medium Home – Stay at Home Family	3,599	9.86	30,116	82.51
Medium Home – Working Family	3,548	9.72	29,718	81.42
Large Home	5,924	16.23	39,654	108.64
New Home	5,263	14.42	28,809	78.93

Table 10 Annual Loads, Electricity & Gas Usage, Dual Fuel Homes, Albany

HOUSEHOLD TYPE	ANNUAL ELECTRICITY USAGE (KWH)	AVERAGE DAILY USAGE (KWH)
Small Home	3,595	9.85
Medium Home – Stay at Home Family	5,439	14.9
Medium Home – Working Family	5,355	14.67
Large Home	8,183	22.42
New Home	7,136	19.55

Table 11 Annual Loads, Electricity Usage, All-Electric Homes, Albany

4. Results

This chapter presents the results of the scenarios modelled. Key scenarios are presented in terms of the payback time and 10-year value of the new electric appliance choice/s, instead of a new gas appliance/s.

For existing homes, this decision occurs at the point at which the existing appliance has (or is near) failed and requires replacement. For new homes, this decision occurs during the planning stage for the new home build. No appliances (gas or electric) exist to this point. Where a solar system is modelled, its installation is assumed to predate the appliance switch. As such, capital costs are applied to new appliances only (i.e. not the solar or batteries).

The model compares the total cost of ownership (i.e. purchase, installation and running cost) using a payback time and a 10-year Net Present Value (NPV) measure (see box below). Although NPV values are expressed to the nearest dollar, in reality the modelling relies on many uncertain inputs and its results should be treated as approximate. The results are structured under six sub-headings:

- Existing Homes – One Gas Appliance
- Existing Homes – Gas All Three Functions
- Existing Homes – Gas for Two Functions
- Geography
- Tariff Type
- New Homes

Payback Time

Payback time in this report is a simple calculation based on cumulative cash flows. The payback time is the year in which this turns positive. Partial years are not considered, giving an integer value. If payback is immediate, it's shown as 0.5. If payback does not occur within a 25-year horizon, it's shown as 26.

Net Present Value (NPV)

Costs and benefits are expressed as Net Present Value (NPV) over 10 years. This expresses the total value of installing efficient electric appliance instead of gas, with a higher NPV being better for the electric appliance choices. Bill savings many years in the future are given less weight than those in year 1, allowing for alternative uses of capital. The discount rate used for this purpose is 2.0% real, to reflect typical household mortgage costs (net of inflation). All dollar values are expressed in today's dollars, eliminating inflation as a factor in the calculations.

For example, where a large home replaces a gas storage hot water system with a heat pump hot water system (which is more expensive than replacing it with a new gas storage hot water system), an NPV of +$2000 means that the household has saved enough from the cheaper running costs of the heat pump to pay off the higher upfront cost, and then save an additional $2000 over the 10 years.

Where the 10-year NPV is between –$1000 and +$1000, we consider it 'marginal' because a small variance in household behaviour or purchase or installation price could make a positive NPV negative, or vice versa. This makes it an 'either/or' case, where the economics mean it doesn't make much difference which fuel is chosen.

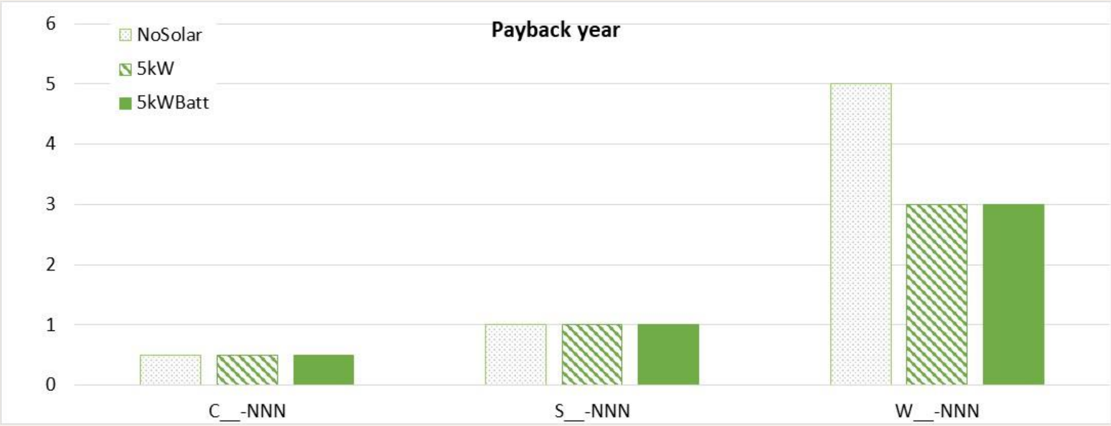
4.1. Existing Homes – One Gas Appliance

4.1.1. Medium Homes

When a household has only gas oven and cooktop and they need replacing, it's economically better to choose an electric oven and induction cooktop rather than gas. Payback is immediate because the electric appliances (including labour) are cheaper. For the Medium Stay-at-Home Household in Perth without solar on a flat tariff, the ten-year net present value of this decision is around $1,000.

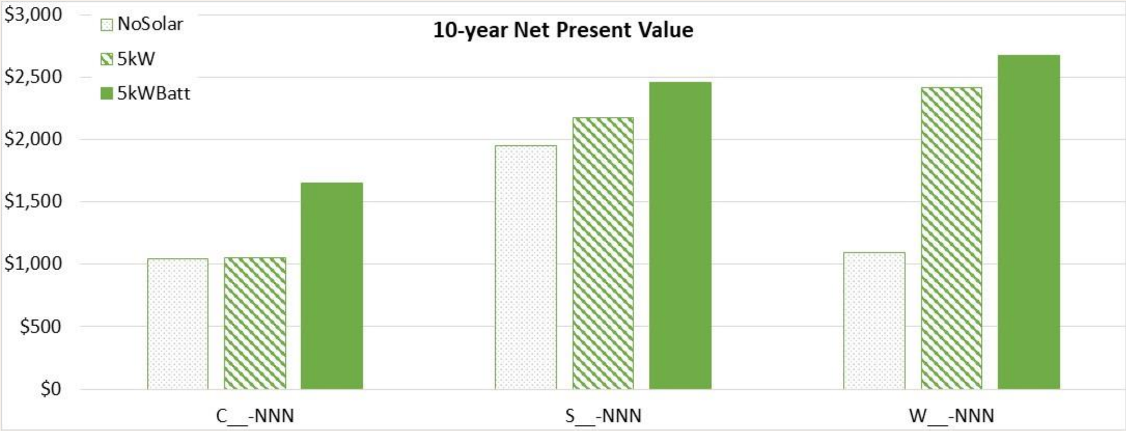
Replacing a gas space heater with a new reverse-cycle air conditioner is also very beneficial, with the same household achieving payback in one year and an NPV of around $1,900.

Replacing a failing gas water heater with a heat pump is attractive with payback in 5 years and a 10-year NPV around $1,000. If the household has a solar system, payback times drop to 3 years and the NPV is over $2,000.



	NoSolar	5kW	5kWBatt
C__-NNN	0.5	0.5	0.5
S__-NNN	1	1	1
W__-NNN	5	3	3

Figure 1: Payback Times of Replacing One Gas Appliance, Medium Home, Perth, Flat Tariff

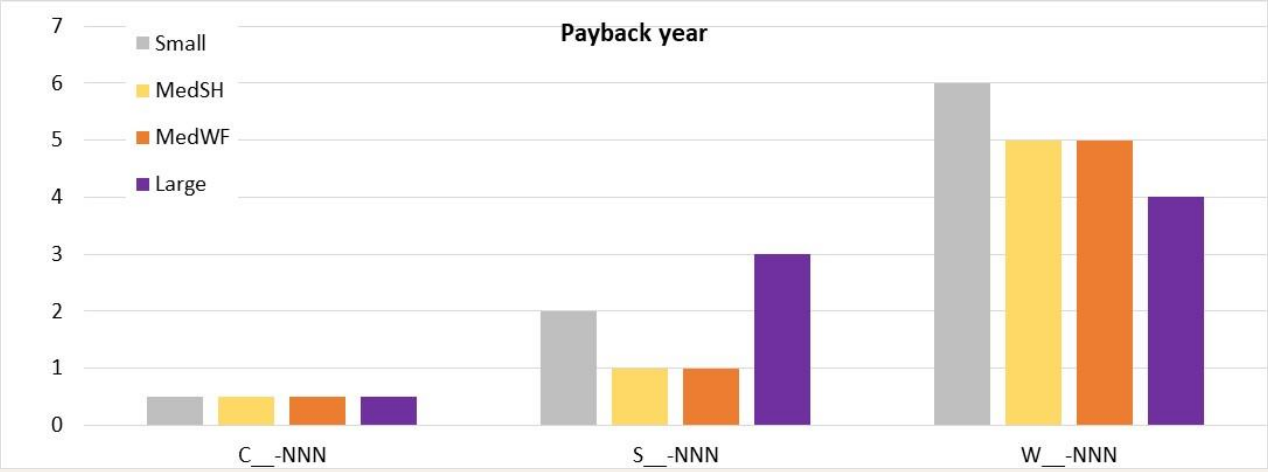


	NoSolar	5kW	5kWBatt
C__-NNN	$1,042	$1,049	$1,654
S__-NNN	$1,952	$2,175	$2,458
W__-NNN	$1,091	$2,414	$2,674

Figure 2: 10-Year NPV of Replacing One Gas Appliance, Medium Home, Perth, Flat Tariff

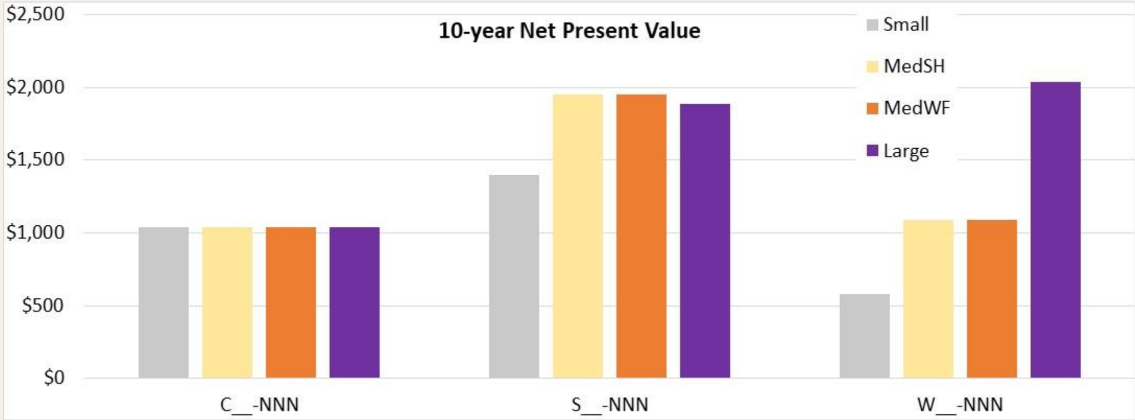
4.1.2. Other Household Types

Results presented in the previous section are consistent across different household types, as shown in the following charts for homes in Perth without solar on a flat tariff. New builds are a special case and will be discussed in a subsequent section:



	Small	MedSH	MedWF	Large
C__-NNN	0.5	0.5	0.5	0.5
S__-NNN	2	1	1	3
W__-NNN	6	5	5	4

Figure 3: Payback Times of Replacing One Gas Appliance, Perth, Flat Tariff, no solar



	Small	MedSH	MedWF	Large
C__-NNN	$1,042	$1,042	$1,042	$1,042
S__-NNN	$1,401	$1,952	$1,951	$1,889
W__-NNN	$580	$1,091	$1,091	$2,039

Figure 4: 10-Year NPV of Replacing One Gas Appliance, Perth, Flat Tariff, no solar

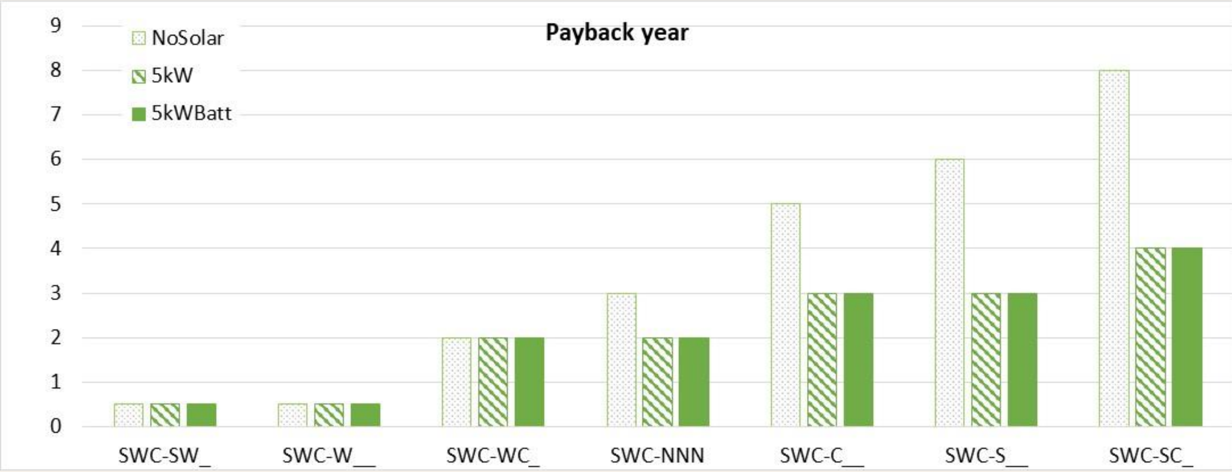
4.2. Existing Homes – Gas All Three Functions

4.2.1. Medium Homes

A household using gas for space heating, water heating and cooking has several different replacement cases, depending on which combination of appliances has failed or are requiring replacement. For a Medium Stay-at-Home Household in Perth without solar on a flat tariff, if only the cooking appliances need replacing, as described in the previous section, choosing electric appliances gives an immediate payback.

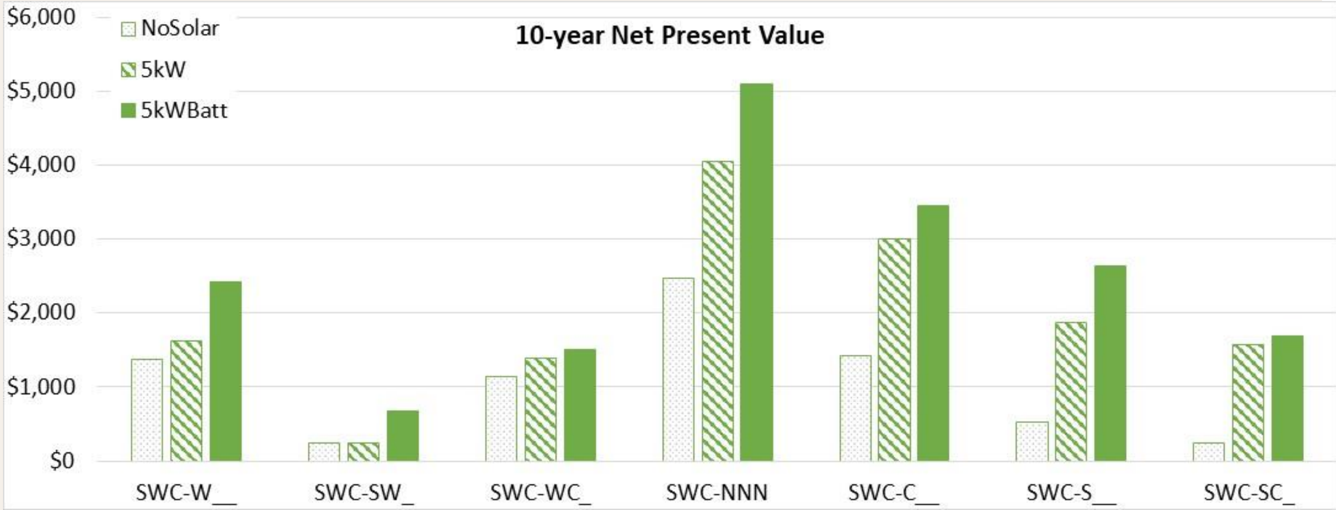
For the same household, replacement cases that eliminate gas space heating are economic, with payback periods ranging from immediate to 5 years and NPVs from $1,000 to $2,400. This is enhanced if the household has solar; in this case payback periods vary from immediate to 3 years and NPVs from $1,300 to $5,000.

It is marginally economic to eliminate gas for hot water while retaining gas for space heating and cooking. Without a solar system, this decision results in a payback period of 8 years and a ten-year NPV of only a couple of hundred dollars.



	NoSolar	5kW	5kWBatt
SWC-SW_	0.5	0.5	0.5
SWC-W__	0.5	0.5	0.5
SWC-WC_	2	2	2
SWC-NNN	3	2	2
SWC-C__	5	3	3
SWC-S__	6	3	3
SWC-SC_	8	4	4

Figure 5: Payback Times of Replacing Multiple Gas Appliances, Medium Home, Perth, Flat Tariff

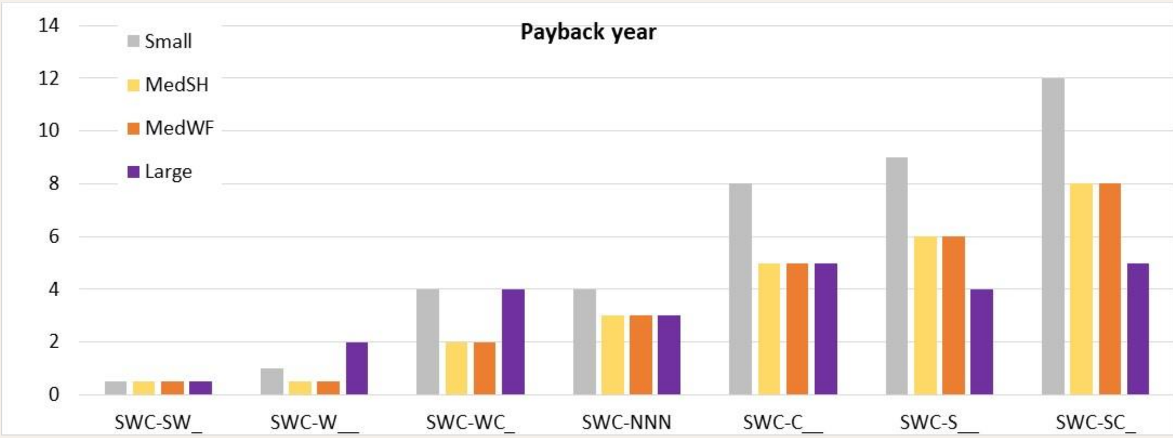


	NoSolar	5kW	5kWBatt
SWC-W__	$1,379	$1,629	$2,425
SWC-SW_	$240	$247	$682
SWC-WC_	$1,138	$1,381	$1,499
SWC-NNN	$2,470	$4,043	$5,098
SWC-C__	$1,427	$2,994	$3,444
SWC-S__	$518	$1,867	$2,640
SWC-SC_	$236	$1,578	$1,689

Figure 6: 10-Year NPVs of Replacing Multiple Gas Appliances, Medium Home, Perth, Flat Tariff

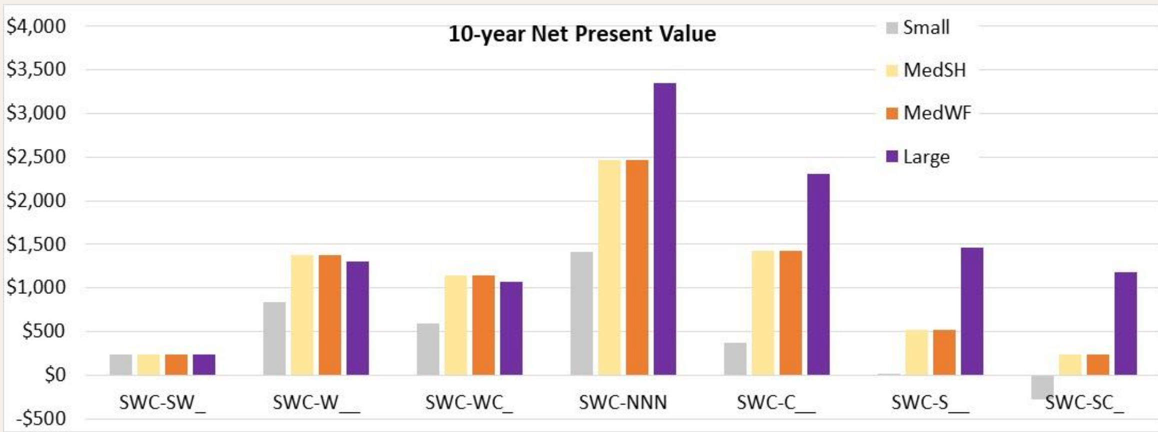
4.2.2. Other Household Types

These results are broadly reflected across all household types except new builds. This is illustrated in the following charts:



	Small	MedSH	MedWF	Large
SWC-SW_	0.5	0.5	0.5	0.5
SWC-W__	1	0.5	0.5	2
SWC-WC_	4	2	2	4
SWC-NNN	4	3	3	3
SWC-C__	8	5	5	5
SWC-S__	9	6	6	4
SWC-SC_	12	8	8	5

Figure 7: Payback Times of Replacing Multiple Gas Appliances, Perth, Flat Tariff



	Small	MedSH	MedWF	Large
SWC-SW_	$240	$240	$240	$240
SWC-W__	$836	$1,379	$1,378	$1,309
SWC-WC_	$596	$1,138	$1,138	$1,068
SWC-NNN	$1,415	$2,470	$2,469	$3,347
SWC-C__	$373	$1,427	$1,427	$2,305
SWC-S__	$14	$518	$518	$1,458
SWC-SC_	-$274	$236	$236	$1,182

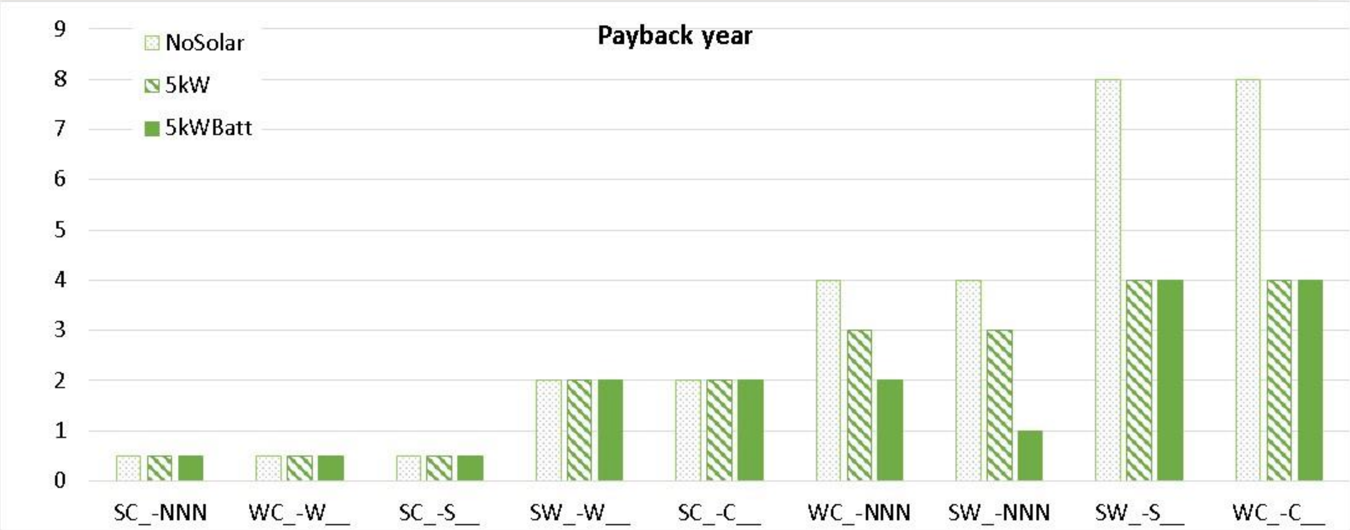
Figure 8: 10-Year NPVs of Replacing Multiple Gas Appliances, Perth, Flat Tariff

4.3. Existing Homes – Gas for Two Functions

4.3.1. Medium Homes

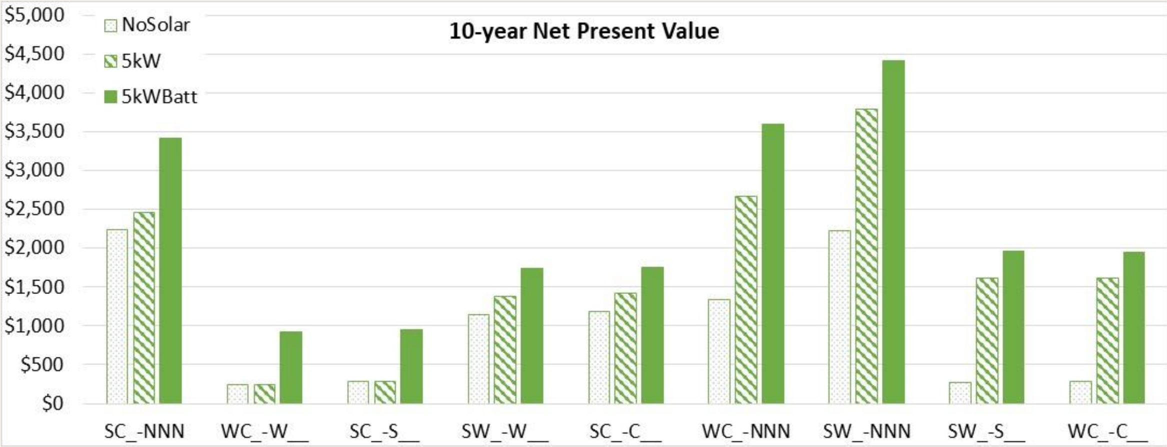
As for the cases discussed above, households using gas for two functions receive attractive economic benefits when replacing both functions with efficient electric appliances, assuming the gas appliances had reached end-of-life. For a Medium Stay-at-Home Household in Perth on a flat tariff, these cases achieve payback in 4 years or less and deliver 10-year NPVs between $1,300 and $3,500. Cases at the upper end are those where solar systems are installed.

The economics are also very good where gas is eliminated for either cooking or space heating but retaining one other gas appliance. Eliminating a water heater but retaining another gas appliance is a break-even prospect unless a solar system is present, in which case paybacks are around 4 years and 10-year NPVs are over $1,500.



	NoSolar	5kW	5kWBatt
SC_-NNN	0.5	0.5	0.5
WC_-W__	0.5	0.5	0.5
SC_-S__	0.5	0.5	0.5
SW_-W__	2	2	2
SC_-C__	2	2	2
WC_-NNN	4	3	2
SW_-NNN	4	3	1
SW_-S__	8	4	4
WC_-C__	8	4	4

Figure 9: Payback Times of Replacing Multiple Gas Appliances, Medium Home, Perth, Flat Tariff



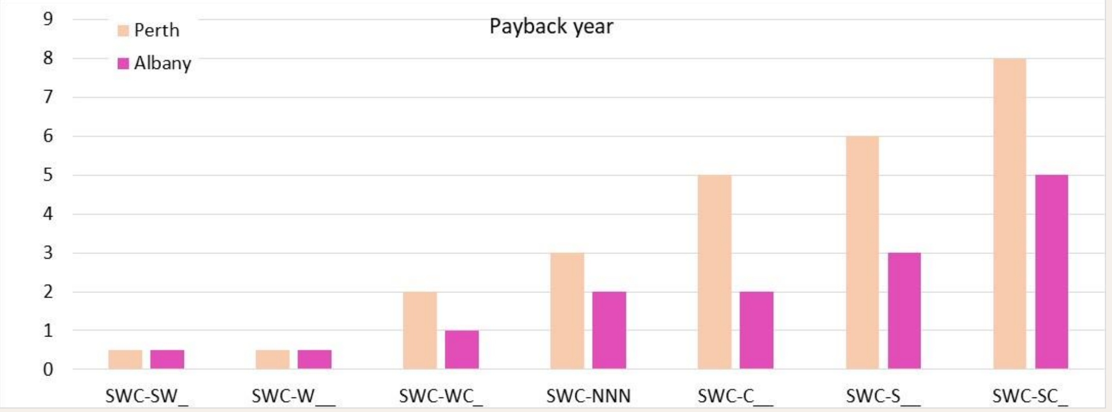
	NoSolar	5kW	5kWBatt
SC_-NNN	$2,234	$2,464	$3,410
WC_-W__	$240	$247	$926
SC_-S__	$283	$289	$951
SW_-W__	$1,138	$1,381	$1,743
SC_-C__	$1,192	$1,415	$1,756
WC_-NNN	$1,331	$2,662	$3,599
SW_-NNN	$2,230	$3,795	$4,417
SW_-S__	$278	$1,620	$1,958
WC_-C__	$289	$1,612	$1,945

Figure 10: 10-Year NPVs of Replacing Multiple Gas Appliances, Medium Home, Perth, Flat Tariff

4.4. Geography

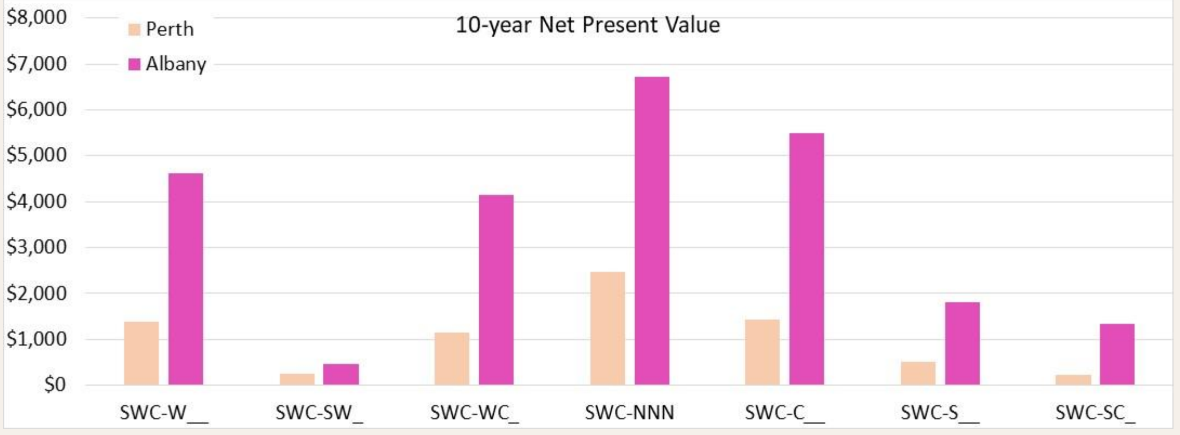
The economic benefits of switching to heat pump hot water and reverse cycle air conditioners are higher in Albany than in Perth, due to Albany's colder climate and Albany's higher gas tariffs. This is illustrated in the following charts for a Medium Stay-at-Home Household using gas for three functions with no solar on a flat electricity tariff.

For a household where all gas appliances need replacing, payback time is halved and NPV is doubled:



	Perth	Albany
SWC-SW_	0.5	0.5
SWC-W__	0.5	0.5
SWC-WC_	2	1
SWC-NNN	3	2
SWC-C__	5	2
SWC-S__	6	3
SWC-SC_	8	5

Figure 11: Payback Times of Replacing Multiple Gas Appliances, Medium Home, Perth & Albany, Flat Tariff, no solar



	Perth	Albany
SWC-W__	$1,379	$4,610
SWC-SW_	$240	$470
SWC-WC_	$1,138	$4,140
SWC-NNN	$2,470	$6,712
SWC-C__	$1,427	$5,480
SWC-S__	$518	$1,810
SWC-SC_	$236	$1,340

Figure 12: 10-Year NPVs of Replacing Multiple Gas Appliances, Medium Home, Perth & Albany, Flat Tariff

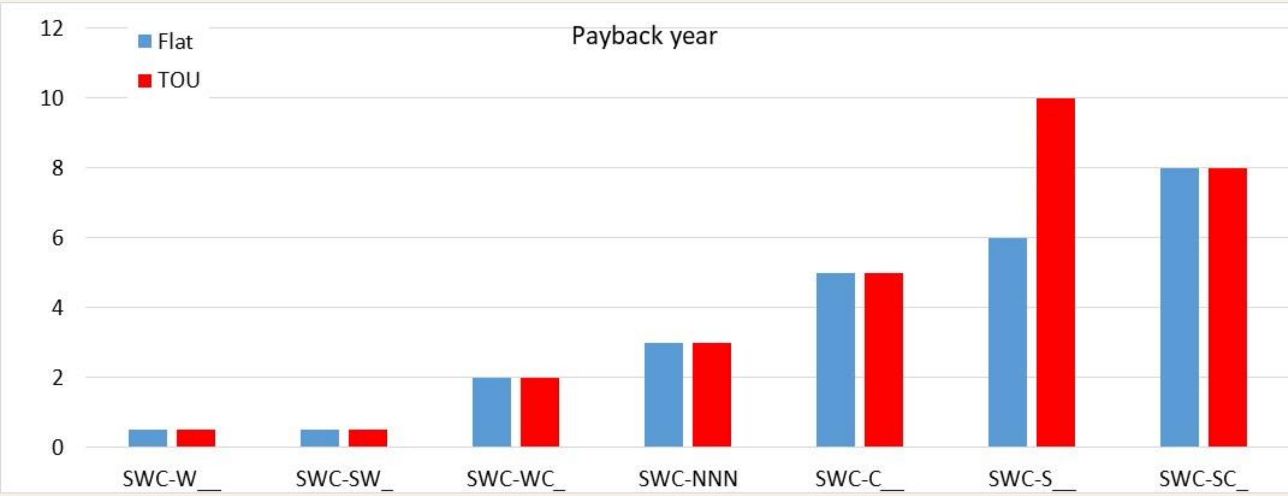
4.5. Tariff Type

For the household types modelled, Time-of-Use (TOU) electricity tariffs resulted in slightly higher bills than flat tariffs.

The effect of this tariff change was mixed but minor, in some cases slightly favouring electric appliances and in others gas. The charts below show this for a Medium Stay-at-Home Household in Perth with no solar originally using gas for three functions.

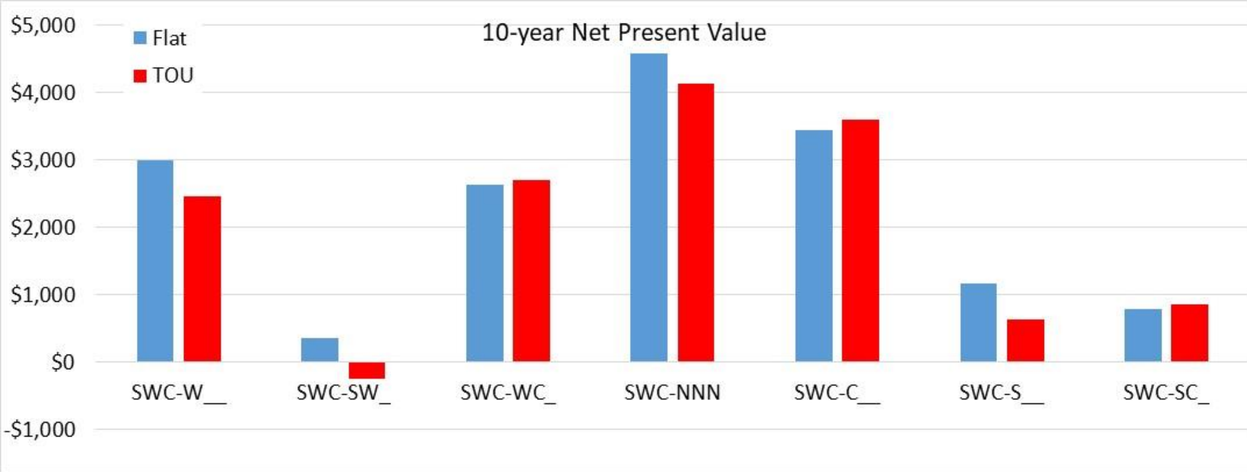
The result for the replacement case "SWC-S__" is an interesting outlier. On detailed investigation, electric cooking with a TOU electricity bill costs $104 more annually than with a flat bill because it occurs during peak time. This difference is significant compared to the small bill saving of switching the hot water to electric, so when switching both together under a TOU tariff the payback time increases significantly. This is not observable when fuel-switching cooking alone, or cooking plus space heating, because in both those cases the electric appliances are cheaper (including labour) than the gas alternatives so payback time is immediate.

It should be noted that these results are pursuant to the existing (2020) time bands provided by Synergy (**Appendix F**). Future changes in the tariff prices or time bands would impact these results.



	Flat	TOU
SWC-W__	0.5	0.5
SWC-SW_	0.5	0.5
SWC-WC_	2	2
SWC-NNN	3	3
SWC-C__	5	5
SWC-S__	6	10
SWC-SC_	8	8

Figure 13: Payback Times of Replacing Multiple Gas Appliances, Medium Home, Perth & Albany, Flat & TOU Tariff



	Flat	TOU
SWC-W__	$2,994	$2,458
SWC-SW_	$355	-$250
SWC-WC_	$2,639	$2,709
SWC-NNN	$4,591	$4,131
SWC-C__	$3,454	$3,598
SWC-S__	$1,164	$634
SWC-SC_	$788	$863

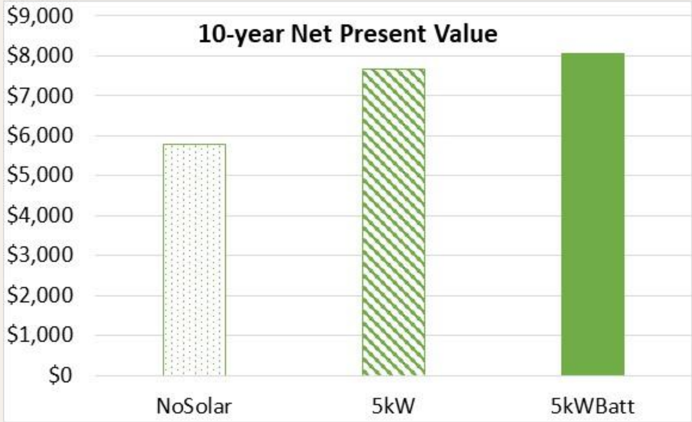
Figure 14: 10-Year NPVs of Replacing Multiple Gas Appliances, Medium Home, Perth & Albany, Flat & TOU Tariff, no solar

4.6. New Homes

A new home that avoids a gas connection achieves very good economics.

We estimate that to connect and plumb a new home for space heating, water heating and cooking would cost about $2,400. This avoided capital expense outweighs the additional expense of installing efficient electric appliances instead of their cheaper gas equivalents, so the payback of this decision is immediate.

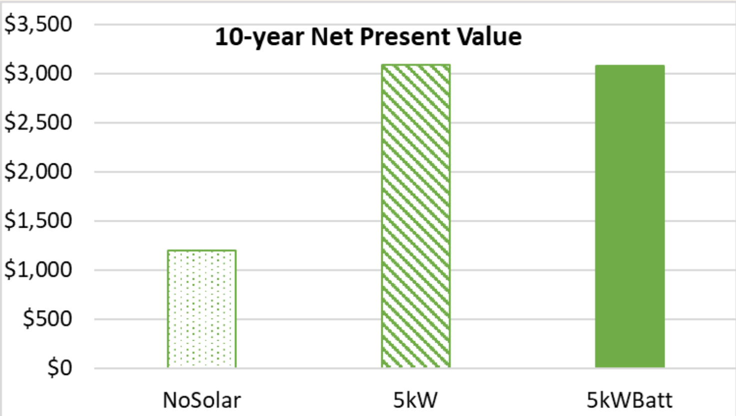
In Perth on a flat tariff, the net present value over ten years is approximately $5,700 without a solar system and is a couple of thousand higher with solar. This is shown in the following chart:



NoSolar	$5,772
5kW	$7,661
5kWBatt	$8,071

Figure 15: 10-Year NPVs of Choosing an All-Electric New Home Instead of Dual Fuel – Medium Home, Perth, Flat Tariff

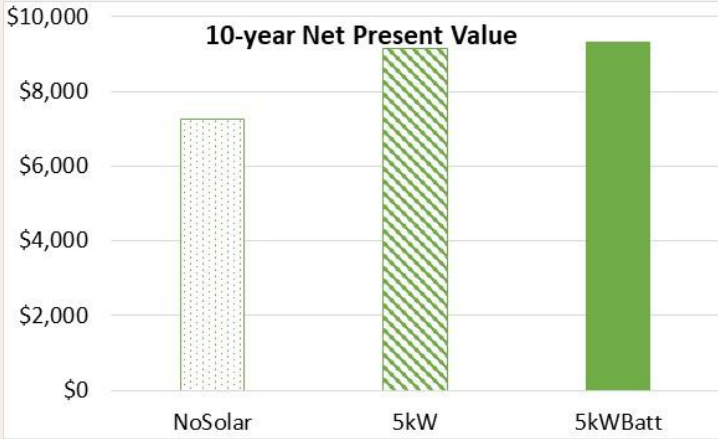
If a household building a new home chooses to install a gas cooktop, most of the benefit noted above is lost because the expensive gas connection is still required. In this case the net present value of reducing the number of gas appliance installs is about $1,000, or about $3,000 with a solar system as shown in the following chart:



NoSolar	$1,200
5kW	$3,085
5kWBatt	$3,083

Figure 16: 10-Year NPVs of Choosing a New All-Electric Home but with Gas Cooking – Medium Home, Perth, Flat Tariff

A new home in Albany achieves even greater value from installing efficient electric appliances rather than gas ones, as shown in the following chart:



NoSolar	$7,258
5kW	$9,156
5kWBatt	$9,327

Figure 17: 10-Year NPVs of Choosing an All-Electric New Home Instead of Dual Fuel – Medium Home, Albany, Flat Tariff

4.7. Homes with Existing Air Conditioners

All analysis in this report assumes that when a gas heater in the living area reaches end of life, the household must purchase a new appliance to replace it.

However, many homes already have an efficient reverse cycle air conditioner that was installed for its cooling function. Many consumers are unaware that it can deliver heat, or they may be under the misapprehension that it would be very expensive to use for heating.

The most economic option for such homes is to start heating with their existing air conditioner, avoiding any need to purchase a new appliance. The payback time of this decision is immediate since there is no up-front cost. The NPV can be estimated by adding the cost of purchasing a new air conditioner to the NPV values in the charts above.

Households with both a gas heater and a reverse-cycle air conditioner are better-off economically to switch to electric heating even if the gas heater is still in good working order. In all scenarios we modelled, this decision lowers the household's total energy bills regardless of other appliances, home type, solar case, location or tariff.

This option is not available to homes that have an evaporative cooler, or an air conditioner which can only cool.

4.8. Impact on the Electricity Grid

The Renew modelling involved calculating and adjusting 30-minute electricity consumption datasets for each household type in each scenario. As such, Renew was able to model electricity import and export from/to the grid, for the household before and after fuel switching. This is of significant interest to the electricity industry in general, and in particular for electricity networks, given solar PV's impact on the "duck curve"[22].

The following data sets have been modelled for consideration. All are for the Medium Stay-at-Home household in Perth. Half-hourly imports and exports shown below are averaged over all days in each season, based on typical meteorological year data. Series are shown separately for the three solar cases discussed previously plus a new case where the battery is "smart". On sunny days the normal battery case (here named "buffer[23]") will often have the battery fully charged by midday and the household will still export to the grid at high power levels in the early afternoon, exacerbating the grid's duck curve.

On cloudy days the smart battery case charges as per the buffer case, as soon as there's excess solar generation available. However, on sunny days it refers to weather forecast data to identify the extent it can avoid charging around midday yet still achieve a full battery charge by sunset. It makes a charging plan at the start of each day and then follows this plan through the day. As the needs of the electricity network changes, battery smart controllers can adapt to deal with evolving network issues.

Please note that when electricity is used for water heating, the heat pump hot water system is set to run from 11am which creates a middle of the day "hump" in electricity consumption. As can be seen below, consumption jumps by around 0.5 kWh in the half hour interval just after 11am – equivalent to a heat pump electrical power of 1 kW over that hour. This increase could be better managed (i.e. smoothed) by a number of technologies and product features associated with heat pumps, including:

- smart relays on solar inverters that divert excess solar energy to hot water systems throughout the day; and
- reducing the power input setting on the heat pump, such that it lowers instantaneous power usage whilst spreading out the heating cycle over the longer period of time.

Such features were outside the scope of this analysis but can be modelled by Renew for further consideration.

Modelling also included cooking for a specific time of day (i.e. 6pm). In reality, diversity among household cooking patterns will spread out this hump.

The following charts consider the Medium Stay-at-Home household with no solar and all three gas appliances in different seasons. A positive kWh figure indicates import from the grid, whilst a negative kWh figure refers to solar export to the grid.

[22] https://en.wikipedia.org/wiki/Duck_curve

[23] A solar buffer battery strategy is the simplest, non-controlled strategy whereby batteries simple charge when excess solar generation is available (until the battery is full); and discharges as soon as solar generation falls below the level of consumption (until the battery is empty). This logic is the standard basis for most products currently available in the market.

4.8.1. Summer

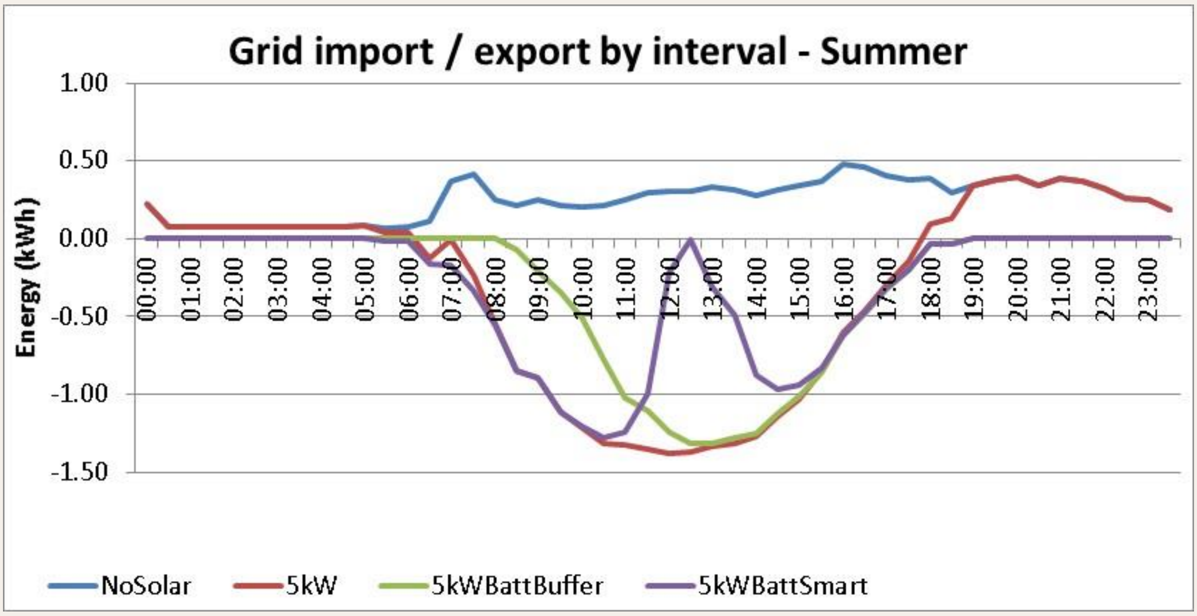


Figure 18: Summer Grid Import / Export – Medium Stay at Home Household, Perth, All 3 Gas Appliances

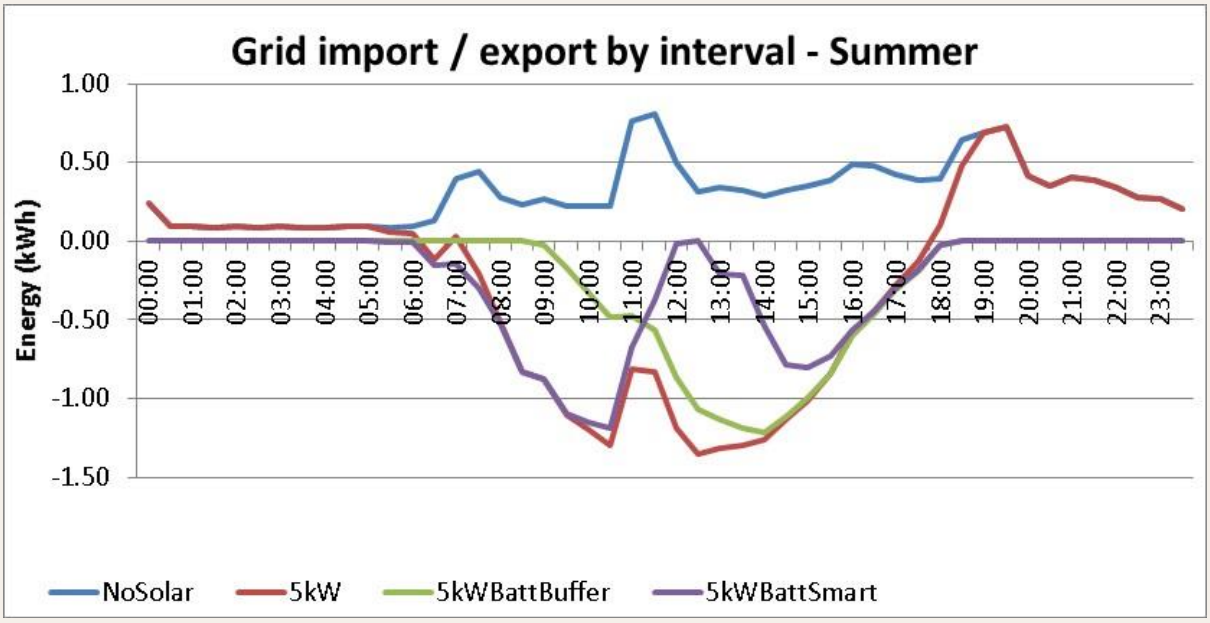


Figure 19: Summer Grid Import / Export – Medium Stay at Home Household, Perth, No Gas Appliances

4.8.2. Autumn

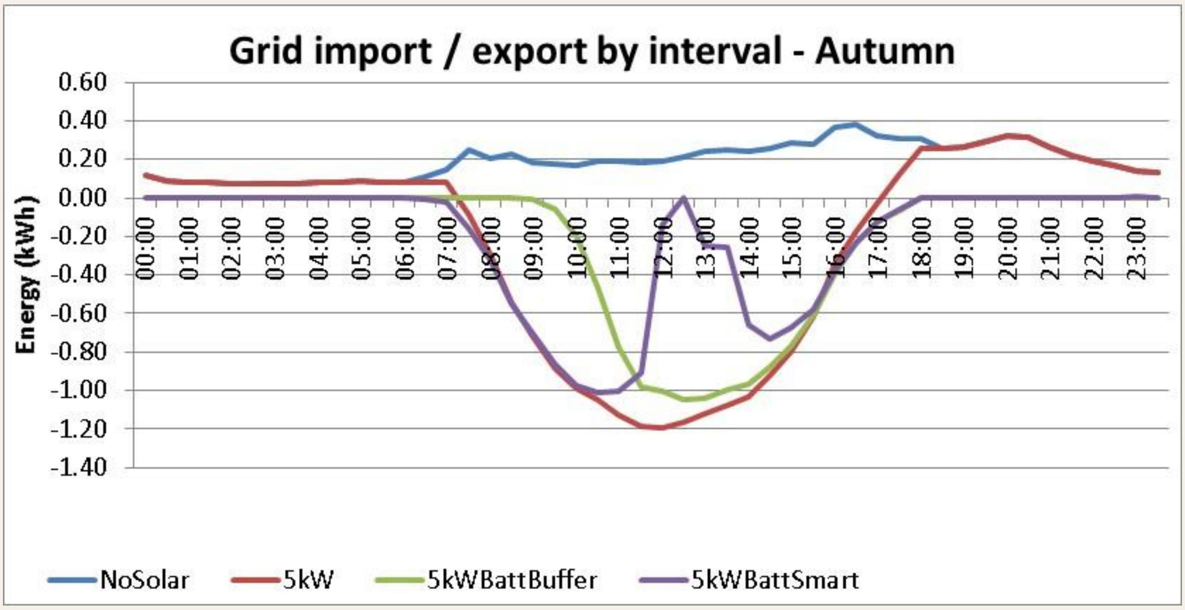


Figure 20: Autumn Grid Import / Export – Medium Stay at Home Household, Perth, All 3 Gas Appliances

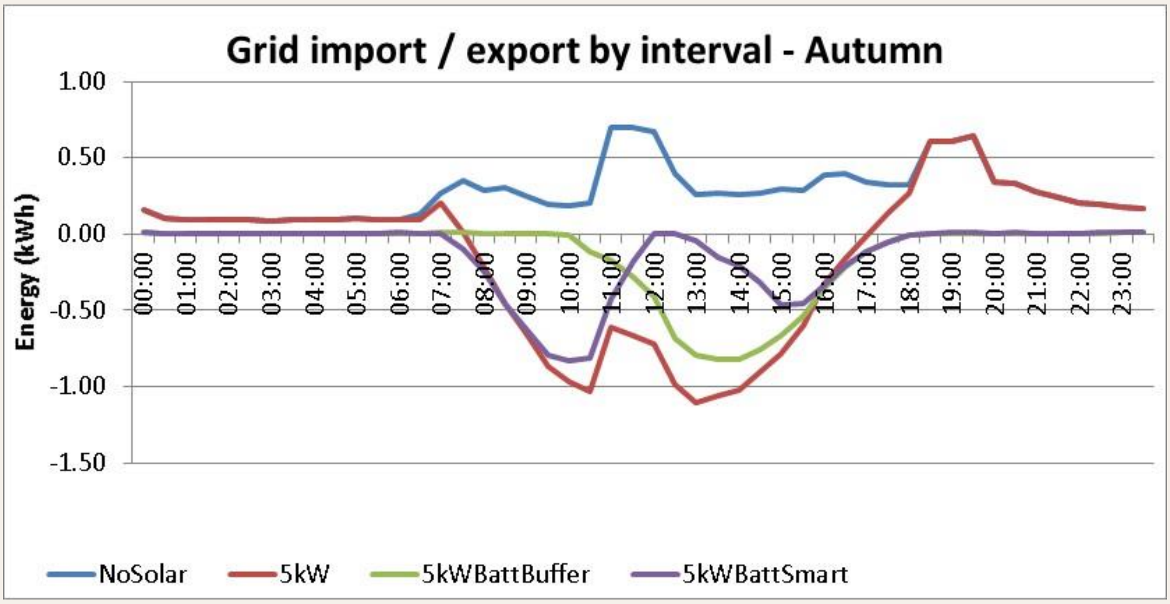


Figure 21: Autumn Grid Import / Export – Medium Stay at Home Household, Perth, No Gas Appliances

4.8.3. Winter

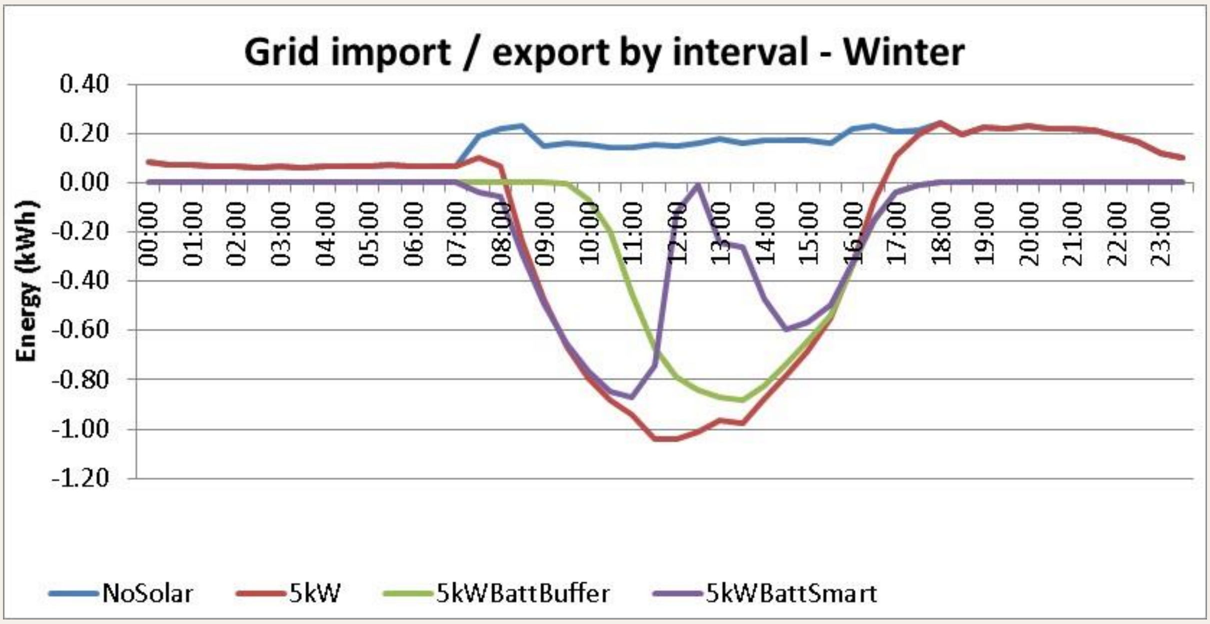


Figure 22: Winter Grid Import / Export – Medium Stay at Home Household, Perth, All 3 Gas Appliances

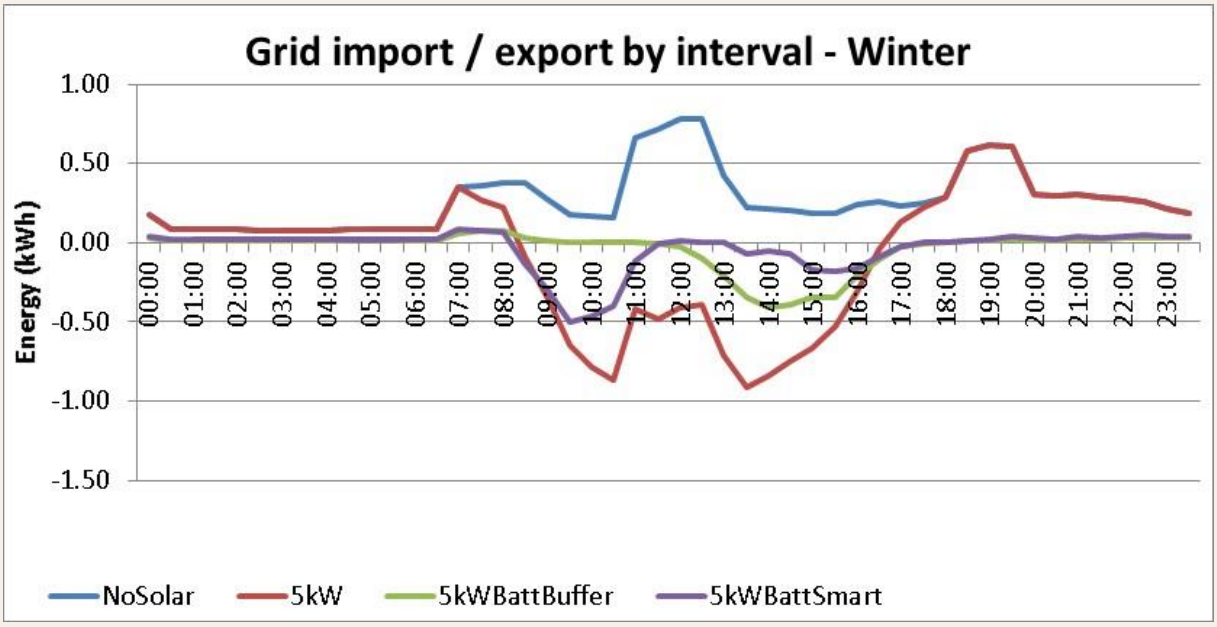


Figure 23: Winter Grid Import / Export – Medium Stay at Home Household, Perth, No Gas Appliances

4.8.4. Spring

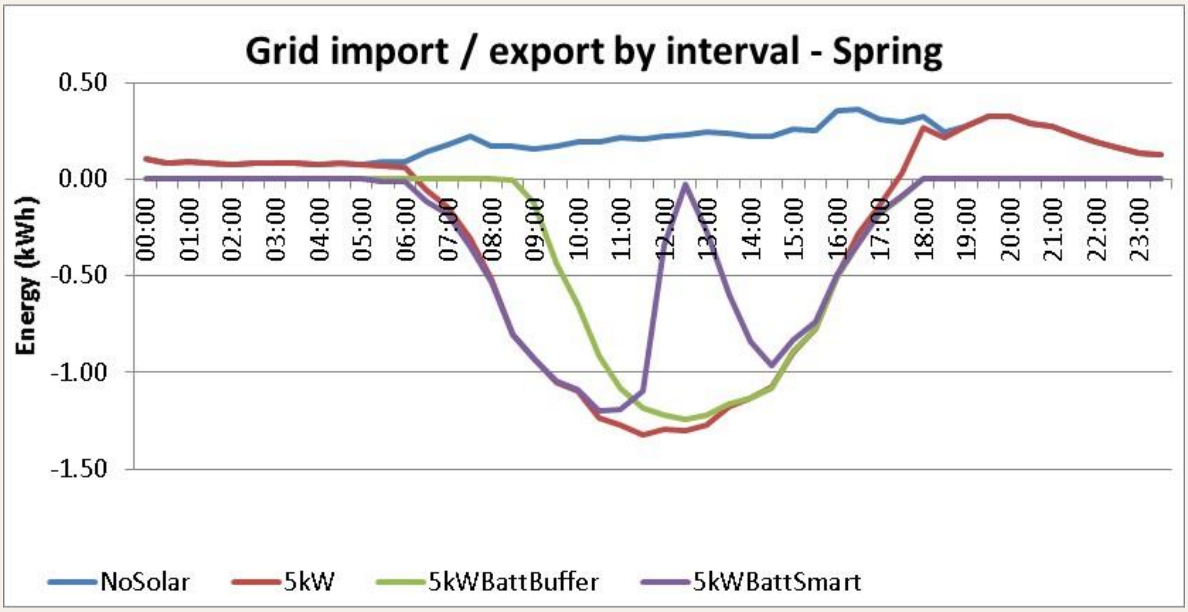


Figure 24: Spring Grid Import / Export – Medium Stay at Home Household, Perth, All 3 Gas Appliances

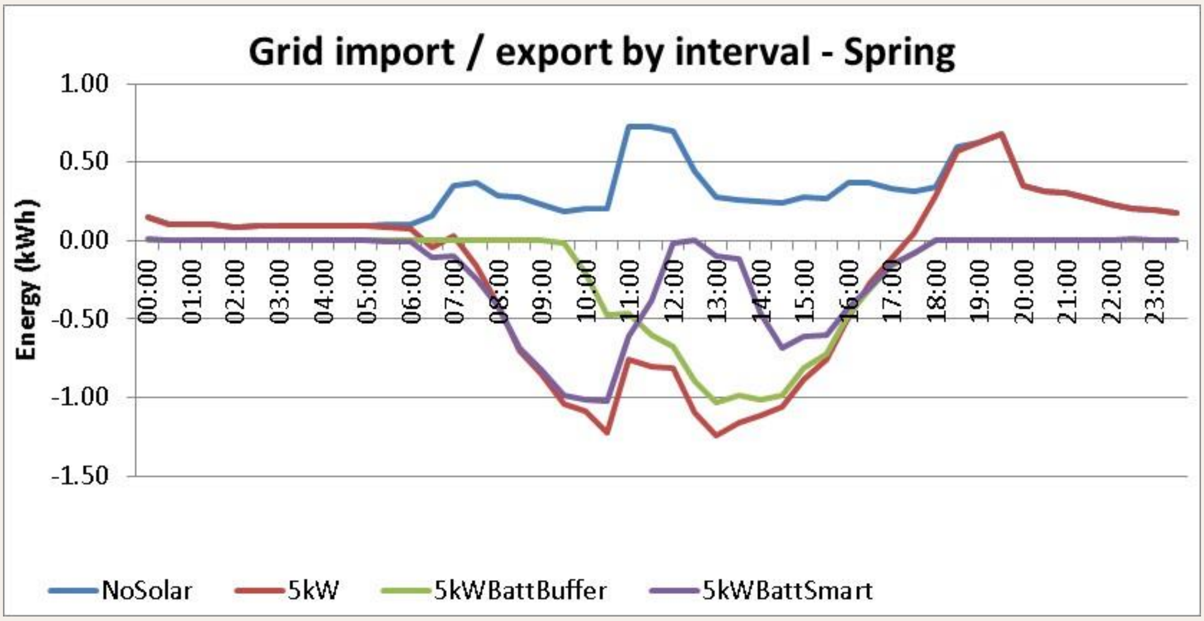


Figure 25: Spring Grid Import / Export – Medium Stay at Home Household, Perth, No Gas Appliances

5. Findings & Recommendations

5.1. Findings

This report finds that in most cases, when a gas appliance requires replacing it's economic to install an efficient electric appliance instead. This implies that over time, as appliances reach the end of life, most homes would migrate to all-electric and disconnect from gas if acting on an economic basis.

The results here represent decisions made in isolation only for gas appliances that require replacing. In some cases, it may also be economic to replace an appliance that has *not* worn out. For example, if you're replacing a worn-out gas hot water system leaving only gas cooking, then it may be economic to replace the cooking appliances[24] in order to save on the gas supply charges. Such decisions are beyond the scope of this project but would tend to accelerate a household's economic migration away from gas.

To provide a summary, economic results of each fuel switching decision were categorised according to their NPV. If the NPV is greater than $1,000 the switch is considered "economic", if it's more than $1,000 below zero it's considered "uneconomic" and if it's between those values then it's "marginal".

The following tables summarise the economics of different appliance replacement cases. Rows are grouped by the number of existing gas appliances, from 1 to 3. A green cell indicates that switching to efficient electric appliances is economic, red means uneconomic and grey means marginal.

When using these results, it should be remembered that households make appliances choices on many criteria other than economics, and that economic results will vary with site-specific conditions such as installation costs and appliance usage.

[24] There are other non-economic considerations for consumers when moving from gas to induction cooking, explained here: https://renew.org.au/renew-magazine/buyers-guides/induction-cooktop-guide/

5.1.1. New Homes

Regardless of location or tariff, it's economic for new homes to avoid a gas connection and install efficient electric appliances instead. With efficient electric appliances running costs are lower, and costs are avoided to install gas plumbing pipes and pay ongoing gas supply charges.

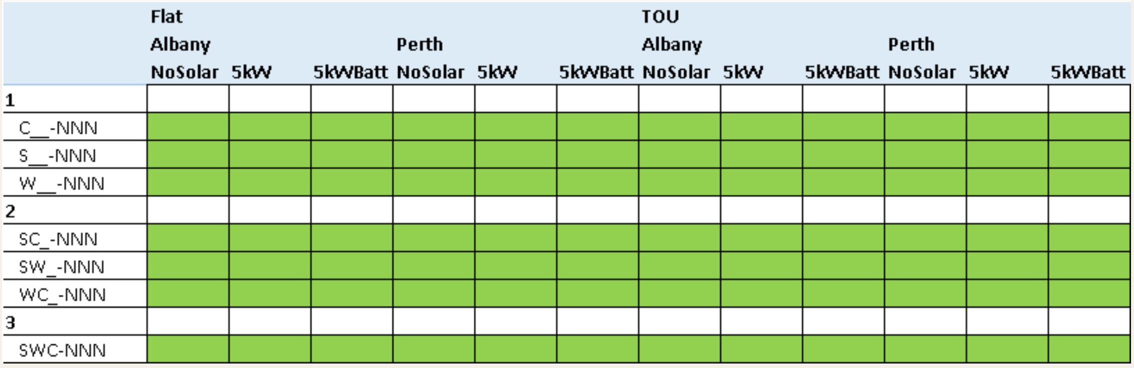


Figure 26: Economics of installing efficient electric appliances instead of gas in new homes.

A supplementary finding is that if a household building a new home wants a mains gas connection just for cooking, it's still economic to install efficient electric appliances for heating and hot water.

Legend

Economic	Marginal	Uneconomic

SWC-NNN indicates the household moves from using gas for space heating, water heating and cooking to using gas for nothing.
MedSH: Medium stay-at-home family.
MedWF: Medium working family.
Flat: Flat tariff. TOU: Time of Use tariff.

5.1.2. Homes with One Gas Appliance (Needs Replacing)

Where a household's sole gas appliance needs replacing, in almost all cases it's economic to install an efficient electric replacement instead of a gas one. This decision eliminates the gas bill including the gas daily supply charge, which is 24c per day in Perth and 22c in Albany.

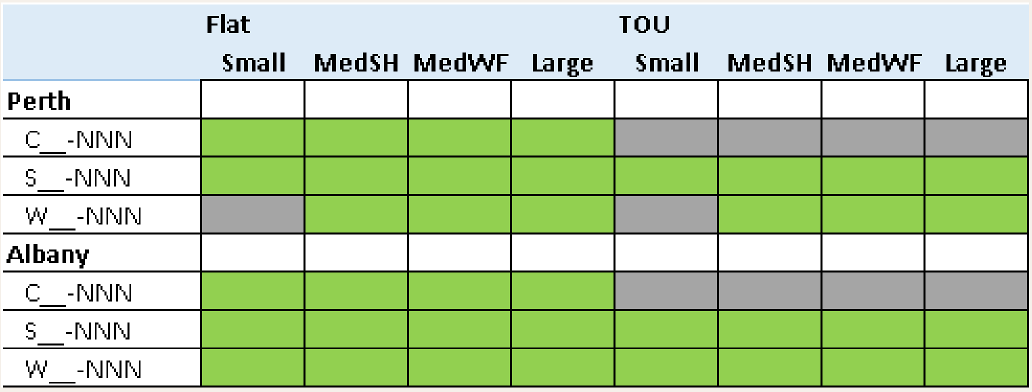


Figure 27: Replacement economics for homes without solar with only one gas appliance.

In a few cases the economics are marginal including:

- Small homes in Perth without solar, where the gas water heater needs replacing.
- Homes on a time-of-use tariff where the cooking appliances need replacing and they have no solar, or they have solar but no battery.

Legend

Economic	Marginal	Uneconomic

SWC-NNN indicates the household moves from using gas for space heating, water heating and cooking to using gas for nothing.
MedSH: Medium stay-at-home family.
MedWF: Medium working family.
Flat: Flat tariff. TOU: Time of Use tariff.

5.1.3. Homes where all Gas Appliances need replacing

There will be times when a gas appliance fails, and the other existing gas appliances are also approaching end-of-life. In such cases the homeowner might consider replacing all of them at once. In most cases it's economic to install efficient electric appliances.

	Flat				TOU			
	Small	MedSH	MedWF	Large	Small	MedSH	MedWF	Large
Perth								
1								
C__-NNN	Economic	Economic	Economic	Economic	Marginal	Marginal	Marginal	Marginal
S__-NNN	Economic	Economic	Economic	Economic	Economic	Economic	Economic	Economic
W__-NNN	Marginal	Economic	Economic	Economic	Marginal	Economic	Economic	Economic
2								
SC_-NNN	Economic	Economic	Economic	Economic	Economic	Economic	Economic	Economic
SW_-NNN	Economic	Economic	Economic	Economic	Economic	Economic	Economic	Economic
WC_-NNN	Marginal	Economic	Economic	Economic	Marginal	Marginal	Marginal	Economic
3								
SWC-NNN	Economic	Economic	Economic	Economic	Marginal	Economic	Economic	Economic
Albany								
1								
C__-NNN	Economic	Economic	Economic	Economic	Marginal	Marginal	Marginal	Marginal
S__-NNN	Economic	Economic	Economic	Economic	Economic	Economic	Economic	Economic
W__-NNN	Economic	Economic	Economic	Economic	Economic	Economic	Economic	Economic
2								
SC_-NNN	Economic	Economic	Economic	Economic	Economic	Economic	Economic	Economic
SW_-NNN	Economic	Economic	Economic	Economic	Economic	Economic	Economic	Economic
WC_-NNN	Economic	Economic	Economic	Economic	Economic	Economic	Economic	Economic
3								
SWC-NNN	Economic	Economic	Economic	Economic	Economic	Economic	Economic	Economic

Figure 28: Replacement economics when all gas appliances need replacing.

Legend

Economic	Marginal	Uneconomic

SWC-NNN indicates the household moves from using gas for space heating, water heating and cooking to using gas for nothing.
MedSH: Medium stay-at-home family.
MedWF: Medium working family.
Flat: Flat tariff. TOU: Time of Use tariff.

Some homes in Perth without solar electricity had marginal replacement economics including:

- Homes on a TOU tariff using gas for cooking only.
- Small homes using gas for water heating, water heating and cooking, or all three functions
- Medium homes with a time-of-use tariff using gas for water heating and cooking.

In Albany the only cases in the "marginal" category was replacing cooking on a TOU tariff.

5.1.4. Existing Homes Without Solar

The following two tables show replacement economics for all homes without a solar electricity system.

	Flat				TOU			
	Small	MedSH	MedWF	Large	Small	MedSH	MedWF	Large
1								
C__-NNN	Economic	Economic	Economic	Economic	Marginal	Marginal	Marginal	Marginal
S__-NNN	Economic	Economic	Economic	Economic	Economic	Economic	Economic	Economic
W__-NNN	Marginal	Economic	Economic	Economic	Marginal	Economic	Economic	Economic
2								
SC_-NNN	Economic	Economic	Economic	Economic	Economic	Economic	Economic	Economic
SW_-NNN	Economic	Economic	Economic	Economic	Economic	Economic	Economic	Economic
WC_-NNN	Marginal	Economic	Economic	Economic	Marginal	Marginal	Marginal	Economic
SC_-C__	Marginal	Economic	Economic	Economic	Marginal	Economic	Economic	Economic
SW_-W__	Marginal	Economic	Economic	Economic	Marginal	Economic	Economic	Economic
SW_-S__	Marginal	Marginal	Marginal	Economic	Marginal	Marginal	Marginal	Economic
WC_-C__	Marginal	Marginal	Marginal	Economic	Marginal	Marginal	Marginal	Economic
SC_-S__	Marginal	Marginal	Marginal	Marginal	Marginal	Marginal	Marginal	Marginal
WC_-W__	Marginal	Marginal	Marginal	Marginal	Marginal	Marginal	Marginal	Marginal
3								
SWC-NNN	Economic	Economic	Economic	Economic	Marginal	Economic	Economic	Economic
SWC-W__	Marginal	Economic	Economic	Economic	Marginal	Marginal	Marginal	Marginal
SWC-C__	Marginal	Economic	Economic	Economic	Marginal	Economic	Economic	Economic
SWC-WC_	Marginal	Economic	Economic	Economic	Marginal	Economic	Economic	Economic
SWC-SC_	Marginal	Marginal	Marginal	Economic	Marginal	Marginal	Marginal	Economic
SWC-S__	Marginal	Marginal	Marginal	Economic	Marginal	Marginal	Marginal	Marginal
SWC-SW_	Marginal	Marginal	Marginal	Marginal	Marginal	Marginal	Marginal	Marginal

Table 12 Economics of replacing gas appliances with efficient electric: Perth, no solar.

	Flat				TOU			
	Small	MedSH	MedWF	Large	Small	MedSH	MedWF	Large
1								
C__-NNN	Economic	Economic	Economic	Economic	Marginal	Marginal	Marginal	Marginal
S__-NNN	Economic	Economic	Economic	Economic	Economic	Economic	Economic	Economic
W__-NNN	Economic	Economic	Economic	Economic	Economic	Economic	Economic	Economic
2								
SC_-NNN	Economic	Economic	Economic	Economic	Economic	Economic	Economic	Economic
SW_-NNN	Economic	Economic	Economic	Economic	Economic	Economic	Economic	Economic
WC_-NNN	Economic	Economic	Economic	Economic	Economic	Economic	Economic	Economic
SC_-C__	Economic	Economic	Economic	Economic	Economic	Economic	Economic	Economic
SW_-W__	Economic	Economic	Economic	Economic	Economic	Economic	Economic	Economic
SW_-S__	Marginal	Economic	Economic	Economic	Marginal	Economic	Economic	Economic
WC_-C__	Marginal	Economic	Economic	Economic	Marginal	Economic	Economic	Economic
SC_-S__	Marginal	Marginal	Marginal	Marginal	Marginal	Marginal	Marginal	Marginal
WC_-W__	Marginal	Marginal	Marginal	Marginal	Marginal	Marginal	Marginal	Marginal
3								
SWC-NNN	Economic	Economic	Economic	Economic	Economic	Economic	Economic	Economic
SWC-W__	Economic	Economic	Economic	Economic	Economic	Economic	Economic	Economic
SWC-C__	Economic	Economic	Economic	Economic	Economic	Economic	Economic	Economic
SWC-WC_	Economic	Economic	Economic	Economic	Economic	Economic	Economic	Economic
SWC-SC_	Marginal	Economic	Economic	Economic	Marginal	Economic	Economic	Economic
SWC-S__	Economic	Economic	Economic	Economic	Marginal	Economic	Economic	Economic
SWC-SW_	Marginal	Marginal	Marginal	Marginal	Marginal	Marginal	Marginal	Marginal

Table 13 Replacement economics: Albany, no solar.

There are several cases where the economics are marginal, but the majority are clearly economic..

Legend

Economic	Marginal	Uneconomic

SWC-NNN indicates the household moves from using gas for space heating, water heating and cooking to using gas for nothing.
MedSH: Medium stay-at-home family.
MedWF: Medium working family.
Flat: Flat tariff, TOU: Time of Use tariff

5.1.5. Existing Homes with Solar

For homes with a solar electricity system, with or without aa battery[25], when a gas appliance requires replacement in almost all cases it's economic to install an efficient electric appliance rather than a new gas one.

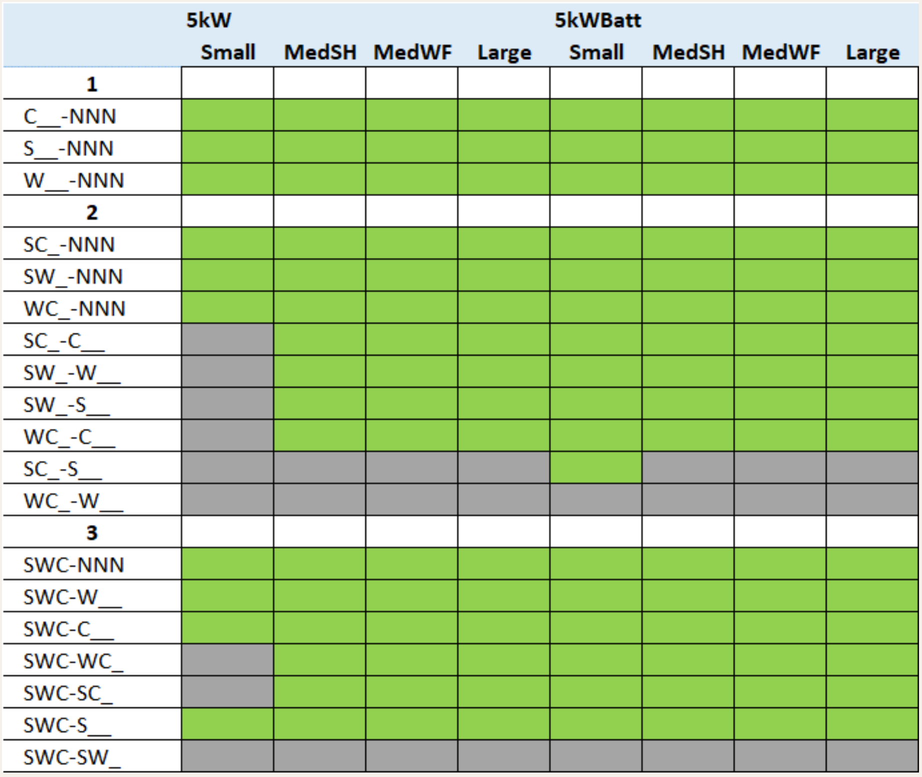


Figure 29: Replacement economics for homes Perth with a solar system on a flat tariff.

Legend

Economic	Marginal	Uneconomic

SWC-NNN indicates the household moves from using gas for space heating, water heating and cooking to using gas for nothing.
MedSH: Medium stay-at-home family.
MedWF: Medium working family.
Flat: Flat tariff. TOU: Time of Use tariff.

The exceptions were found in Perth but not Albany. The following cases fell into the "marginal" category:

- Homes where the cooking appliances need replacing, but they still have other gas appliance(s).
- Small homes with a space heater that needs replacing, but they'll still heat water with gas.

Homes with solar panels but no battery had similar results to the ones with a battery. A few extra cases in Perth (but not Albany) fell into the "marginal" category:

- Small homes replacing a gas appliance with efficient electric but still retaining at least one more appliance on gas.
- On a time-of-use tariff only, as per the previous point for medium homes as well.

[25] Modelling assumed 5 kilowatts of solar panels and 13.5 kilowatt-hours of energy storage capacity.

Although these cases fall into the "marginal" category, solar households may have opportunities to obtain greater economic advantage from switching to efficient electric appliances. For example, they may be able to adjust when they cook and use air conditioners to make use of sunny times of day.

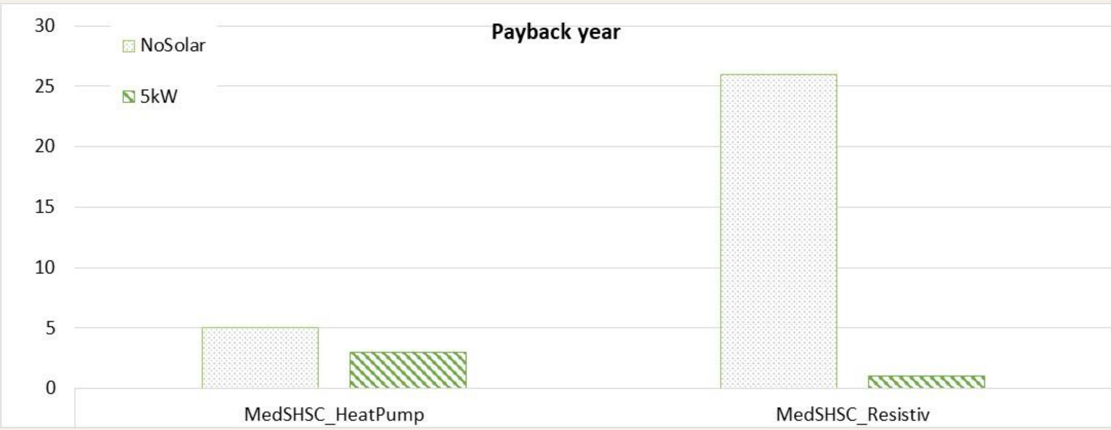
5.1.6. Resistive hot water systems

Resistive hot water systems were considered as a sensitivity analysis. These hot water systems are cheaper to purchase than a heat pump hot water system, as they simply heat the water with a resistor, like an electric kettle. However, they consume much more energy than a heat pump.

Resistive water heating was modelled as a replacement for an instantaneous gas hot water system that's reached end-of life, rather than installing another gas unit. This was for a medium stay-at-home family in Perth with no other gas appliances, on a flat tariff, both with and without a solar system. In the simulation, the resistive heater was set on a timer to run from 11:00am. A resistive heating element with a power level of 1.8 kW was selected, as it was found to result in lower bills than the more common 3.6 kW element. This is because on cloudy days the solar system's generation power is often insufficient to cover the larger element, resulting in importing some electricity from the grid to make up the difference. This occurs to a small extent even with the 1.8 kW element, on very cloudy days. The resistive water heater was assumed to cost $1,500 including labour.

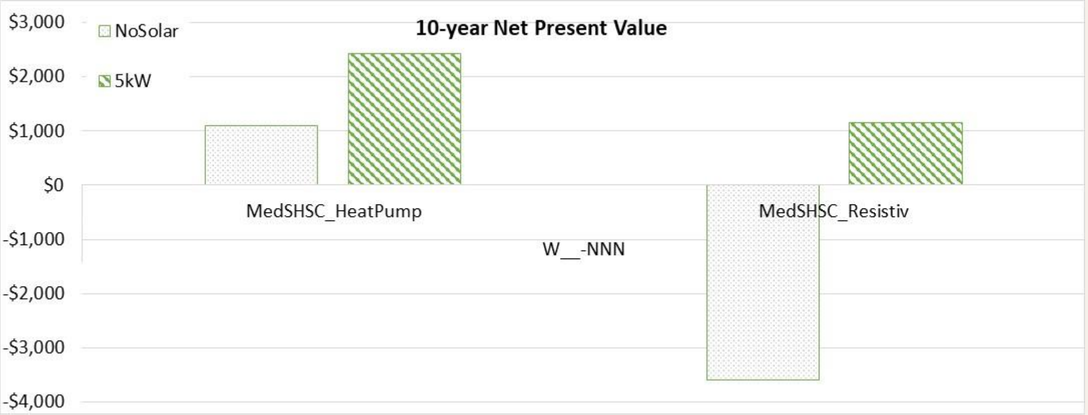
As mentioned in an earlier section of this report, good economics are derived from replacing the gas water heater with a heat pump. Illustrated in the two charts below, this option results in a 5-year payback, or 3 years if a 5 kW solar system is present. The ten-year net present value of the heat pump is about $1,100, or $2,400 with solar.

Without a solar system, replacing the old gas unit with resistive electric increases both the up-front cost and ongoing electricity bills, so it makes no economic sense. It never achieves payback and the NPV is negative. However, this changes dramatically with a solar system. Here it pays back in only a single year, as its upfront cost is only slightly greater than the gas alternative and easily covered by bill savings due to heating water with low-value excess solar. If both accompany solar, the resistive system's ten-year NPV ($1,160) is inferior to the heat pump, as its bill savings are smaller.



W__-NNN	26	3
MedSHSC_HeatPump	5	3
MedSHSC_Resistiv	26	1

Figure 30 Payback time replacing a gas water heater with either heat pump or resistive electric. Perth, medium home, flat tariff.



	NoSolar	5kW
W__-NNN	**-$1,250**	**$1,797**
MedSHSC_HeatPump	$1,091	$2,434
MedSHSC_Resistiv	-$3,590	$1,160

Figure 31 Net Present Value replacing a gas water heater with either heat pump or resistive electric. Perth, medium home, flat tariff.

This analysis assumes the resistive hot water tank is switched on using only a simple timer. Smarter options exist which can switch the heater on and off through the day depending on solar conditions, or even to adjust its power to match the level of surplus solar that would otherwise be exported. Using such methods would reduce bills further, but would incur additional up-front cost.

5.2. Recommendations

Renew's general recommendations from this study are as follows:

Recommendation 1:

Educate the building and energy industries, along with new home buyers, of the substantial value of all-electric homes.

A key finding of this work is that by choosing an all-electric home with solar PV (and potentially a battery), a new home buyer will be in the order of $7,500 to $10,500k better off over 10 years, as compared with establishing that home as dual fuel (i.e. electricity and gas), without solar.

This finding applies to the majority of Class 1 dwellings that will be built across WA over the coming decade. Very few of these would be unable to install solar PV for technical reasons.

Given the rate of connection to the reticulated gas grid of new homes in major Australian cities in general, it is imperative that consumers understand the significant cost impact of choosing to establish a new home as dual fuel versus all-electric with solar.

Recommendation 2:

Review of policy and programs that subsidise/support the expansion of gas networks.

Given the general trend from this study regarding the cost effectiveness of fuel switching from gas to electricity, it is critical that all governments and regulators with an interest in energy infrastructure review policies that seek to promote the expansion of reticulated gas networks to greenfields sites.

To continue to promote reticulated gas to new Class 1 dwelling estates in particular is to lock most of those new home buyers into significantly higher energy costs for the medium to longer term.

The National Gas Objective states:

> *"promote efficient investment in, and efficient operation and use of, natural gas services for the long-term interest of consumers of natural gas with respect to price, quality, safety, reliability and security of supply of natural gas."*

Continued expansion of reticulated gas to most greenfield developments across WA is likely to fail this objective on at least two important counts:

- The infrastructure delivered could not, by any credible measure, be considered ’efficient investment’; and therefore
- such programs are clearly no longer in the ‘long term interests of consumers’, with particular reference to price.

Since the capital cost implications for existing all-electric households considering connecting to a new gas network are similar to or higher than they are for new homes, and gas prices in new areas of the network are usually higher than elsewhere, expansion of gas networks to existing residential is also likely to offer no financial benefit to households and thus may similarly fails the National Gas Objective. This needs to be verified by additional modelling.

Recommendation 3:

Provide better information for consumers regarding the cost of owning and operating gas and electric appliances.

This analysis further strengthens similar work undertaken for the NEM by Renew which suggests that gas is no longer the cheapest fuel source for some residential activities in many locations.

As such, consumers need to be better informed of the real cost of purchasing and operating both gas and electric appliances in order that they can confidently make better decisions regarding those appliance choices that are in their long-term interest.

The role of governments and industry here is to assist in the provision of accurate, targeted information and advice, that is easy to understand, and that assists consumers in making these choices over the medium-to longer term.

Recommendation 4:

Strengthen the regulatory oversight of the marketing of gas as cheaper and more efficient than electricity.

Questionable claims about the affordability of gas continue to be communicated by gas appliance sellers, gas retailers and gas networks – often with very little detail as to how individual appliance loads and running costs are calculated, and little regard for appropriate alternatives.

Renew recommends that the ACCC and/or relevant jurisdictional departments of consumer affairs dedicate focus and resources to monitoring relevant marketing material in this area.

Recommendation 5:

Provide support to landlords, and disadvantaged owner-occupiers, to replace less efficient and expensive-to-run appliances with more efficient appliances.

Assistance measures – such as and low/no interest loans, rebates, energy efficiency schemes – should be provided to disadvantaged consumers, considering the findings of this report with respect to distributional impacts.

These policies should be technology agnostic and designed in a way that achieves the reduction of the capital cost for the most cost-effective technologies for those consumers who face the strongest capital-cost barriers.

Recommendation 6:

Consider the impact of fuel switching when making energy consumption and demand forecasts.

Energy market institutions and energy businesses use short- and long-range consumption and demand forecasts in planning and decision-making. Since the end result of households basing appliance replacement fuel choice on economic benefit is ultimately for most households to switch away from gas (whether all at once, or one at a time), this trajectory should be considered (along with other observable and predictable trends) when developing such forecasts.

5.3. Limitations & Further Work

As with any modelling exercise, there are always limits to the model's capability and therefore interpretation of findings. Specific limitations to the current version of the Renew model, and therefore suggested further work, is outlined below:

- *Tariffs:* Given budget and time constraints for this specific project, Renew was only able to capture the most basic electricity and gas tariff structures for WA.

  Electricity tariff structures are becoming more complex in other parts of the country, and WA may follow suit in the future. Three-part time of use (peak, shoulder and off-peak) and demand (i.e. kilowatt-based) tariffs are beginning to enter the residential market in the NEM.

  These more complex tariff structures may change the costs and benefits from any particular fuel choice/appliance decision and more work is required to understand their impact.

- *Apartments:* The household types used in this modelling largely pertain to detached or semi-detached (i.e. Class 1) dwellings. (The Small Home could be a proxy for apartments but has not been specifically designed this way).

  With increasing density in Australia's major cities, apartments are fast becoming a major component of all new dwelling approvals (some 35% in 2016[26]). As such, accurate consumer advice for apartment dwellers is becomingly increasingly important.

  Apartments function very differently from detached and semi-detached dwellings in their energy loads, typical appliance mix and constraints and opportunities regarding specific appliances and solar.

  The work could be expanded to include the ability to develop appliance-level loads for different apartment types and capture potential value from solar PV.

[26] https://www.rba.gov.au/publications/bulletin/2017/jun/pdf/bu-0617-1-houses-and-apartments-in-australia.pdf

- *10 Year NPV:* Calculating value over this timeframe is limited regarding the longer-term value of the solar-based households. Solar photovoltaic technology lasts over 20 years with little maintenance requirement and typically only a small "Repex" (replacement Capex) cost to change the inverter sometime between years 10 and 15.

  Understanding the longer-term value to residential consumers (e.g. over 20 years) would be beneficial in this context. The Renew model currently has the capability to generate 20-year[27] operational costs, longer term Repex and NPVs, with just additional time required for set up and model simulation, along with results analysis and write up.

- *Existing RCACs:* Following on from the commentary in **Section 4.7**, further analysis could be done to understand the economic case for space heating for those households that have existing RCACs and existing gas ducted or wall furnace systems.

  Whilst most of the space heating analysis for this project compares RCACs with gas heaters and takes account of the capital cost of both appliances, the reality for a significant proportion of households is that where gas space heaters exist, one or more RCACs are also in existence and can be used for space heating as well as cooling. Over one third of Australian households (38%) use electricity as the main source of energy for heating[28].

  In considering a transition from an existing dual fuel home to all-electric, where RCACs exist and can serve part of the heating load, this obviously has significant implications for reduced capital cost impacts of this transition.

- *Connecting existing all-electric homes to gas:* A key scenario modelled in previous Renew projects considered the case of existing all-electric homes (i.e. without current mains gas connection) choosing to connect to mains gas. This scenario is important in the context of programs to subsidise gas network expansion[29].

  A critical decision for energy consumers in these areas is whether they will be better off connecting to mains gas and installing new gas appliances; as compared with remaining all-electric and installing efficient electric appliances and solar PV.

  Given the strength of the results for the solar / all-electric new home cases presented in this study, connecting existing all-electric to mains gas is unlikely to be the best economic decision for many households across many locations.

- *Emissions:* The current model seeks to understand fuel and appliance choice from an economic perspective only.

  Given the broader debate regarding the environmental impact of different stationery energy sources, it will be important to understand the emissions intensity of each fuel choice and appliance decision.

  Renew has previously undertaken this type of analysis for the NEM[30]. It showed that in almost all cases, switching from gas to efficient electric appliances reduced greenhouse gas emissions. Since 2015, the increased rollout of renewable energy across the country has seen the emissions intensity of electricity begin to decrease. This, coupled with the rapid uptake of roof-top solar, means the environmental impact of electric appliance choices is likely to have further improved and requires fresh analysis.

[27] The model actually extends to 30 years max.
[28] http://www.abs.gov.au/ausstats/abs@.nsf/mf/4602.0.55.001
[29] The *Energy for the Regions* Program
[30] https://renew.org.au/research/7809/

6. Appendix A: Methodology – Heating & Cooling

The overall aim of the heating and cooling model is to produce plausible daily input[31] heating and cooling loads that are sensitive to ambient temperature, household size and occupant behaviour, and are reasonable at the annual aggregate level (given publicly available data for the relevant location).

Ultimately, the same output[32] heating and cooling loads (on an annual megajoule 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).

The Renew heating and cooling model does not do a full “energy balance” (as compared with heating/cooling software such as FirstRate[33] or AccuRate[34]) but mimics that behaviour and reconciles back to NatHERS’ annual MJ/m2 results by climate zone.

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

6.1. Approach

The output heating and cooling load (by household type, by location) is generated to begin with by the application of specifically sized reverse cycle air conditioners (RCACs) to keep the target indoor temperature within a desired comfort band, as defined below.

6.1.1. Analysis of Climate/Temperature

The model begins with a Bureau of Meteorology (BoM) dataset of the 30-minute ambient indoor air temperature (over 12 months) for a home without mechanical heating/cooling in that location. A moving average of the ambient temperature is then defined, which includes more intervals for higher building star rating, giving greater smoothing. This results in a "natural" indoor temperature.

A target indoor air temperature is then set based on user inputs regarding their acclimatised ideal temperature and adjusted for building star rating[35].

6.1.2. Calculation by Interval

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 mechanical heating or cooling is affecting it. The difference between the ambient and simulated indoor temp is used to calculate operating coefficients of performance of the RCACs.

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[31] Input load refers to the amount of input fuel (e.g. electricity or gas) an appliance requires to supply the required output heating or cooling load.
[32] Output load refers to the amount of output heat or coolth energy required to keep a room/area within the desired temperature band.
[33] https://www.fr5.com.au/
[34] http://www.nathers.gov.au/assessors-and-assessor-accrediting-organisations/using-nathers-accredited-software
[35] Well-insulated buildings have milder surface temperatures - reduced radiant heat allowing for less conditioning of air temperature.

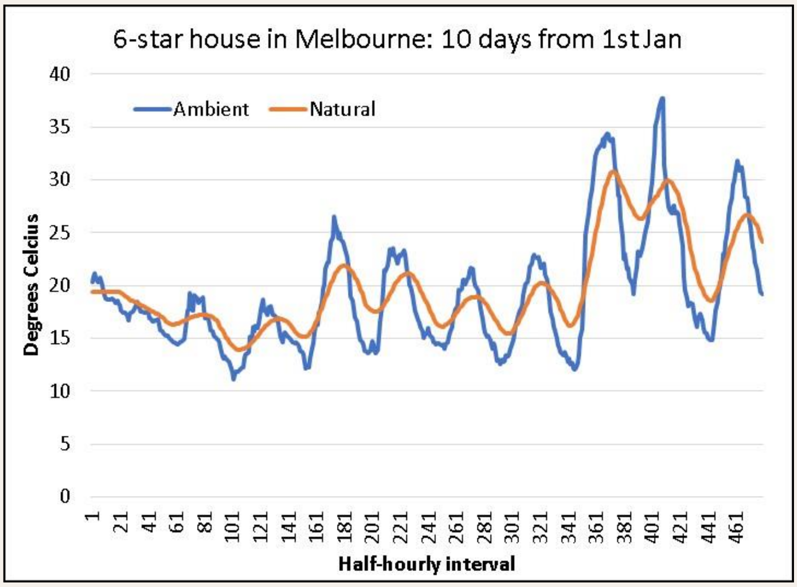


Figure 32 An example of "Moving Average" of Ambient versus Natural Indoor Air Temperature, Melbourne

The acclimatised ideal temperature settings selected for this project are as follows:

SET POINTS	SETTINGS
Ideal indoor temperature	20.0 degrees C
Degrees tolerated below ideal, before turning on heater	3.0 degrees C
Degrees tolerated above ideal, before turning on cooling	3.0 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	4.0
No. of half-hour intervals to maintain the target temperature	4.0
No. of half-hour intervals to for indoor temp to revert to base, per star	3.0
Intervals of moving average for natural indoor temperature per star	5.0

Table 14 Acclimatised Ideal Temperature Settings, Heating & Cooling Model

The divergence between the current indoor temperature and the ideal temperature is calculated, allowing for a tolerance range:

- The tolerance range is +3/-3 degrees from the ideal acclimatised ideal temperature;
- The tolerance range is different during sleeping hours (+1/-2.5 degrees).

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; and then
- the RCAC will turn off, and the inside temperature will ramp down to the "natural" indoor temperature, taking 1.5 hours.

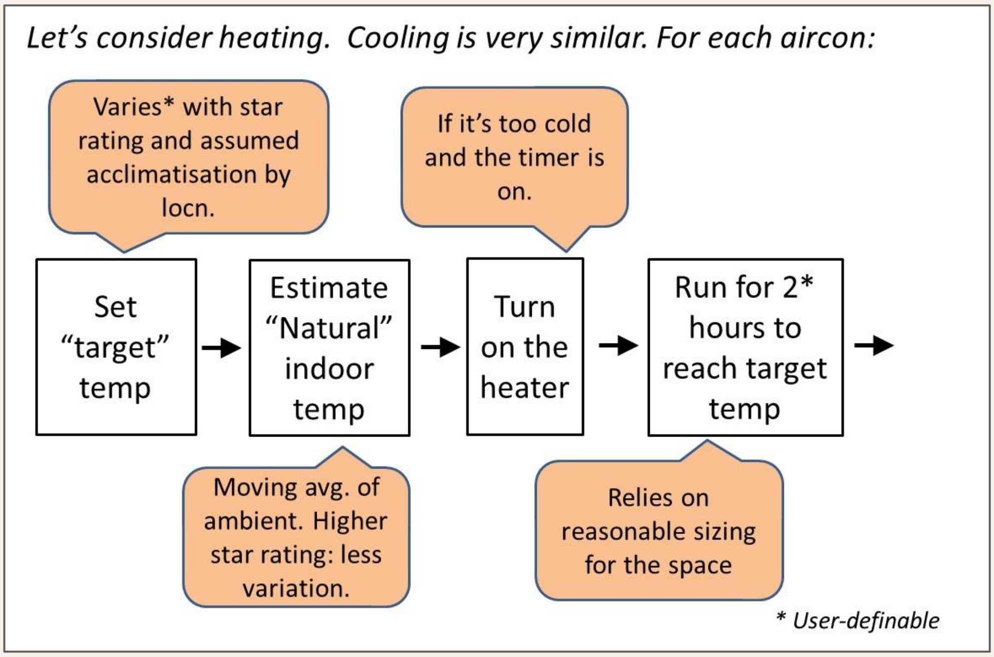
The RCAC output power level varies during the heating or cooling cycle. The model assumes that during the "maintenance" phase, it only has to run at "steady state" power:

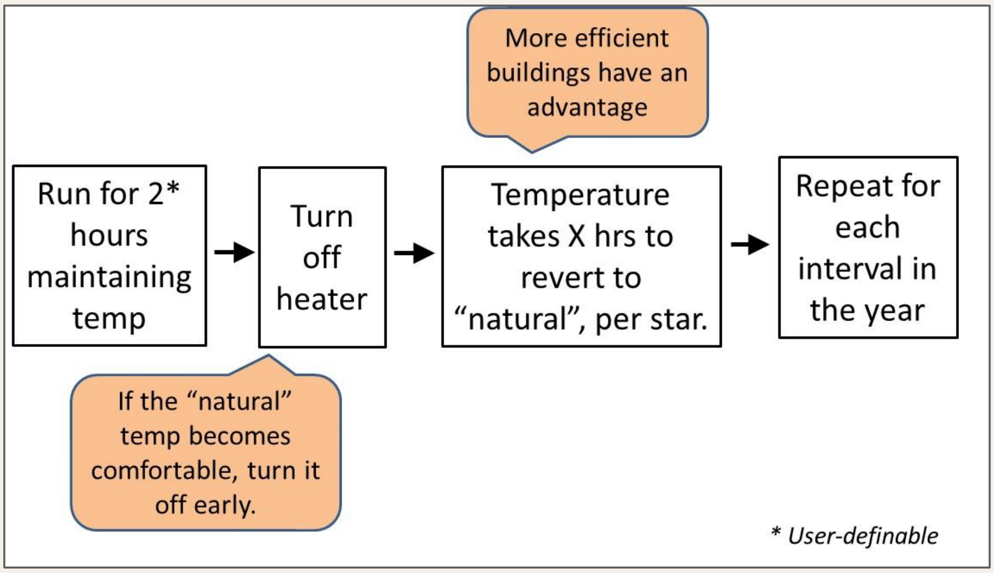
- this is assumed to be 13% of its rated maximum power level for a 5-star home and 5-degree temp diff inside-outside;
- the power level required varies by star rating and temperature differential.

The model assumes that for the first interval when the RCAC 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 RCAC 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. This logic is outlined in the charts below:

Figure 33 Flow Chart Logic, Air Conditioning Control





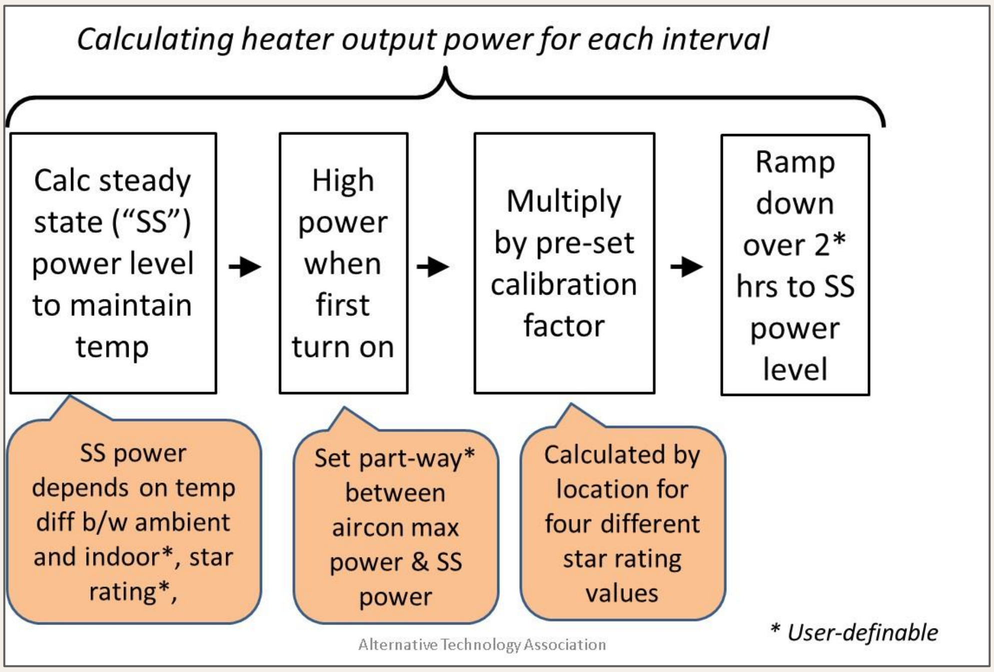


Figure 34 Flow Chart Logic, Air Conditioning Energy Usage (1)

6.1.3. Application of Air Conditioners

Multiple RCACs are then 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.

A heating and cooling load is then generated by the application of specifically sized RCACs to keep the target indoor temperature within the desired comfort band.

Once generated, the heating load as supplied by the RCACs is then applied to gas space heaters (in this case, gas wall furnaces), considering gas space heater performance, to generate an annual gas load.

Table 15 shows the number and sizing of RCACs by home type. Essentially, only one appropriately sized RCAC was assumed for the living space in each home. Bedrooms and other rooms were not supplied by individual RCAC units:

ROOM		SMALL	MEDIUM	LARGE	NEW
Living Space	Heat/Cool Output (kW)	5.0	7.0	9.0	9.0
Bedrooms/Other	Heat/Cool Output (kW)	None	None	None	None

Table 15 RCAC Number & Sizing by Home Type

Table 16 shows the efficiency and standby power consumption of the RCAC units:

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

Table 16 Efficiency & Standby Power Consumption of RCACs

Table 17 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	
Time the heater must turn off, for weekdays.	09:00	
Time the heater can turn on, for weekdays. 2nd period.	16:00	
Time the heater must turn off, for weekdays. 2nd period.	00:00	
Time the heater can turn on, for weekends.	07:00	
Time the heater must turn off, for weekends.	00:00	

Table 17 Timer Settings by Living Space/Bedroom Units

6.1.4. Efficiency Calculation

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. 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.

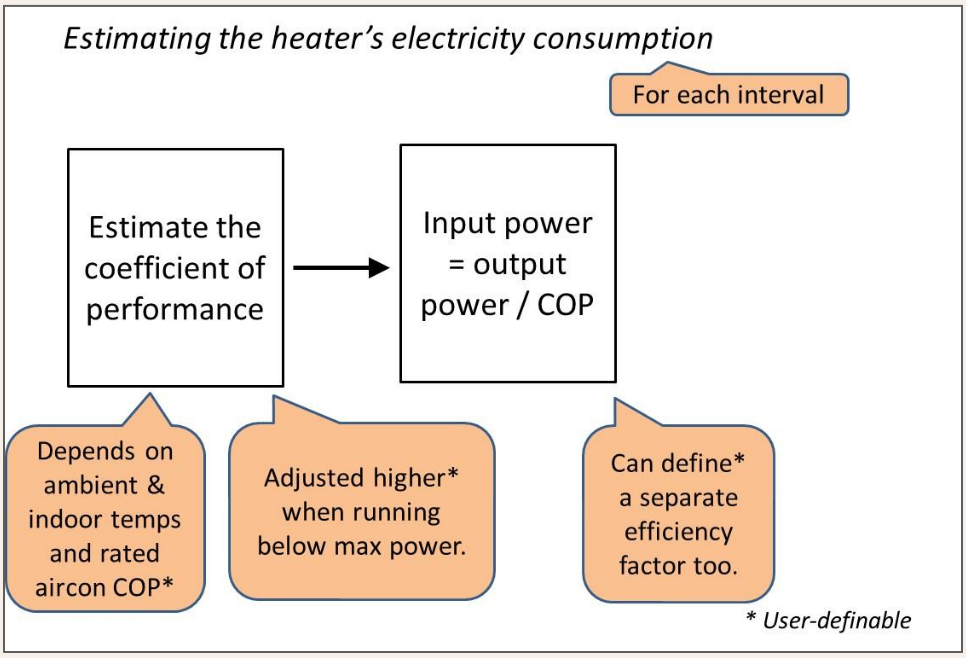


Figure 35 Flow Chart Logic, Air Conditioning Energy Usage (2)

6.1.5. 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[36]. 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:

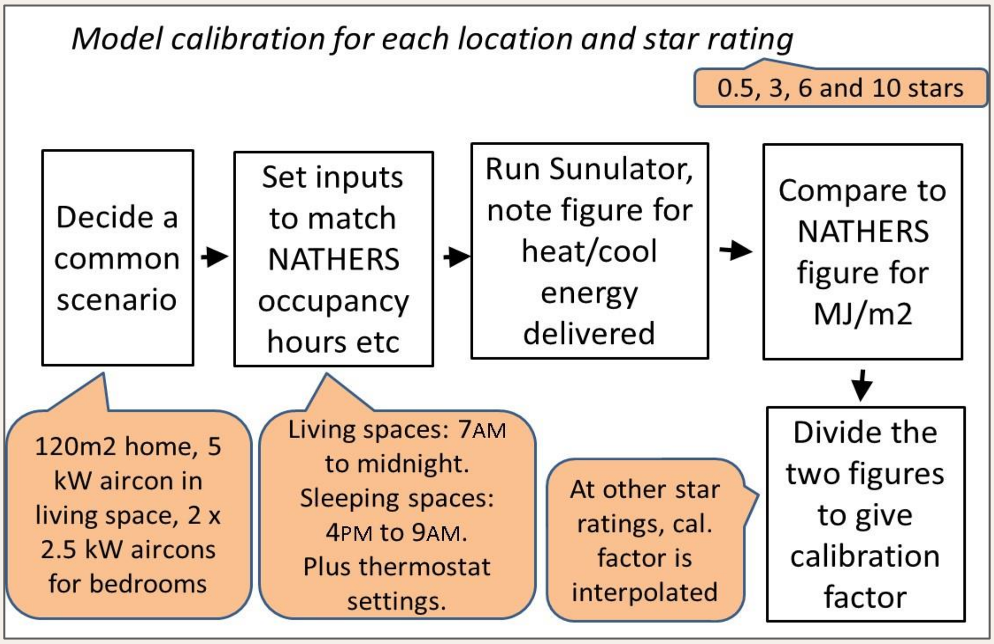


Figure 36 Flow Chart Logic, Calibration against NatHERS

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

6.2. Annual Energy Use

The methodology outlined above calculated the following annual heating loads by household type, by location, for this project:

LOCATION	SMALL HOUSE	MEDIUM – STAY AT HOME FAMILY	MEDIUM – WORKING FAMILY	LARGE HOUSE	NEW BUILD
Perth	0.207	0.319	0.291	0.548	0.161
Albany	0.364	0.559	0.526	0.655	0.444

Table 18 Annual Electricity Consumption for Space Heating by Location and Household Type (MWh p.a.)

LOCATION	SMALL HOUSE	MEDIUM – STAY AT HOME FAMILY	MEDIUM – WORKING FAMILY	LARGE HOUSE	NEW HOME
Perth	4.53	6.69	6.48	8.15	3.15
Albany	9.34	13.95	13.55	16.81	5.97

Table 19 Annual Gas Consumption for Space Heating by Location and Household Type (GJ p.a.)

LOCATION	SMALL HOUSE	MEDIUM – STAY AT HOME FAMILY	MEDIUM – WORKING FAMILY	LARGE HOUSE	NEW HOME
Perth	1.26	1.86	1.80	2.26	0.87
Albany	2.59	3.87	3.76	4.67	1.66

Table 20 Annual Gas Consumption for Space Heating by Location and Household Type (MWh p.a.)

6.3. Appliance Costs

6.3.1. Capex

Mid-priced 5kW, 7kW and 9kW RCACs and gas wall furnaces were chosen and deployed differently in different household types as shown in the tables below. Capex includes typical installation costs.

HOME TYPE	NO. 5KW RCACS	NO. 7KW RCACS	NO. 9KW RCACS	TOTAL	CAPEX ($)
Small House	1			1	$2,270
Medium – Stay at Home Family		1		1	$2,430
Medium – Working Family		1		1	$2,430
Large House			1	1	$2,850
New Home			1	1	$2,850

Table 21 Size, Number & Capex for RCACs by Household Type

HOME TYPE	SIZE WALL UNITS (KW)	NO. WALL UNITS	CAPEX ($)
Small House	2.9	1	$1,900
Medium – Stay at Home Family	5	1	$2,180
Medium – Working Family	5	1	$2,180
Large House	5	1	$2,180
New Home	5	1	$2,180

Table 22 Size, Number & Capex for Gas Wall Furnaces by Household Type

7. Appendix B: Methodology – Water Heating

A "bottom-up" model of hot water consumption for each home type at each location was developed for the project, based on the following approach.

7.1. Mains Water Temperature

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;
- 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; instead it changes slowly throughout the year, with a lag effect.

Using a methodology documented by the National Renewable Energy Laboratory in the USA[37], Renew modelled mains water temperature for 23 locations around Australia. We used air temperature data previously purchased from the Bureau of Meteorology for use in Sunulator[38] 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[39]. 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:

[37] 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
[38] http://www.ata.org.au/ata-research/sunulator
[39] 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

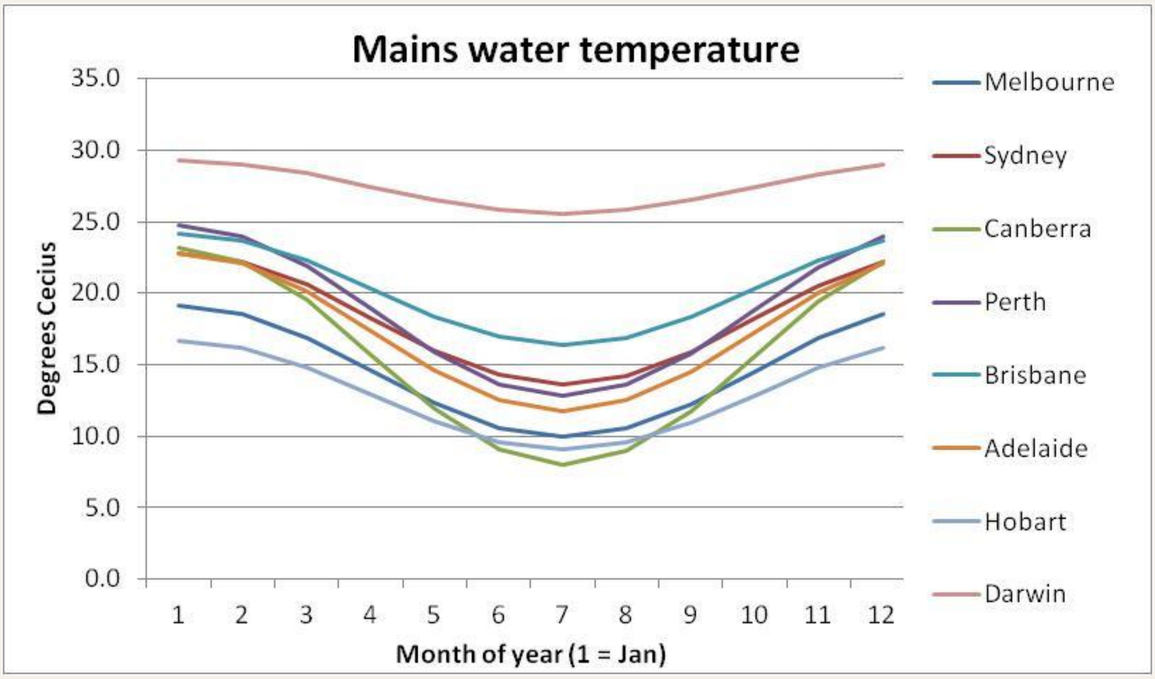


Figure 37: Mains Water Temperature in Australian Capital Cities

7.2. Hot Water Consumption & Energy

For each home 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;
- 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);
- 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.

7.2.1. 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 include:

- Number of showers per day: Small Home: 2, Medium Homes: 3, Large home & New Build: 5
- Duration: 10 minutes
- Shower flowrate (mixed water): 8 litres per minute[40]
- Mixed shower temperature: 38 degrees[41]

7.2.2. Hand Basins

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

- 50 hand basin uses for each shower (Small & Medium Homes. 100 hand basin uses for each shower (Large & New Build Homes[42])
- Mixed volume per basin use: 1.3 litres
- 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.

7.2.3. Dish Washing

While dishwashers use hot water, modern dishwashers are made with a built-in heating element and do not use hot water from the household's hot water system.

Some modern dishwashing 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. For this study we have assumed that all households use a dishwashing machine that only uses cold water input.

[40] http://www.waterrating.gov.au/consumers/water-efficiency
[41] https://forums.whirlpool.net.au/archive/1952143
https://www.reference.com/home-garden/average-shower-water-temperature-e5d7e7ee9f9eef37
[42] https://www.clearwater.asn.au/user-data/research-projects/swf-files/10tr5---001-melbourne-residential-water-use_brochure.pdf, page 21

7.2.4. Clothes Washing

While clothes washing machines can use hot water, modern machines also come with a built-in heating element and do not use any hot water from the household's hot water system.

Some modern clothes washing 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. For the purpose of this study we have assumed that all households use a washing machine that only uses cold water input.

7.2.5. Energy Losses by Hot Water Appliance

Based upon the hot water consumption outlined above, we have determined the volume of hot water needed for each household type, in each location.

It takes 4.187 kilojoules of energy to heat one kilogram of water (one litre) by one degree Celsius. On this basis, Renew calculated the amount of energy required to heat the relevant volume of water from the temperature of the mains water to 65°C.

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 the next section. The efficiencies of each type of hot water system were used as follows:

SYSTEM TYPE	HEATING EFFICIENCY	HAS TANK?
Gas Storage	70%	Y
Gas Instant	86%	N
Electric Storage	98%	Y
Electric Instant	100%	N
Heat Pump	98%[43]	Y

Table 23 Efficiencies of Different Hot Water System Technologies

7.2.6. Tank Heat Losses

For gas storage, electric resistance, and electric heat pump hot water systems, we also considered the energy losses from the hot water as it sits in the tank waiting to be used.

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.

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.

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

7.3. Annual Energy Use

7.3.1. Gas Hot Water Systems

Taking all of the above into consideration, Renew calculated the total annual gas energy use for water heating for each household type in each location:

LOCATION	SMALL HOUSE	MEDIUM – STAY AT HOME FAMILY	MEDIUM – WORKING FAMILY	LARGE HOUSE	NEW HOME
Perth	9.7	12.8	12.8	19.1	19.1
Albany	10.2	13.5	13.5	20.2	20.2

Table 24 Annual Gas Consumption for Gas Instant. Hot Water by Location and Household Type (GJ p.a.)

LOCATION	SMALL HOUSE	MEDIUM – STAY AT HOME FAMILY	MEDIUM – WORKING FAMILY	LARGE HOUSE	NEW HOME
Perth	2.7	3.6	3.6	5.3	5.3
Albany	2.8	3.8	3.8	5.6	5.6

Table 25 Annual Gas Consumption for Gas Instant. Hot Water by Location and Household Type (MWh p.a.)

7.3.2. Heat Pump Hot Water Systems

For the electric heat pump hot water systems, the amount of input energy was converted from megajoules to kilowatt hours, and the 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:

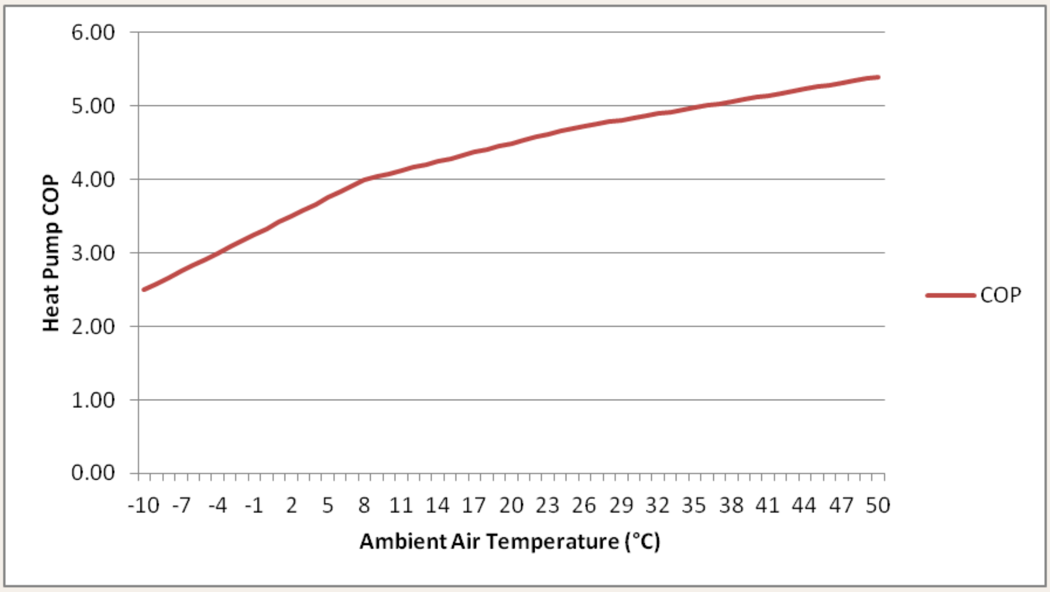


Figure 38: Mains Water Temperature in Australian Capital Cities

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

LOCATION	SMALL HOUSE	MEDIUM – STAY AT HOME FAMILY	MEDIUM – WORKING FAMILY	LARGE HOUSE	NEW BUILD
Perth	0.72	0.85	0.85	1.16	1.16
Albany	0.76	0.92	0.92	1.24	1.24

Table 26 Annual Electricity Consumption, Heat Pump Hot Water by Location & Household Type (MWh p.a.)

7.4. Appliance Costs

7.4.1. Capex

Mid-priced instantaneous or storage (depending on household type) gas hot water systems and heat pump hot water systems were chosen. Heat pump prices vary depending on STC rebate zones. Capex includes typical installation costs.

HOME TYPE	GAS HWS TYPE	GAS HWS CAPEX	HEAT PUMP CAPEX
Small House	Instantaneous	$1,050	$2,266
Medium – Stay at Home Family	Instantaneous	$1,360	$2,589
Medium – Working Family	Instantaneous	$1,360	$2,589
Large House	Instantaneous	$1,420	$2,755
New Home	Instantaneous	$1,420	$2,755

Table 27 Efficiencies of Different Hot Water System Technologies

8. Appendix C: Methodology - Cooking

While different in a number of ways, gas and electric induction cook tops are considered to be of similar enough quality to be interchangeable for the purposes of this research.

8.1. Energy Use

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

According to the NSW Independent Pricing and Regulatory Tribunal (IPART)[44], household use of gas for cooking is around 500 MJ of energy per quarter (138 kWh per quarter). This estimate agreed closely with the findings of ClimateWorks Australia in their 'Low Carbon Lifestyles' reports (2012) that assumed 1,552 MJ per annum (431 kWh 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[45]
Cook top	Elec - Induction	85-90%	Choice 2013[46]
Cook top	Natural gas	40%	UBC students citing US DoE[47]
Cook top	Elec - Induction	84%	UBC students citing US DoE[48]
Cook top	Elec - Induction	80%	Wuppertal 2013
Cook top	Natural gas	Approx. 30%	US DoC[49]
Cook top	Elec	77-82%	US DoC[50]

Table 28 Point of Use Efficiency Factors of Gas & Induction Cooktops

44 http://www.ipart.nsw.gov.au/Home/For_Consumers/Compare_Energy_Offers/Typical_household_energy_use
45 https://www.choice.com.au/reviews-and-tests/household/kitchen/ovens-...1
46 https://www.choice.com.au/reviews-and-tests/household/kitchen/ovens-...1
47 Leung, Lin, Mohamed, Lo, 2011: An Investigation into Induction versus Gas Stovetops. University of British Columbia
48 Leung, Lin, Mohamed, Lo, 2011: An Investigation into Induction versus Gas Stovetops. University of British Columbia
49 Aprovecho Research Center, Shell, US EPA, 2002: Test Results of Cook Stove Performance. Partnership for Clean Indoor Air
50 Aprovecho Research Center, Shell, US EPA, 2002: Test Results of Cook Stove Performance. Partnership for Clean Indoor Air

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[51]. The resultant gas cooktop load for all household types was 2,628 MJ p.a (730 kWh per annum).

8.2. Appliance Costs

8.2.1. Capex

As with heating, cooling and hot water appliances, Renew reviewed an online sample[52] of 23 gas cook tops and ovens; and 27 electric cook tops and ovens, to understand appropriate capital and installation costs for the modelling. As a result of this analysis, the following capital and installations costs were chosen as model inputs:

	PURCHASE PRICE ($)	INSTALLATION COST ($)
Gas:		
Cook top	350	170
Oven	1,000	230
Electric:		
Induction Cooktop	500	150
Oven	500	250

Table 29 Purchase & Installation Costs, Gas & Induction Cooking

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

[52] Current retail price and installation cost estimates were taken from:

https://www.bunnings.com.au/	https://www.powerland.com.au/
https://www.thegoodguys.com.au/	https://www.appliancesonline.com.au/
http://www.productreview.com.au/	https://onestepoffthegrid.com.au/
http://www.handycrew.com.au/cooking/	https://streamaster.com.au/
http://www.2ndsworld.com.au/	http://www.handycrew.com.au/cooking/
http://forums.whirlpool.net.au/archive/1781669	http://acuraelectrical.com.au/oven-installation-perth
http://www.whitfordshomeappliances.com.au/	http://www.harveynorman.com.au/
https://www.kambos.com.au/	https://www.binglee.com.au/
http://www.homeimprovementpages.com.au/	http://www.handycrew.com.au/cooking/
http://forums.whirlpool.net.au/archive/2485868	http://www.wyz.com.au/Install.aspx

9. Appendix D: Methodology – Residual Load

The "residual load", for the purposes of the modelling, is defined as the remaining load exclusive of any 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 type, but not by location. To generate the residual load for each household type, Renew considered the target annual load for each household type in each location.

Renew and Synergy reviewed publicly available data sources for typical annual electricity and gas loads for households in the SWIS (discussed in **Section 3.6.1**).

Using a combination of data sources, the project team came up with the following annual electricity and gas reference loads for the Medium Homes:

LOCATION	ANNUAL ELECTRICITY USAGE (KWH)	AVERAGE DAILY USAGE (KWH)	ANNUAL GAS USAGE (GJ)	AVERAGE DAILY GAS USAGE (MJ)	AVERAGE DAILY GAS USAGE (KWH)
Perth	5,000	13.7	20	54.7	15.2
Albany	5,000	13.7	20	54.7	15.2

Table 30 Reference Loads, Annual Electricity & Gas Usage

Renew then developed a base load profile with an annual load that sat between the Reference Loads above and the combination of the heating/cooling, hot water and cooking loads calculated:

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

Table 31 Residual Loads by Household Size, Annual & Daily Electricity Usage

10. Appendix E: Methodology – Solar & Batteries

Each scenario was modelled three separate times for three different solar PV and battery system configurations, as follows:

- No solar or battery installed;
- An existing 5kW solar PV system only (i.e. no battery); and
- An existing 5kW solar PV system with a 13.5kWh battery.

This approach considered the value of existing solar and battery systems but ensured the value of different appliance mixes could still be understood separately in the results.

10.1. System Sizes

A range of different solar PV system sizes could be included in the modelling. Renew selected a 5kW solar system and 13.5kWh battery size as:

- 5kW is reflective of the average solar PV system size currently being installed in Australia[53];
- 5kW 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[54];
- 5kW single phase is the pre-approval limit for grid connection of residential solar across a range of distribution network businesses in Australia;
- 13.5kWh is the size of the Tesla Powerwall 2 – one of the most cost-effective household batteries in the current market and can easily be charged by a 5kW solar PV system for most days across the year;
- The modelling will assume that at least some of the electricity required to power one of the three end uses (i.e. space heating, hot water, cooking) will come from solar and/or battery, 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 combination reduces the complexity and number of the modelled scenarios.

Feed-in tariff assumptions were based on the current WA Government Renewable Energy Buyback Scheme offer of $0.07135 per kilowatt hour[55].

[53] http://reneweconomy.com.au/graph-of-the-day-australias-average-solar-pv-system-size-hits-5 kW-47293/
[54] http://www.solarchoice.net.au/blog/news/residential-solar-pv-system-prices-january-2017
[55] http://www.treasury.wa.gov.au/Public-Utilities-Office/Solar-PV/Renewable-Energy-Buyback-Scheme/

10.2. Value of Solar/Batteries

Specific electrical loads have been individually constructed on a half-hourly basis. For the scenarios with solar PV only, or solar PV and batteries, these loads have been modelled on a 30-minute basis, for a full 12-month period, to understand exactly how much of the total electrical load the solar and or batteries will supply over the course of that year.

The modelling calculated the value of solar PV and batterie for each scenario using Renew's in-house "Sunulator" model.

Sunulator is currently the most detailed modelling tool for grid-connected solar and solar-battery systems publicly available in Australia. The key characteristics of the model are:

- To accurately inform generation, ATA integrated 19 years (1994-2013) of solar insolation data from the Bureau of Meteorology (BoM) into Sunulator. The data exists across five-kilometre grids for all of Australia and is the basis for the generation calculations within the model.

- Regarding consumption, Sunulator has the capability to:

  - directly accommodate interval data files of any time period (as Sunulator averages both generation & consumption back to a typical meteorological year and typical consumption year). For most accurate results, at least 12 months of data is preferable;

  - alternatively, a detailed consumption profile can be built based on relevant input assumptions regarding load patterns, including daily, weekly and seasonal variations; and other variables such as public and private holidays, weekends and standby loads.

Economic and energy 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. System design and configuration can then be optimised to maximise the value of solar generation and minimise the cost of consumption from the grid.

Sunulator calculates economic impacts (e.g. electricity bill, 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). The carbon impact of the project is also automatically calculated.

11. Appendix F: Methodology – Energy Prices

11.1. Gas Prices

Renew obtained the following gas tariffs by location from the WA government's website (all prices are inclusive of GST). Note that in WA, gas is billed by kWh. For Renew's model, these tariffs were divided by 3.6 to get a price per MJ.

LOCATION	GAS NETWORK	SUPPLY CHARGE ($/DAY)	ENERGY CHARGE – BLOCK 1[56] ($/kWh)	ENERGY CHARGE – BLOCK 2[57] ($/kWh)
Perth	Alinta	$0.2198	$0.1518	$0.1369
Albany	Alinta	$0.2373	$0.1726	

Table 32 Gas Tariffs used in the Modelling, Flat by Location

11.1.1. Price Forecasts: Gas

Energy price forecasting is an inherently complex exercise and not one that Renew sought to conduct any primary research upon as part of this project. Gas tariffs are assumed to stay constant, as agreed with the client, and means that should any future gas price increases occur, the results can be considered conservative.

11.2. Electricity Prices

Renew obtained the following electricity tariffs by location from Synergy's website (all prices are inclusive of GST):

LOCATION	SUPPLY CHARGE ($/DAY)	ENERGY CHARGE ($/kWh)	FEED-IN TARIFF ($/kWh)
Perth	$1.033263	$0.2833	$0.07135
Albany	$1.033263	$0.2833	$0.07135

Table 33 Electricity Tariffs used in the Modelling, Flat by Location

LOCATION	SUPPLY CHARGE ($/DAY)	ENERGY CHARGE (PEAK) ($/kWh)	ENERGY CHARGE (OFF-PEAK) ($/kWh)	ENERGY CHARGE (SHOULDER) ($/kWh)	FEED-IN TARIFF ($/kWh)
Perth	$1.033263	$0.548142	$0.151002	$0.287076	$0.07135
Other	$1.033263	$0.548142	$0.151002	$0.287076	$0.07135

Table 34 Electricity Tariffs used in the Modelling, Time of Use by Location

[56] First 12 units per day
[57] Remainder above 12 units per day

For the Time of Use (TOU) tariffs, the following time bands applied:

- Off-Peak: 9pm to 7am weekdays & weekends;
- Shoulder: 7am to 3pm weekdays and 7am to 9pm weekends; and
- Peak: 3pm to 9pm weekdays.

11.2.1. Price Forecasts: Electricity

Renew used future tariffs supplied by the client. Starting in the second year and continuing to the fifth year, increases were 1.75%, 2.00%, 2.25% and 2.25% respectively. After that, tariffs were assumed to stay constant.

12. Monthly Consumption by Type

Further to the Import/Export charts provided in **Section 4.8**, Renew was also able to extract monthly kWh usage figures by end use (e.g. space heating, hot water, cooking or "base load"). The following scenarios are again for the Medium Stay-at-Home household in Perth.

The following chart considers the monthly usage for the Medium Stay-at-Home household with no solar and all three gas appliances:

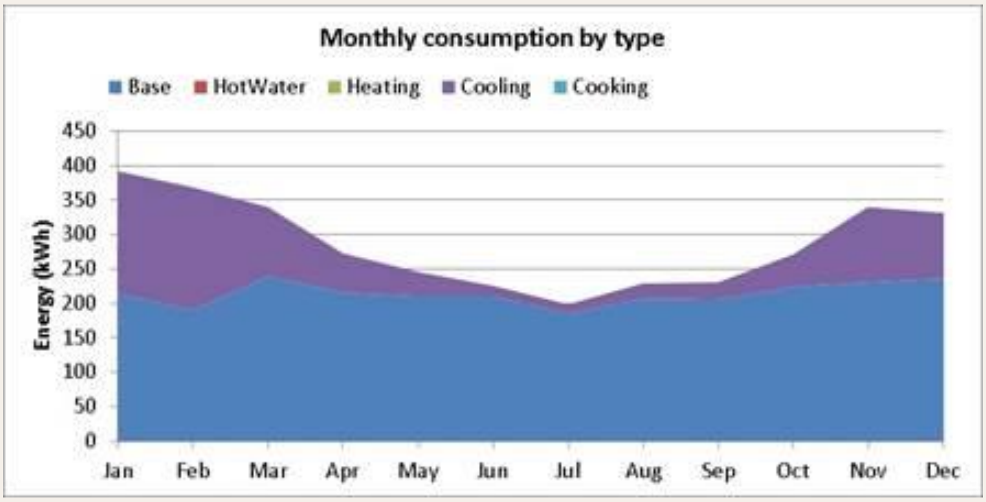


Figure 39: Monthly Consumption by Type – Medium Stay at Home Household, Perth, No Solar, All 3 Gas Appliances

As can be seen, this profile differs significantly from the Medium Stay-at-Home household with no solar and no gas appliances:

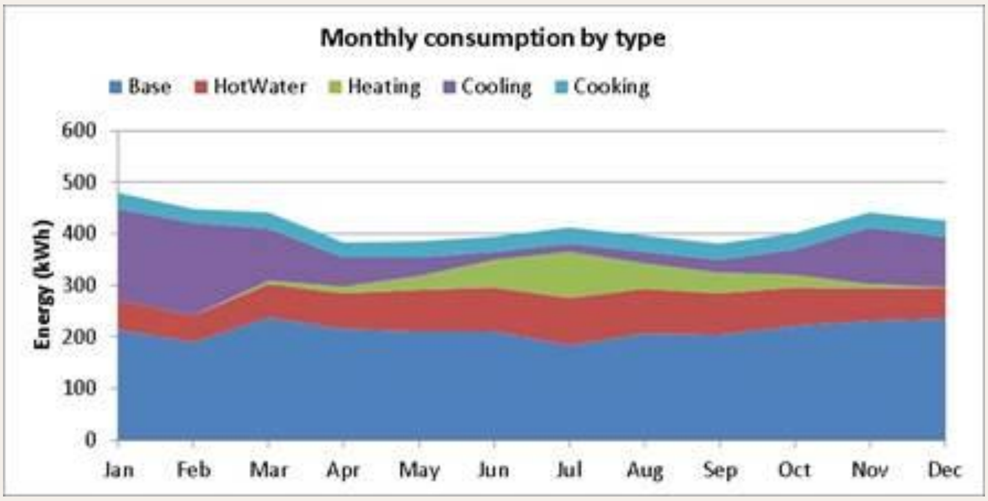


Figure 40: Monthly Consumption by Type – Medium Stay at Home Household, Perth, No Solar, No Gas Appliances

The chart below is the same home with a 5 kW solar system and all three gas appliances (i.e. the same monthly consumption as the first chart in this section:

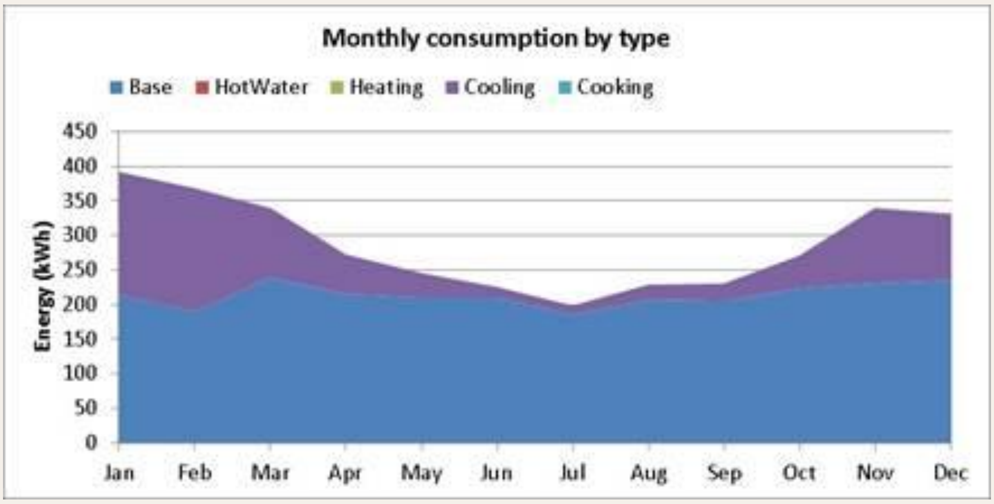


Figure 41: Monthly Consumption by Type – Medium Stay at Home Household, Perth, 5kW Solar, All 3 Gas Appliances

And with a 5 kW solar system and no gas appliances:

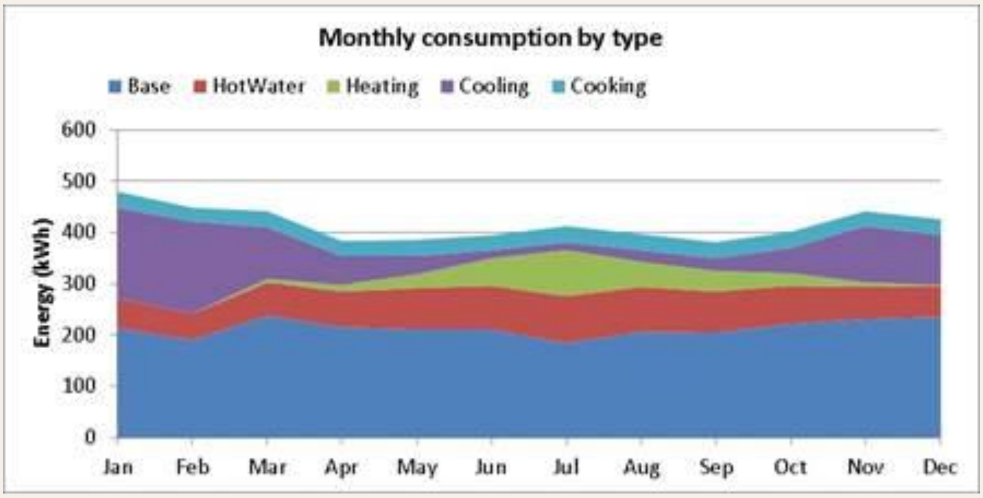


Figure 42: Monthly Consumption by Type – Medium Stay at Home Household, Perth, 5kW Solar, No Gas Appliances

The same monthly usage chart would also result with the addition of the 13.5kWh battery.

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