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August 2021

# NCC 2022 Update
# Whole-of-Home Component

Prepared by Energy Efficient Strategies Pty. Ltd.

With assistance from IT Power Renewable Energy Consulting

NCC 2022 Update – Whole-of-Home Component

**Report prepared for:**
Australian Building Code Board (via TI Consulting)

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## General Abbreviations

| | |
|---|---|
| AC | Air Conditioner |
| AS | Australian Standard |
| AS/NZS | Joint Australian-New Zealand Standard |
| AU/NZ | Australia and New Zealand (countries) |
| CEC | Comparative Energy Consumption (energy on an energy label) |
| CFL | Compact Fluorescent Lamps |
| E3 | Equipment Energy Efficiency committee (Australia and New Zealand) |
| EES | Energy Efficient Strategies Pty Ltd |
| GEMS | *Greenhouse and Energy Minimum Standards Act 2012* (Commonwealth) |
| GJ | Gigajoule ($10^9$ joules) (energy for a specific fuel) |
| HE | High Efficiency |
| IT | Information Technology |
| kWh | Kilowatt hour |
| MEPS | Minimum Energy Performance Standards |
| MEPSL | Minimum Energy Performance Standards and (energy) Labelling |
| NZS | New Zealand Standard |
| PAEC | Projected Annual Energy Consumption – see also CEC |
| TMY | Typical mean year, usually pertaining to weather data |
| W | Watt |

# 1 Introduction

This report forms part of the documentation prepared for the Australian Building Codes Board (ABCB) for its proposed update to the energy efficiency provisions for residential buildings in the National Construction Code (NCC) 2022. The purpose of this study is to develop enhanced energy efficiency provisions for residential buildings for NCC 2022.

The study was originally required to recommend two options for residential buildings (i.e. Class 1 buildings, Class 2 sole-occupancy units and Class 4 parts of buildings) that would enable a 'whole-of-home' approach to be used to achieve compliance:

a) Option 1 will achieve net zero regulated energy through increased efficiency of the building services (space conditioning, heated water systems, lighting and pool and spa pumps) and on-site renewable energy (generation and storage);
b) Option 2 will achieve an intermediate stringency between the current NCC provisions and Option 1 by identifying a maximum annual energy use budget greater than zero for the regulated elements of a building.

In fact a total of three options were eventually developed for this study, the third option, added somewhat later, was an intermediate stringency option between Option 1 and Option 2 called Option 1.5.

The "net zero energy" in the term net zero regulated energy refers to the net total of imported and exported energy into a dwelling in all its forms. The term "regulated" refers to those end uses in a dwelling that are regulated in some way under the NCC such as heating, cooling, hot water, lighting and pool and spa pumps but not end uses such as cooking and plug loads (see Figure 7 later in this report for a graphical representation of this concept).

The concept of net zero regulated energy is understood to encompass a number of possible metrics including energy cost (to the consumer), energy cost (at a societal level), and energy cost in terms of greenhouse gas emissions or simply the energy itself (joules). The acronym ZNRE (zero net regulated energy) is used throughout this study as a generic term that covers any of these metric options. However, as will be noted later in this report at the direction of the ABCB, the actual metric adopted for use in NCC 2022 was a form of societal cost.

Societal cost in the context of this report refers to the notional cost to society as a whole, including but not necessarily limited to, costs to the building user, costs to the environment and costs to energy networks.

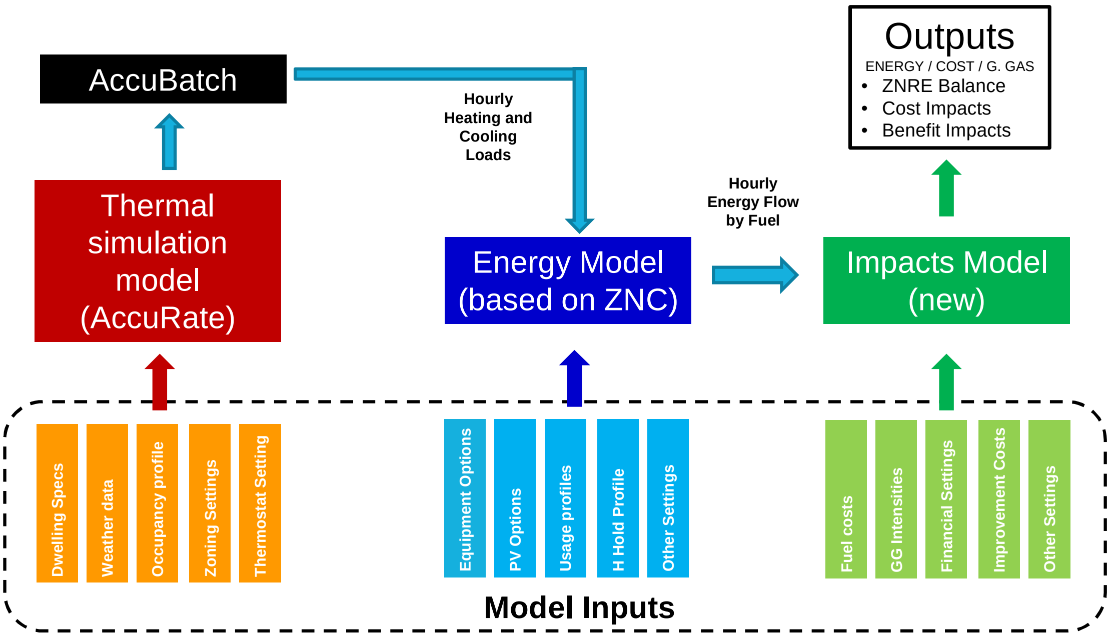
This report component describes the methodology used for modelling of whole-of-home energy flows, the setting and achieving of various whole-of-home performance targets and the methodology for determining energy and cost impacts of the various regulatory stringencies examined. Much of the data generated from this analysis was then used as an input into the Regulation Impact Statement (RIS) process.

## 2 Overview of the Model

### 2.1 *Overview*

Modelling of whole-of-home energy flows is conducted across three separate modules (See - Figure 1). The first component of the model involves a thermal simulation of a limited range of representative housing types specifically developed for this study.

**Figure 1: Whole-of-Home Modelling Schematic**




These dwellings are modelled across 14 representative climate zones plus two representative occupancy profiles. The output from this modelling is in the form of hourly heating and cooling load intensity data across a whole year (8760 hours).

The hourly load intensity data is then fed into an energy model. This model, based on Sustainability Victoria's Zero Net Carbon model, calculates hourly end use energy consumption across all end-uses within the dwelling including:

- Heating
- Cooling
- Water heating
- Lighting
- Swimming pool pumps
- Spa pumps

In this model the user can select different combinations of building shell performance, appliance type and appliance performance. These various combinations are referred to as "End Use Scenarios" in this report.

Also modelled but not accounted for in the (ZNRE) calculations are the remaining loads within the dwelling including cooking, plug loads and standby power. These other loads are included in the modelling process as they are almost all electrical loads that tend to increase the proportion of PV generation used on site, thereby improving the economic returns to the householder who installs a photovoltaic (PV) system. If these other end uses were to be ignored, then a significant proportion of on-site generation would be assumed to have been exported to the grid rather than used on-site, noting that exported returns are typically only one-third the returns associated with the displacement of imported power by PV systems. The concept of accounting for plug loads as part of ZNRE accounting is illustrated in Figure 7 in Section 3 Metrics and Performance Targets.

The energy model also models energy production by PVs ranging from 0 kW capacity to 10 kW capacity in 1 kW increments, calculating hour by hour how much of the production is used to offset on-site use (in either regulated or non-regulated equipment) and how much is exported to the grid.

The output from the Energy Model takes the form of hourly energy consumption by end use and fuel type (electricity, natural gas, LPG or firewood) plus exported electricity production from a range of differently sized PV arrays (1 – 10kW).

The energy consumption data by hour of day is then fed into the third module – an Impacts model that applies data including:

- Improvement costs (building shell, equipment, PVs)
- Fuel costs
- Greenhouse gas intensities of fuels
- Discount rates
- Learning rates
- Time of use cost profiles (for electricity consumption).

This data is applied to the energy data in order to estimate the impact of differing levels of PV on the energy budget of the building and thereby determine to what extent ZNRE is achieved or exceeded.

The model allows the user to conduct an assessment on the basis of 4 different metrics as follows:

- Energy
- Fuel cost
- Greenhouse gas emissions
- Societal costs.

Societal costs are a construct of the retail cost of fuels consumed or exported (which varies in value by hour of use) plus an assumed cost of associated greenhouse gas emissions. In reality, only grid-supplied electricity is assumed to vary in cost by hour of use with higher costs associated with peak demand hours of usage (see Section 6.10)

Each combination of dwelling type/performance level, appliance type/performance level and PV array size is costed such that a benefit versus cost analysis can be undertaken. The benefit cost analysis compares a base case of 6 star rated dwellings without PVs against dwellings of the same design but 7 star rated and with PVs.

The following sections provide more detail on each of the three main model components.

## 2.2 Thermal Simulation Model Component

### 2.2.1 Overview

Annual energy consumption estimates for the heating and cooling product types are based on estimates of heating and cooling loads for each hour of the year. These estimates of loads are derived from thermal simulation modelling using CSIROs AccuRate software (Version to be applied in 2022 – including updated weather files). The software is executed using a batching program called Accubatch. Accubatch has a facility to deliver heating and cooling loads by zone for each of the 8760 hours over the period of one year.

Hourly load data is required such that granular analysis could be undertaken, including matching hourly heating and cooling load data to hourly solar PV generation. Hourly PV generation estimates utilized the same climate files as those used for the thermal performance simulation, including the same solar radiation levels and ambient temperatures for each hour of the year.

The representative dwellings modelled (see Section 4.1) include dwelling types and construction formats typical of current day practice. For each house type, a range of performance levels were modelled. This included a BAU case (typically 6 star NatHERS rated) and an assumed NCC 2022 case (typically 7 star NatHERS rated).

Each of the eight BCA climate zones were modelled using 14 representative NatHERS climate zones (see Section 5).

Once the dwellings details had been set up in AccuRate, multiple simulations were run using the batching tool, Accubatch. Once the various runs were completed then the data was aggregated and compiled (using a compiler tool) into a suitable format for import into the Energy Model Component, to form the basis of the heating and cooling energy demand estimates.

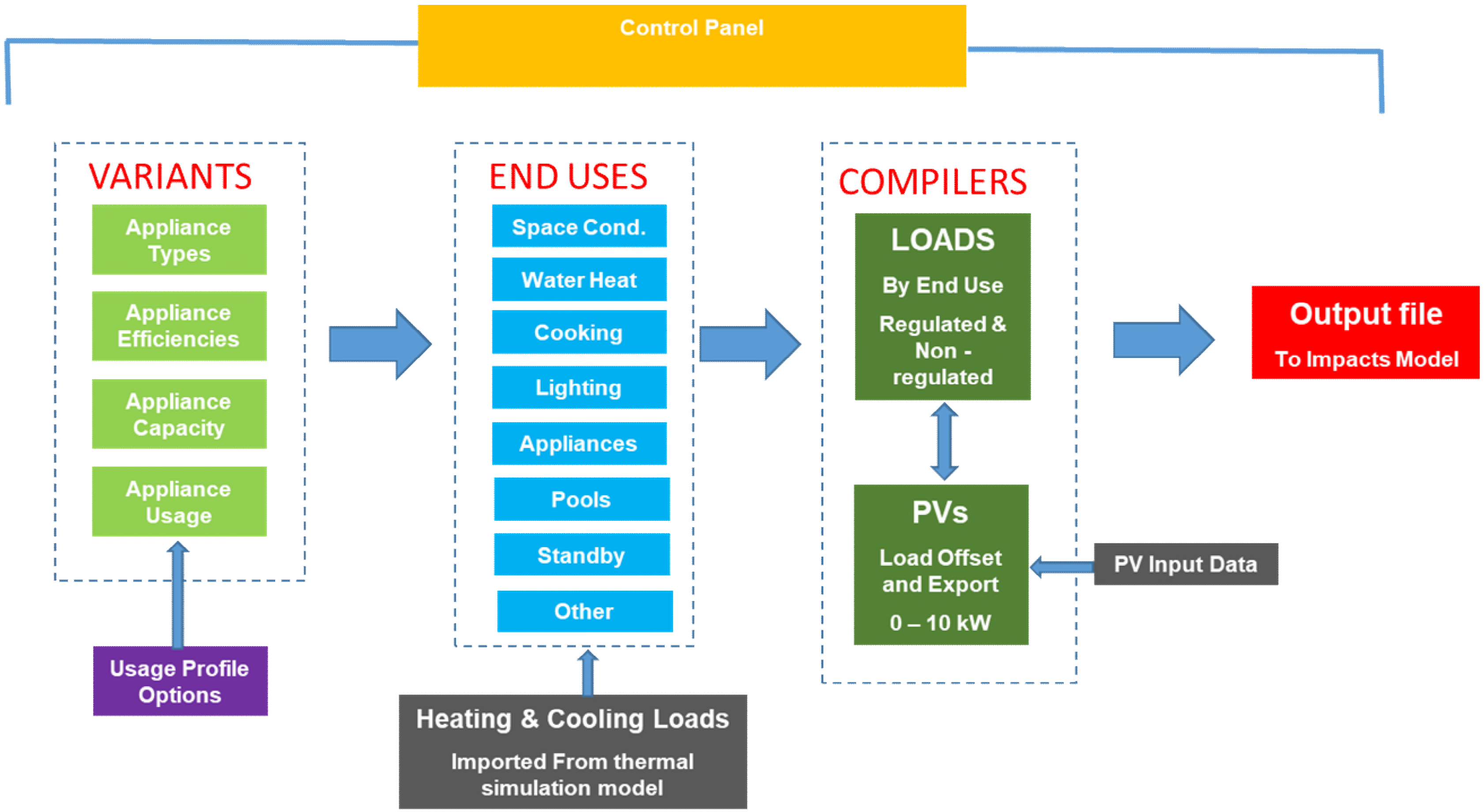
## 2.3 Energy Model Component

### 2.3.1 Overview

The energy model component is based on the Victorian Zero Net Carbon Model as developed by Sustainability Victoria.

The model has been constructed in the form of a MS-Excel workbook. A schematic of the conceptual basis of the model is provided in Figure 2 below.

**Figure 2: Schematic of Energy Model Conceptual Basis**



Annual energy consumption for each end use is calculated based on a range of factors and assumptions (see Section 6). In the case of heating and cooling end uses, the assumed heating and cooling loads are based on separate thermal simulation modelling (see Section 2.2). This modelling generates hourly loads throughout the entire year by fuel type.

In addition to end use load modelling, a profile of energy usage for each hour in a year for each end use is also set up within the model. In the case of heating and cooling this is based on thermal simulation modelling of hourly loads for the selected dwelling type in a selected climate zone. For other end-uses, the usage profile is determined from a range of data sources (see Section 6).

A "compiler" sheet is then used to compile all of the data relating to each end use including, annual loads by fuel type, hourly usage profiles, ownership and whether or not the end use is to be used as part of the ZNRE accounting. The compiler generates for each end use/fuel type combination a full year (8760 hours) energy use profile.

A spreadsheet that operates in parallel with the compiler sheet estimates the hourly inputs from any PV array that is present. It estimates how much of the PV generation is exported to the grid each hour, or how much energy must be imported from the grid, in each hour of the year, depending on the electrical loads and PV generation in that hour.

The PV generation estimates are based on the same climate file data that is used to estimate the heating and cooling loads. This use of common weather data for both estimating hourly heating and cooling loads and PV generation provides a realistic simulation of the interplay between PVs and weather sensitive electrical loads within a dwelling. Other relevant details in relation to PV can be found in Section 6.

### *2.3.2 PV Modelling*

The model calculates the size of PV system that is required to generate sufficient energy in a year to offset all of the energy (that is in terms of MJ, $ or Tonnes $CO_{2\text{-}e}$ according to the selected metric) imported and consumed by the dwelling over the course of one year. The result depends upon a wide range of factors including:

- Dwelling size
- Household size
- Building shell performance
- Climate zone
- Occupancy profile
- Types and numbers of installed appliances and equipment
- Efficiency of installed appliance and equipment.

Expected hourly PV generation was calculated by IT Power Renewable Energy Consulting based on the meteorological data sets used in NatHERS rating tools for each of the 14 climate zones and for each of the 4 ordinal orientations.

The key determinants of output were:

- Global horizontal solar radiation
- Diffuse horizontal solar radiation
- Ambient air temperature.

Output data was generated for a 1 kW array. Advice from IT Power Renewable Energy Consulting was that for larger arrays the values obtained for a 1kw array can simply be scaled up based on the rated output of the array. The model allows for pre-set array outputs from 1 kW to 10 kW[1] in 1kW increments.

Modelled annual output from 1 kW arrays is shown in Table 1 below. Of course, output from the PV panels is not evenly distributed throughout the year, with maximum output in the summer months and minimum in the winter months. This can be seen in the output sample for a dwelling located in Melbourne with a 5 kW PV array fitted– see Figure 3. Likewise, PV output is not evenly distributed throughout the day. This can be seen in the output sample for a dwelling located in Melbourne with a 5 kW PV array fitted on an average June day – see Figure 4. However, the model accounts for these seasonal and daily variations and ensures that the total expected PV generation balances with total expected energy consumption over a whole year.

**Table 1: Modelled Annual PV Output per kW of Installed Capacity (kWh/annum)**

| Representative NatHERS Climate zone | North | South | East | West |
|---|---|---|---|---|
| 1 | 1644 | 1383 | 1523 | 1533 |
| 3 | 1802 | 1388 | 1630 | 1591 |
| 10 | 1675 | 1265 | 1474 | 1503 |
| 13 | 1639 | 1241 | 1450 | 1461 |
| 16 | 1555 | 1148 | 1337 | 1389 |
| 21 for Class 2 | 1379 | 1000 | 1188 | 1224 |
| 24 | 1586 | 1131 | 1384 | 1364 |
| 26 | 1296 | 906 | 1106 | 1119 |
| 27 | 1661 | 1204 | 1470 | 1443 |
| 28 for Class 1 | 1478 | 1054 | 1282 | 1284 |
| 32 | 1582 | 1349 | 1468 | 1489 |
| 56 for Class 2 | 1490 | 1066 | 1285 | 1302 |
| 60 for Class 1 | 1372 | 1005 | 1187 | 1230 |
| 69 (Class 1 only) | 1416 | 1082 | 1279 | 1245 |

[1] In cases where greater than 10kW of PV capacity was required to meet a ZNRE target extrapolation was used to give an approximate estimate of required PV capacity. Generally however this approach is not recommended and for dwellings requiring more than 10kW of PV capacity a Whole-of-Home simulation should be undertaken using PV capacities greater than 10kW.

**Figure 3 : Sample Output Demonstrating the Variability of PV Output over a Year[2]**

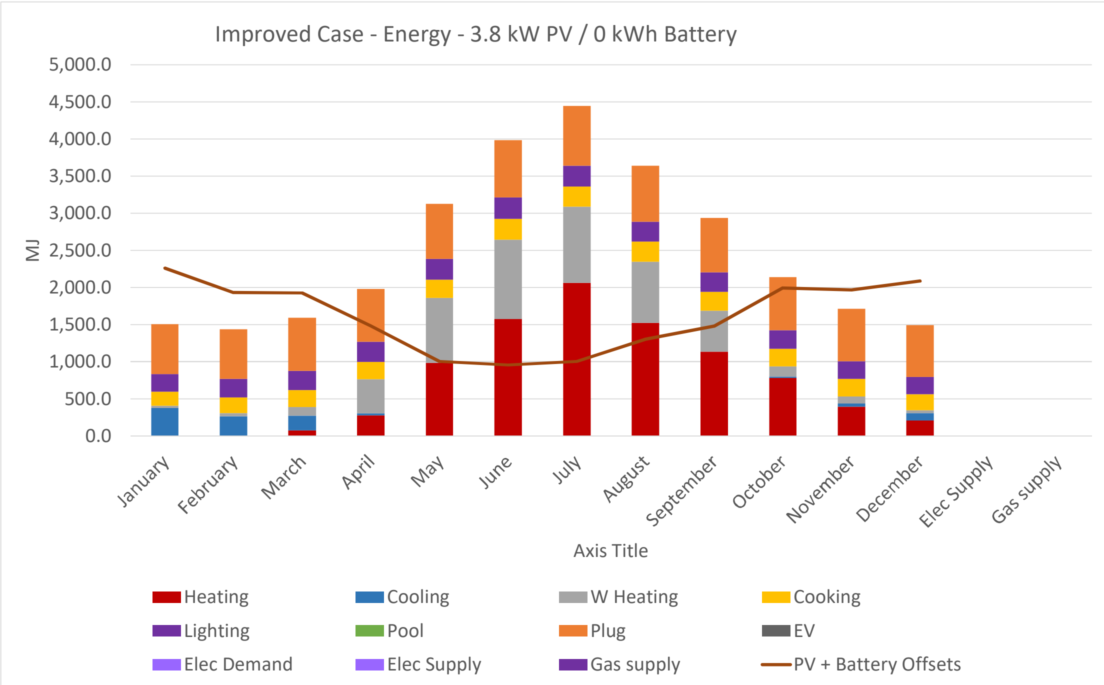
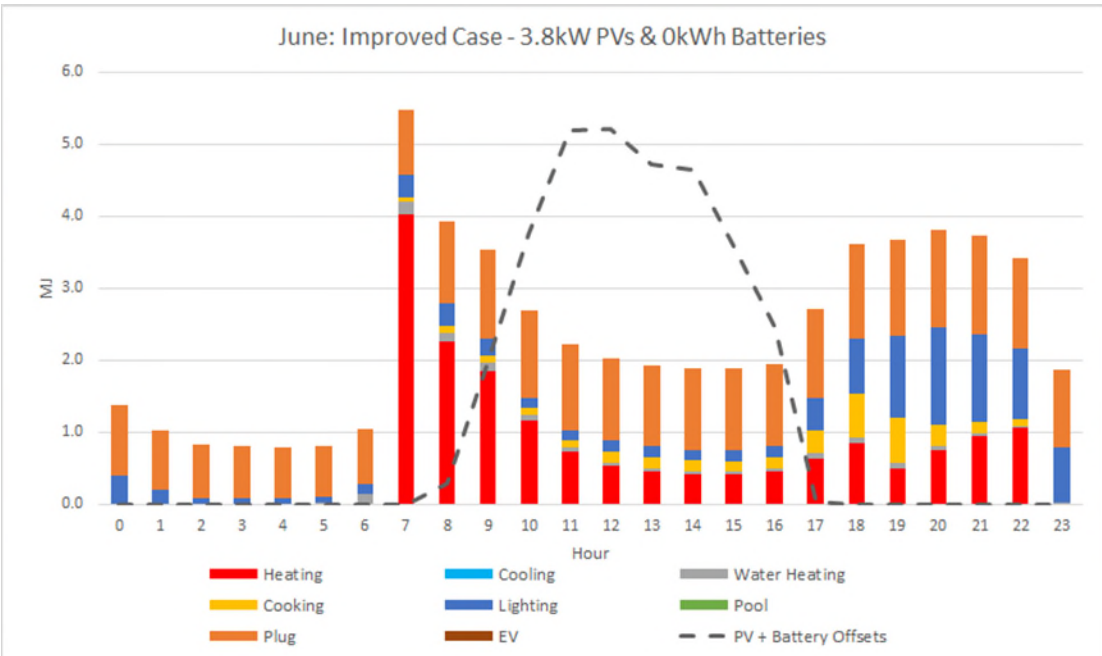



**Figure 4 : Sample Output Demonstrating the Variability of PV Output over a Day**




[2] The figures on this page include references to "PV + Battery offsets". However, in the context of this study only the impacts of PVs alone have been considered. Batteries could provide further benefits or dis-benefits depending on the metric adopted.

### 2.3.3 End Use Consumption and Profiling

For each end-use and end-use scenario included in the scope of the model, an estimated annual energy consumption is determined. The annual end use consumption is assumed to vary according to a range of parameters as noted in Section 6. Full details for the basis of energy consumption estimates can be found in Appendix 1 – End Use Estimates Basis. A summary of the main parameters impacting on annual energy consumption can be found in Table 2 below.

For each end use, an hourly load profile over an entire year is estimated (i.e., the proportion of the annual energy consumption that is expected to be utilized in each hour of the 8760 hours that make up a year). For some end-uses, the hourly load is relatively constant over the course of the year and a simple proportion of the annual load can be used for each hour in the year. For example, for a refrigerator, a freezer or for standby power, the load for every hour in the year might simply be 1/8760 of the estimated annual load, noting that refrigerators and freezers are somewhat seasonal in their energy consumption and there is also some time of day variation from indoor temperature changes and usage patterns. For most other end- uses the load is generally confined to particular times of day (e.g. cooking, TV viewing etc.). Some other end-uses also exhibit a degree of seasonality (e.g. lighting, swimming pool pumps). Finally, in the case of heating and cooling, actual hourly loads as generated by the AccuRate simulation software have been used to apportion total annual energy consumption to each hour of the year. This load is seasonal, highly variable and driven primarily by the weather files used for simulation.

Full details of the load profiles by end-use can be found in Appendix 1 – End Use Estimates Basis. Table 3 below provides an outline summary of the key sources used to determine the hourly load profile for each end-use.

**Table 2: Parameters Impacting On Annual Energy Consumption by End Use**

| End Use | House size | Number of occupants | Occupancy profile | Building Shell Performance | Appliance Efficiency |
|---|---|---|---|---|---|
| Heating | x | | x | x | x |
| Cooling | x | | x | x | x |
| Water heating | | x | | | x |
| Cooking | | x | | | x |
| Lighting | x | | x | | x |
| Refrigerators | | x | | | x |
| Freezers | | x | | | x |
| Clothes Washers | | x | x | | x |
| Dishwashers | | x | x | | x |
| Clothes Dryers | | x | x | | x |
| Televisions | | x | x | | x |
| Swimming pool | | | | | x |
| Standby | | x | | | x |
| Other | | x | | | x |

**Table 3: Key Sources for Load Profiles**

| End Use | Source of load profile |
|---|---|
| Heating | AccuRate Thermal simulation hourly loads (In the case of off peak electric heating, loads were shifted to hours designated for off peak power supply) |
| Cooling | AccuRate Thermal simulation hourly loads |
| Water heating | Based on metering data primarily supplied by Sustainability Victoria* |
| Cooking | Based on Pacific power metering data |
| Lighting | Based on Pacific power metering data |
| Refrigerators | Based on Pacific power metering data |
| Freezers | Based on Pacific power metering data |
| Clothes Washers | Based on Pacific power metering data |
| Dishwashers | Based on Pacific power metering data |
| Clothes Dryers | Based on Pacific power metering data |
| Televisions | Based on Pacific power metering data |
| Swimming pools | Based on Pacific power metering data |
| Standby | Assumed to be continuous over the year |
| Other | Assumed to be continuous over the year |

* Data for creating representative load profiles was drawn from various sources including metering data gathered by both Energy Efficient Strategies and Sustainability Victoria. For clothes washers the Pacific Power data was primarily top loaders with no heating, whereas 50% of sales are now front loaders with mostly internally heated water, so the energy balance and load profiles will be slightly different.

## *2.4 Impact Model Component*

The impacts model (see schematic in Figure 5) has three main sub-modules as follows:

- ZNRE compliance assessment module
- Benefit assessment module
- Cost assessment module

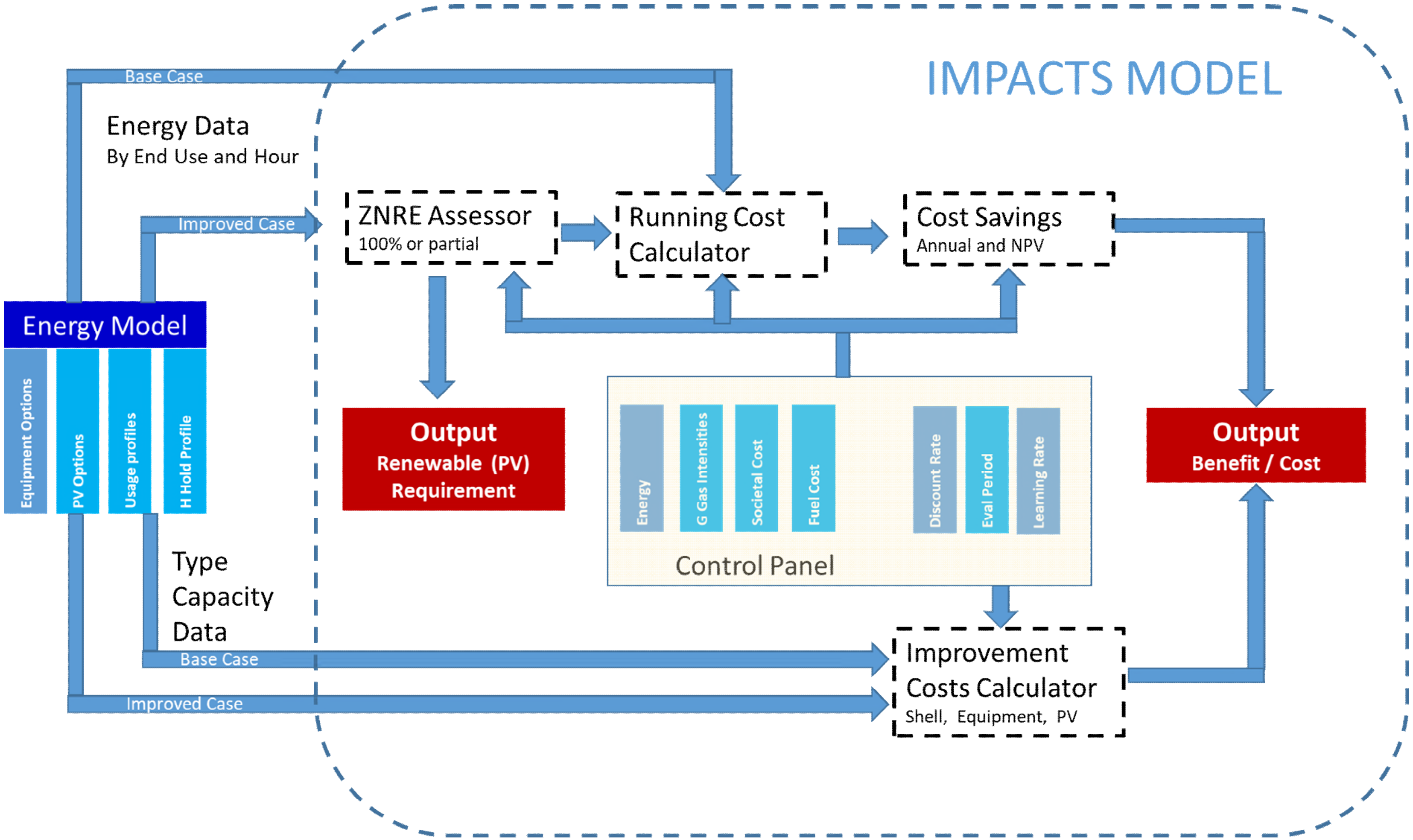
Note: The indicative benefits and costs assessed in this study were only at an individual dwelling level (i.e. not a RIS assessment). A weighted assessment at a jurisdictional level was undertaken as a separate (RIS) study by others using some input data from this study plus a range of other settings specifically selected for the RIS assessment.

**ZNRE ASSESSMENT MODULE**

The ZNRE compliance module examines each case as generated by the Energy module and then determines if the particular combination of building shell, equipment and PV capacity meets the performance target (ZNRE or part ZNRE requirement as applicable).

The model is set up such that the ZNRE status can be assessed against any of the four metrics previously detailed. Data relating to each metric (e.g. fuel costs, greenhouse gas emission intensities of fuels, etc.) are all stored in the model and can be adjusted as required. The performance target can also be adjusted as required from net 100% offset of regulated usage to any selected percentage of a nominated base case. For this study, however, the part-ZNRE case was defined by a benchmark equipment and building fabric performance level, refer to Section 3 for details of the benchmark settings adopted.

**Figure 5: Schematic of Impacts Model Conceptual Basis**



ZNRE assessment is carried out for each case with between 0kW and 10 kW of PVs applied in 1 kW increments. The exact renewable energy input requirement needed to meet the selected ZNRE target is determined via linear interpolation between the PV capacities that yield outcomes immediately above and immediately below the target. For the purposes of calculating expected costs and benefits (as distinct from the determination of a precise PV capacity requirement needed to meet a particular performance level) exceptions made to this rule as follows, particularly in relation to the part ZNRE options (option 1.5 and option 2) where the PV requirement might be very small (less than 2kW for example).

**Class 1 dwellings:** Because PV systems of less than 3.0 kW capacity are rarely installed, where a PV requirement was found to be greater than 0kW and less than 3.0 kW, it has been assumed for cost benefit calculations only that a minimum 3.0kW system would be installed.

**Class 2 dwellings**: For Class 2 dwellings, it has been assumed that the most likely outcome would by a jointly-owned roof-mounted PV system serving the entire block.[3] This means that even though the PV requirement for individual units might be very small (say 0.5kW per unit), the actual system installed could easily be 10kW or more (e.g. 20 units each needing 0.5kW PV would be supplied by a single 10 kW system). In this case, PV system costings were calculated on the basis of larger more cost-effective arrays with a 25% cost impost applied to cover the cost of longer cable runs etc.

**BENEFIT ASSESSMENT MODULE**

Once the required renewable capacity needed to meet the selected ZNRE target is determined, a calculation is then made of the cost of operating each regulated end-use (by fuel type), and also of the offset afforded in such costs from export of renewable energy to the grid (eg, from feed-in tariffs earned by the exported energy), and of reductions in energy consumption from unregulated plug in type appliances on account of the on-site renewable energy generation.

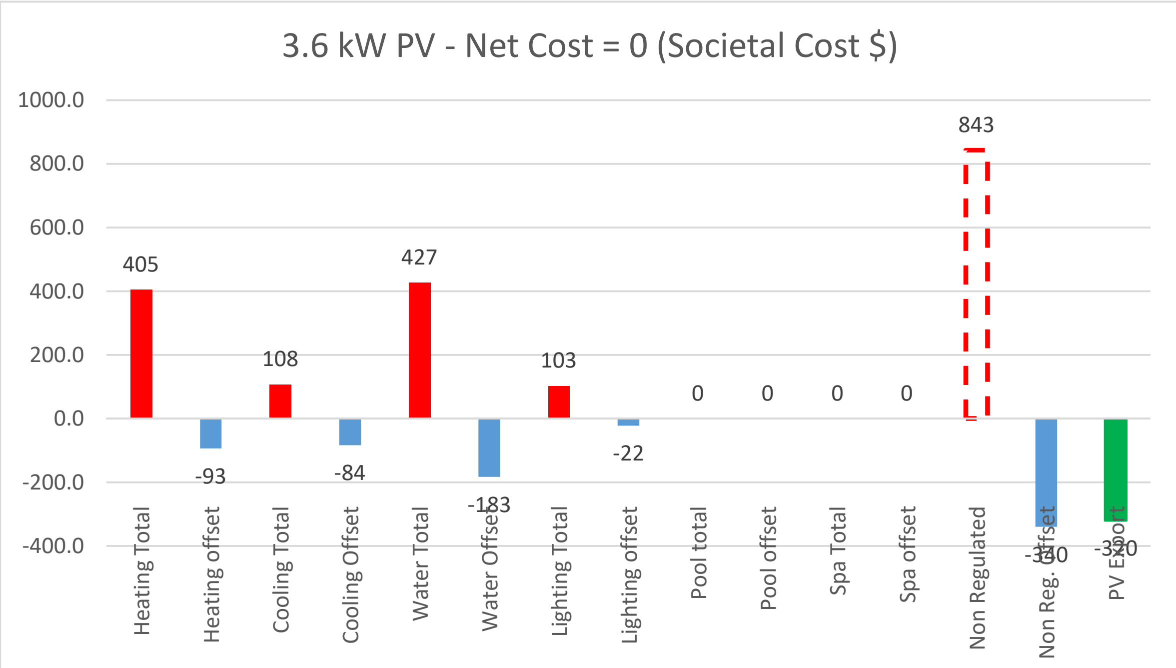
The resulting savings in a typical mean year are calculated by multiplying the estimated energy savings by fuel type by the intensity factor for that fuel (intensity factors can be for any of the 4 metrics e.g. $ Cost, Tonnes CO2-e etc.,) The model also allows the user to set an expected rate of real increase (or decrease) in the intensity factor over time.

In a 100% ZNRE scenario, the net “cost”, whether it be in terms of dollars or mega-joules or greenhouse gas emissions is zero and this value is compared to a base case (i.e. an unimproved building shell with no on-site renewable energy generation).

An example of a 100% ZNRE is shown in Figure 6. In this chart the red bars above the zero axis represent total energy consumption (both imported and site generated i.e. the amount of external energy that would have been used in the absence of any on-site renewable generation) and the blue bars below the zero axis represent the portion of energy consumption that is offset by the PV array.

[3] The alternative, each unit having its own separate system is unlikely except possibly in very small 2 storey blocks. Roof areas are typically common property (owned by the body corporate not individual owners) and separate cable runs from each unit to a titled space on the roof would be quite onerous to set-up

**Figure 6: Example – 100% ZNRE based on Societal Cost Metric**




Non-regulated consumption is indicated by the dotted red bar (not accounted for in the ZNRE accounting) and the offset to the non-regulated energy as a blue bar to the immediate right of the regulated energy consumption (offset is included in the accounting). Finally, the green bar on the far right of the chart represents the PV export to the grid (counted as a credit). In this case, the PV array size has been set such that it exactly offsets the regulated consumption according to a societal cost metric (i.e. the sum of the blue and green bars is equal to the sum of the red bars – excluding the red dotted bar)

**COST ASSESSMENT MODULE**

For each case examined, this module assesses the costs of:

- Upgrades to the energy performance of the building shell
- Regulated equipment (heating, cooling, hot water and lighting)
- The PV installation including inverter (sized to meet the particular ZNRE target).

Account is also taken of the need to replace elements of these systems on a regular basis (e.g. PVs every 20 years and inverters every 10 years). Details of this costing basis can be found in the following Section 2.4.1.

Primarily, however, it is the cost of building shell upgrades and the cost of any required on-site renewable energy installation that is of primary concern because it is these elements that are the subject of proposed regulatory requirements.

Of course, an individual designer/builder may choose to supply a more efficient heating system than required under the proposed regulations. Any legal heating system can be used, but the more efficient the system, the lower the on-site renewable energy requirement will be. The model has the capacity to compare base and improved cases with different end-use equipment types and or efficiencies,[4] but this is not the main focus of this study.

### *2.4.1 Benefit Cost Analysis*

Benefit cost analysis is undertaken for a range of elements as follows:

**Costs**

- Building shell improvement costs
- Appliance costs
- PV costs
- Inverter for PV costs.

Both costs and benefits are analysed on both an average annual basis and a Net Present Value (NPV) basis. Benefit cost outcomes are determined on a NPV basis, with facilities within the tool to vary both the evaluation period, the discount rate and (any) learning rates (i.e. the real incremental costs of higher performance equipment over time).

Costs relating to building shell improvements were modelled specifically for this project (see Section 7). As noted, PV and inverter costs were also specifically modelled for this project by ITP renewables - see ITP Technical Note 0357 in Appendix 4 – PV and Inverters – Basis for Cost Estimates.

Default cost data for appliance costs loaded into the model has been drawn from a range of pre-existing sources, including some limited market research undertaken for Sustainability Victoria several years ago. Appliance costs are, however, of lesser importance in the context of the proposed regulations. Whilst regulations are likely to mandate changes to the building shell performance, and also may mandate the provision of PV systems as a means for offsetting other energy consumption, there is no proposal to alter regulations in respect of the minimum performance standards for installed equipment. Such changes are typically determined under the Greenhouse and Energy Minimum Standards (GEMS) program. This means that, in general terms, there is no expectation that builders will alter the types and efficiencies of the equipment being installed unless in their view it will be beneficial for them to so do. So generally, the impact of the regulations on equipment costs is assumed to be neutral. However, highly inefficient energy-using technologies would require the installation of larger PV arrays to offset their energy consumption, and some builders may decide that it is more cost-effective to install more costly but more efficient equipment, and thereby reduce the cost of PVs that will be required to be installed.

[4] This sort of comparison would be important in cases where the particular end use equipment initially selected results in a very high on-site renewable energy requirement. Where such a requirement is found to be either too costly or impractical to achieve then other (more efficient) end use equipment options that can reduce the on-site renewable energy requirement will become attractive to the designer/builder.

**Small-Scale Technology Certificate (STC) Savings**
When PV panel are installed, the full cost of the installation is calculated (see Section 7.3). The number of Small-Scale Technology Certificates (STCs) is then calculated based on the kW capacity of the installation and the (current) number of STCs awarded per kW of installed capacity (noting that this can vary by climate zone).

This value is then multiplied by the current market price for STCs (approximately $37 per STC as of March 2020) to give the total discount expected to be realised on the cost of the PV installation. Both the number of STCs awarded per kW of installed PV capacity and the market price for STCs can be adjusted in the model by the user from the dashboard.

Note that for the purposes of benefit cost analysis at a societal level, the discount afforded to householders via STC rebates is not included, as these represent a financial transfer from taxpayers to householders, rather than a net social benefit. STCs are only required to be included in the calculus in relation to an individual householder or private costs.

**Evaluation Periods**
Costs and savings can be estimated over any period by the model. For the purposes of this study the evaluation period has been set to 40 years in line with recommendations in the study Residential Buildings Regulatory Impact Statement Methodology (HoustenKemp 2017).

Each improvement measure is assigned an assumed economic lifetime (see Appendix 1 – End Use Estimates Basis). For example, PV inverters are assumed to have an average lifetime of 10 years. The model therefore factors in replacements of each improvement measure over the evaluation period. For example, in the case of PV inverters, if the evaluation period were set to 20 years, then costs would be assumed to apply in year one and year 11. If the evaluation period were set to 25 years, then costs for PV inverter installations are assumed to apply in year 1, year 11 and year 21; however, the cost in year 21 is discounted by half to reflect the fact that the evaluation period ends half-way through the life of the 2$^{nd}$ replacement of the PV inverter.

The model can also factor in expected declines in the real incremental costs of higher performance equipment over time (sometimes called learning rates). This means that the cost of a particular improvement in the future is expected to be less in real terms compared to its present-day cost. Of course, such cost reductions are not expected to continue indefinitely, and consequently the model includes the option to select a "sunset" period for cost decreases into the future (this is set to 10 years)[5].

In this study, by default, learning rates for all costs have been set at a conservative 1% per annum. There are few studies regarding this aspect, however Houston Kemp in their report *Residential Buildings Regulatory Impact Statement Methodology* (Houston Kemp 2017) recommend the following:

> *….a cost efficiency rate of 2 per cent year-on-year as a starting point with sensitivities of 1 per cent (lower bound) and 3 per cent (upper bound). These rates are broadly consistent with what is considered in other sectors, e.g., the electricity and gas network sector.*

[5] This may be a conservative assumptions as we are not talking about absolute costs, but incremental costs. As the old technology reduces in production volume, and the new technology increases, the latter can eventually end up cheaper overall.

Building and equipment cost estimates are taken as an average over an assumed 10-year life of regulations starting in 2022; i.e., costs are in present day dollars based on estimated costs mid-term of the regulations, an approximate assumed real cost reduction of 5% on year 1 costs across the life of the regulations.

For each case examined, the net present value of all of the costs and all of the savings are compared and a benefit/cost ratio determined.

# 3 Metrics and Performance Targets

## 3.1 Overview

This section outlines the basis for the metric applied to the performance estimates and the performance target options examined in this study.

## 3.2 Metrics

Historically, three main types of metric numerator have been used in performance assessments of dwellings and or their equipment:

- Energy Consumption (MJ)
- Cost of Operation ($)
- Greenhouse gas emissions (Tonnes $CO_{2\text{-}e}$)

Denominators are typically per $m^2$ or per deemed occupant or per dwelling. Because the NCC 2022 energy efficiency provisions are to be expanded to include an assessment of the whole-of-home, the per dwelling denominator is used.

Generally, the choice of numerator for the metric is based on the policy objective of the proposed regulation. The original brief for this project was couched in terms of an energy metric i.e. Zero Net Regulated Energy.

Where a single fuel type is involved (e.g. electricity only, as is the case for end-use equipment such as lighting), a reduction in energy consumption will also result in a reduction in operational costs and greenhouse gas emissions. However, where multiple fuels are involved (primarily electricity, gas and firewood), as is often the case in Australian housing, the outcome is less clear.

For example in Victoria, switching from a high-efficiency gas heater to a resistance electric heater will reduce delivered energy consumption but increase running costs and greenhouse gas emissions significantly. Alternatively, switching from a MEPS-level heat pump heater to a high efficiency gas heater will significantly increase delivered energy consumption but will have limited or no impact on running costs and greenhouse gas emissions. These relationships will differ from state to state, however, as the greenhouse intensity of electricity, in particular, varies, as does the availability of other fuels such as natural gas.

Direction on this aspect was sought from the ABCB, which has been developing the NCC whole-of-home performance requirement in parallel to this study (Quantified Residential Energy Efficiency Performance Requirements for NCC 2022 – Draft Report). Advice received was that the performance requirement was to be based on a “societal cost”.

Societal cost was defined as:

> ***The cost to society as a whole, including but not necessarily limited to, costs to the building user, costs to the environment and costs to energy networks.***

In practical terms, for modelling purposes this meant that societal cost is composed of two main elements:

- The cost of fuel to the building user
- The cost of the greenhouse gas emissions associated with the use of that fuel.

In addition, in relation to electricity use, the ABCB required that the cost of fuel be broadly reflective of its network cost according to its time of use, higher at times of peak demand and lower at times of minimum demand.

Calculation of societal cost therefore requires calculation of hourly energy demand (at least for electricity consumption), this is then combined with time of use energy tariffs, greenhouse gas intensity of fuels and feed-in tariff data. Note that NCC climate zones that span more than one jurisdiction required separate analysis of that climate zone in each jurisdiction (due to variations in fuel costs and greenhouse gas intensities by jurisdiction). Actual values adopted by jurisdiction are detailed in Section 6 of this report.

## *3.3 Performance Targets*

The brief for this project required that two different performance targets be evaluated. These were:

- Option 1: 100% ZNRE
- Option 2: Part ZNRE.

**Option 1: 100% NZRE** i.e. irrespective of the installed regulated equipment types, the societal cost of operating that equipment must be fully offset by on-site renewable energy generation (typically roof mounted PVs). The more efficient/less costly the regulated equipment is to operate the less the renewable energy offset requirement. This offsetting concept is illustrated in Figure 7 below using notional societal costings.

**Option 2: Part NZRE** - In this option, a benchmark equipment and building fabric performance level is set (e.g., by regulation), and the societal cost of operating that equipment is calculated. A compliant dwelling must have the same societal cost as a 7-star dwelling with specified benchmark heating, cooling and hot water appliances. The following (above average) benchmark appliance profile was used, broadly consistent with the ABCB Scoping Study [Energy efficiency: NCC 2022 and beyond Scoping study, ABCB 2019]:

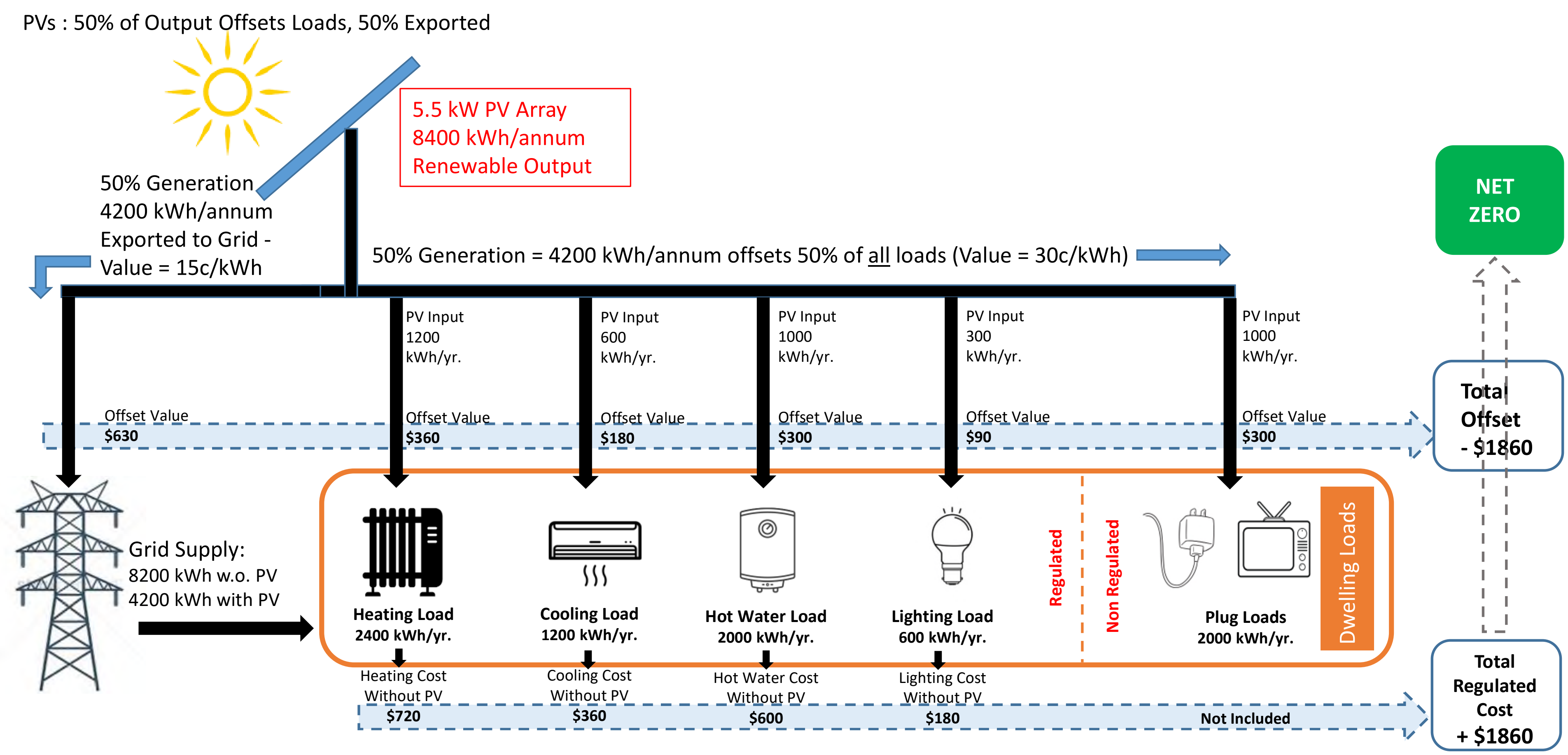
- Building shell performance level: Equivalent to a 7 star NatHERS rated dwelling
- Heating : Equivalent to a 4.5 star rated (GEMS 2012) heat pump heater (AEER = 4.5)[6]
- Cooling Equivalent to a 4.5 star rated (GEMS 2012) heat pump cooler (ACOP = 4.5)[7]
- Water heater: Gas instantaneous.

[6] Under the latest 2019 GEMS determination, in terms of seasonal ratings, this would equate to 3 Stars i.e. A Heating Seasonal Performance Factor (HSPF) of 4.5

[7] Under the latest 2019 GEMS determination, in terms of seasonal ratings, this would equate to 3 Stars i.e. A Total Cooling Seasonal Performance Factor (TCSPF) of 4.5

It is noted that whilst the water heater benchmark has at the direction of the ABCB been based on a gas fired water heater, not all dwellings in Australia have access to a gas supply. This is not an issue insofar as equivalence with the benchmark can be achieved using other forms of equipment (e.g. a heat pump or solar boosted electric water heater for instance) either alone or in combination with PVs as required. The benchmark simply sets a level of performance it does not dictate the types of equipment that must be installed.

**Figure 7: Schematic of Net Zero Accounting**



# 4 Sample Dwelling and Equipment Types Modelled

## *4.1 Dwellings*

For thermal modelling purposes, a single representative dwelling type in each climate zone was modelled as the basis for the heating and cooling load profile as follows:

**Sample Detached Dwelling**

- Single Storey Detached Dwelling on a concrete slab floor
- Wall construction – Typical for the jurisdiction (mostly brick veneer)
- Gross floor Area (including Garage and External Walls - 202 $m^2$ approx.)
- Garage Area (37.3 $m^2$)
- Net Conditioned floor area (136.2 $m^2$)
- Details provided in Appendix 5 – Simulated House Plans.

Whilst the range of dwelling types modelled was by necessity limited, it should be understood that the chosen dwelling type delivers a representative load profile for a 7 star rated dwelling into the energy analysis model in each climate zone. Variations in proportions of heating and cooling that would exist across the range of new dwellings will only have a minor impact on results because, whether its heating or cooling biased, a designer will still have to offset that total space conditioning load, which is always a given total (heating + cooling) for a particular star rating and size of dwelling.

Whilst only a single dwelling type was used for establishing heating and cooling load profiles, a broader range of dwellings types and sizes were modelled (12 types) to establish representative costs associated with meeting the new building shell performance target. These costs were used in the benefit/cost analysis.

**Sample Class 2 Dwelling**

For Class 2 dwellings (apartments or units), a broad range of dwellings were initially modelled. Middle and corner units on ground floors, intermediate floors and uppermost floors across the 4 main orientations (the exact details are described elsewhere in this report). These dwellings ranged in performance from a minimum of 6 NatHERS stars to more than 8 NatHERS stars with the weighted average at 7 stars.

From this range of 24 apartment options, a representative sample dwelling was selected for use in the whole-of-home calculations. The selected dwelling was selected on the basis that its performance level was close to the average target of 7 stars (typically 7 stars ± 0.2 stars variation) and also that the balance between heating and cooling loads was close to the average across all units in the block.

As with the Class 1 dwellings, whilst a single dwelling type only was used for establishing the heating and cooling load profiles, a broader range of dwelling types and sizes were modelled (24 types) to establish representative costs associated with meeting the new building shell performance target. These costs were used in the benefit/cost analysis.

## 4.2 Equipment

As noted previously, a range of end-uses were factored into the ZNRE modelling. The types modelled were selected to be representative of the most commonly available equipment types and included combinations of the following into ‘end use profiles’:

**Heating**

- No Heating
- Central Gas (ducted)[1]
- Central Heat Pump
- Room Gas[2]
- Room Heat Pump[2]
- Central Elec Panels[2]
- Wood (closed combustion) [2]
- Electric slab heating[2]

**Cooling**

- No cooling
- Central Heat Pump (ducted)
- Central evaporative
- Room Heat Pump (split or multi-split) [2]

**Water heating**

- Electric Storage (“peak” or uncontrolled load)
- Electric Storage (“off peak” or controlled load)
- Heat Pump (Standard)
- Heat Pump (off-peak)
- Solar electric (Standard)
- Gas storage
- Gas Instantaneous
- Solar Gas

**Lighting**

- All forms (based on assumed power density)

**Swimming pool pumps**

- No pool pump
- Pool pump (sized to suit an average 40,000 litre pool[3])

**Spa pumps**

- No spa pump
- Spa pump (sized to suit an average 4,000 litre spa[3])

Notes:

1. Whilst central gas hydronic panel heating is not specifically modelled its performance may be assumed to be similar to central gas ducted heating
2. In the case of room heaters or coolers the model can be configured to assume that these devices are installed only in living spaces or alternatively multiple devices are installed throughout the dwelling. For regulatory purposes whole-of-home conditioning is assumed.
3. Based on data supplied from the BASIX tool.

## 4.3 Equipment Efficiency

Not only does the type of installed equipment impact on energy use, but so does the efficiency of that equipment. In reality, new dwellings contain a range of equipment efficiencies from very low (e.g. at or near MEPS levels where applicable) to very high (best in market).

**HEATING AND COOLING EQUIPMENT**

In order that the range of efficiencies could be modelled adequately, for each technology, four different levels were modelled as follows:

- Very Low (approximately MEPS levels or lowest available)
- Low Efficiency (approximately market average or slightly less)
- Medium Efficiency (better than market average)
- High Efficiency (approximately best available).

For simplicity and to encompass a broad range of performance levels, the lowest performance levels have in some cases been set below the current minimum available (e.g. the poorest performing ducted gas neater available in 2019 (AGA register) was rated at just over 2 stars). Likewise, the highest performance levels modelled are sometimes set above the highest currently available (e.g. the best performing gas space heater available in 2019 rates at 5 stars only).

By modelling four levels of efficiency, it is then possible through interpolation to approximate energy demand associated with intermediate levels of efficiency as required.

The actual efficiency levels modelled were as described in Table 4 (heating) and Table 5 (cooling). With respect to these tables the following should be noted:

1. System losses such as through ductwork or slab edges are dealt with separately in Section 6.12, the values in the following tables relate to the heating or cooling plant efficiency only.
2. Heat pump ratings shown in the table are based on the 2013 GEMS determination. At the time of modelling for this project, the majority of product available in the market was rated according to the 2013 determination based on non-seasonal performance (AEER or ACOP) and such product shall be available until 2024. Product registered post 1 April 2020 is registered to the 2019 GEMS determination and is rated based on its seasonal performance characteristics (TCSPF or HSPF). The star rating value for products registered to the 2019 GEMS determination is based on a different scale compared to product registered to the 2013 GEMS determination (i.e., as shown in Table 4 (heating) and Table 5 (cooling). A concordance of the two rating values is provided in Table 6. NCC regulations that might cite star ratings will need to accommodate ratings to both the 2013 determination and the 2019 determination at least until 2025.
3. For central (ducted) gas heaters, the star rating is a combination of both the seasonal operating efficiency (up to a maximum of 5 stars) plus up to one additional star for the units heat load reduction factor (HLR). The HLR is a measure of the heater’s ability to turn down its capacity to supply fewer duct outlet points. This heat load reduction measure of the standard is intended to encourage the use of two stage or variable gas control valves and variable speed fans in heater designs.

**Table 4 Heating Equipment – Modelled Efficiency Levels**

| End Use Type | Very Low Efficiency | Low Efficiency | Medium Efficiency | High Efficiency | Metric |
|---|---|---|---|---|---|
| Central Gas | 1.5 (55%) | 3.0 (70%) | 4.5 (85%) | 6.0 (~90%) | Stars (%)[1] |
| Central HP | 1.5 (300%) | 3.0 (375%) | 4.5 (450%) | 6.0 (525%) | Stars (%)[2] |
| Room Gas | 1.5 (64%) | 3.0 (73%) | 4.5 (82%) | 6.0 (97%) | Stars (%) |
| Room HP | 1.5 (300%) | 3.0 (375%) | 4.5 (450%) | 6.0 (525%) | Stars (%)[2] |
| Central Elec Panels | 100 | 100 | 100 | 100 | % |
| Wood Central | 60 | 65 | 70 | 75 | % |
| Slab[3] | 90 | 90 | 90 | 90 | % |

Notes:

1. The star ratings applied to ducted gas heaters can include an allowance for up to one additional star for the unit's heat load reduction factor. The % efficiencies shown above relate to the seasonal efficiency for the particular star rating indicated. In reality a unit with the noted % efficiency may score up to 1 star higher than that noted due to credits for its heat load reduction factor (HLR) credited for features such as two stage or variable gas control valves and variable speed fans. For high efficiency rated units (e.g. 6 stars) the HLR is typically close to one and the seasonal efficiency approximately 90%.
2. Star ratings are based on the AEER values i.e. pre 2019 determination. The "equivalent" star ratings based on seasonal ratings (2019 GEMS determination) are as follows:
   a. 1.5 Stars = 1.5 stars
   b. 3.0 stars = 2.25 stars
   c. 4.5 stars = 3.0 stars
   d. 6 stars = 3.75 stars
3. Efficiency for slab heating unlike electric panels factors in a degree of extended hours of heating due to the significant amount of thermal inertia associated with this type of heating.

**Table 5 Cooling Equipment – Assumed Efficiency Levels**

| End Use Type | Very Low Efficiency | Low Efficiency | Medium Efficiency | High Efficiency | Metric |
|---|---|---|---|---|---|
| Central HP (Cool) | 1.5 | 3.0 | 4.5 | 6.0 | Stars |
| Central evaporative | 1500* | 1500* | 1500* | 1500* | % |
| Room HP (Cool) | 1.5 | 3.0 | 4.5 | 6.0 | Stars |

* Note: This efficiency level is based on a comparative level associated with heat pump technology (i.e. they use approximately ¼ of the energy used by heat pumps) , noting however that the same service is not provided by evaporative coolers (no dehumidifying) as compared to heat pump type coolers

**Table 6: Air-conditioner Star Ratings: GEMS 2013 versus GEMS 2019**

| AEER/ACOP/TCSPF/HSPF | GEMS 2013 (old stars) | GEMS 2019 (new stars) |
|---|---|---|
| 2.5 | 0.5 | 1 |
| 2.75 | 1 | 1.25 |
| 3 | 1.5 | 1.5 |
| 3.25 | 2 | 1.75 |
| 3.5 | 2.5 | 2 |
| 3.75 | 3 | 2.25 |
| 4 | 3.5 | 2.5 |
| 4.25 | 4 | 2.75 |

| AEER/ACOP/TCSPF/HSPF | GEMS 2013 (old stars) | GEMS 2019 (new stars) |
|---|---|---|
| 4.5 | 4.5 | 3 |
| 4.75 | 5 | 3.25 |
| 5 | 5.5 | 3.5 |
| 5.25 | 6 | 3.75 |

The "low efficiency option" in the above tables is considered to be most representative of the budget end of the market and is therefore likely to be commonly used in new project homes and relevant in terms of any cost benefit analysis. The following non-sales weighted data sources provided a rudimentary picture of the current market.

**Gas Heaters**

In the Australian Gas Association directory of certified products 2019 the following performance ranges were observed:

- Central Gas heating: 2.4 – 6 stars
- Room gas heaters: 1 – 5 stars.

**Heat Pump Heaters and Coolers**

Reference was made to the CSIRO website (https://ahd.csiro.au/dashboards/fixtures-and-appliances/air-conditioning/) which draws non sales weighted data from the GEMS register – See Figure 8. From this analysis it can be seen that performance levels range from 2.5 stars to 5.5 stars with some variation by size and mode of operation. In the case of larger units, it is known from examination of the register that there are a few units with a performance equivalent to less than 2.5 stars (1.5 and 2 stars), but these are apparently not picked up in the CSIRO analysis (possibly because for three-phase and ducted units, inclusion of a label indicating a star rating under the GEMS provisions is optional).

#### WATER HEATING EQUIPMENT

In the case of water heaters, a stock-average efficiency level only was modelled for each technology type (see Table 7). In many of the technology types available, there is no available rating system that could be used in any case, while in the case of gas hot water heaters that do have a rating system,[8] the performance of most units is already at the higher efficiency end of the rating scale leaving little room for differentiation. This means that for the purposes of this study, 'high efficiency' for water heaters was defined simply in terms of the technology used rather than different levels of efficiency within a particular category of technology.

[8] Note: The GEMS MEPS level (2013) sets a lower limit of 4 stars for outdoor units but no limit for indoor units. Consequently, all units rated below 4 stars must be indoor type units (which are less common than outdoor type units).

**Figure 8: CSIRO "Dashboard Data – Air Conditioners**

**Table 7 Water Heating Equipment – Modelled Efficiency Levels**

| End Use Type | Efficiency | Metric |
|---|---|---|
| Electric Storage (peak)[1] | Average (nominally 100% plus heat loss allowances) | N/A |
| Electric Storage (off peak) [1] | Average<br>(nominally 100% plus heat loss allowances) | N/A |
| Heat Pump (Standard) | Average<br>Marginal COP range 3.0 – 3.5 (CZ 3) | N/A |
| Heat Pump (off-peak) | Average<br>Marginal COP range 3.0 – 3.5 (CZ 3) | N/A |
| Solar electric (Standard) | Average<br>Close coupled thermos-syphon – non selective | N/A |
| Gas storage[2] | 4 Star<br>(nominally 60%) | Stars |
| Gas Instantaneous | 5 Star<br>(nominally 66%) | Stars |
| Solar Gas | Average<br>In-line type non selective surface | N/A |

Notes

1. Use of resistance electric water heaters is subject to limitations under the current provisions of the NCC – see following text
2. In relation to Gas water heaters the available performance levels noted in the Australian Gas Association directory of certified products 2019 range from 2.5 stars to 5.3 stars (storage) and 4.4 stars to 6 stars (instantaneous).Deemed to satisfy provisions in the NCC mandate 5 stars in most jurisdictions but this does not apply in NSW (under BASIX) or in South Australia for internal water heaters (see following text). Consequently the lower GEMS regulated standard of 4 stars was modelled for gas storage water heaters. In the case of gas instantaneous, because most available units rate at 5 stars or better, 5 stars was modelled.

### Heated water service provisions of the NCC

The heated water service provisions of the NCC are somewhat complex and state variations add to the varied options available.

The current NCC part 3 performance requirement (BP 2.) requires that a heated water service, including any associated distribution system and components, must obtain heating energy from one, or a combination, of the following:

a) A source that has a greenhouse gas intensity up to and including 100 g CO2-e/MJ of thermal energy load.
b) An on-site renewable energy source.
c) Another process as reclaimed energy.

Provision (a) would in theory permit the use of resistance electric water heating in jurisdictions with electricity supplies that have a greenhouse intensity of less than 100 g CO2-e/MJ. At present this would include Tasmania and the ACT and potentially South Australia in the near future. The Tasmanian variation in part 3 in fact explicitly permits the use of resistance electric water heating. Furthermore, clause B2.2 permits resistance electric water heating generally in 1-bedroom apartments where the capacity is less than 50 litres. Also, under the NSW variation (BASIX) use of electric resistance heating is also possible although not often used except in smaller apartments.

In relation to gas water heaters, provision (a) above would in theory permit the use of a water heater with an efficiency as low as 61% (given that the deemed greenhouse gas intensity of natural gas is 61 g CO2-e/MJ i.e. 61 g CO2-e/MJ / 61% = 100 g CO2-e/MJ (a gas water heater with an efficiency of 61% would rate as 4.15 stars). In the deemed to satisfy provisions of the NCC a gas water heater with a minimum performance of 5 stars is specified by default. However, in SA, there is a specific exemption from the 5 star DTS requirement for internal gas water heaters which can rate as low as 3 stars. In NSW under the BASIX provisions (state variation) any performance rating could be used provided it meets the GEMS MEPS requirement (4 stars for outdoor units).

Provision (b) means in theory that practically any type of electric water heater (including resistance electric) could be used provided sufficient on-site renewable energy is generated / supplied to the water heater. This aspect is worthy of further consideration in the context of potential minimum renewable energy requirements in NCC 2022.

## LIGHTING EQUIPMENT

The brief for this project included no changes to the current performance requirements in respect of lighting installations.

In the NCC, efficiency levels for lighting equipment are couched in terms of a maximum power density requirement ($W/m^2$ of floor area). The NCC sets a maximum level of 5 $W/m^2$ (with some dispensations for various control systems). In the context of wide usage of LED technology this level of 5 $W/m^2$ represents a relatively high level of service provision for most new housing. Even assuming a modest average lamp efficacy of say 50 lumens per watt this would equate to a service provision of 250 lumens/ $m^2$ or 400 lumens / $m^2$ if a more realistic lamp efficacy (post 2022) of 80 lumens/Watt was assumed.

Consequently, it was decided to model an assumed average new housing lighting power density of 4 $W/m^2$ (note: this is not to say that it is assumed that the minimum performance level will be re-set from 5 to 4 $W/m^2$, but rather that on average actual installed lighting power densities in housing will be closer to 4W than $5W/m^2$).

Because energy use by modern day lighting is now so low, it was not considered necessary to model a range of efficiencies below the maximum because the impact on loads is relatively insignificant. Effectively it has been assumed that there will be a fixed amount of lighting energy consumption per unit floor area for all housing and that simple DTS provisions will not consider the specifics of the efficiency of each lighting system in determining the load that will need to be offset by renewables.[9]

## POOL PUMPS

For pool pumps there is a GEMS labelling scheme currently available with ratings typically ranging from 2 to 9 stars. This scheme is currently voluntary but is slated to become mandatory before 2022. For the purposes of this study four different levels of efficiency were modelled as follows:

[9] Whole-of-home simulation tools (when available) could be used to model a specific lighting installation if the building designer so desired.

- Very Low (approximately MEPS levels or lowest available)
- Low Efficiency (approximately market average or slightly less)
- Medium Efficiency (better than market average)
- High Efficiency (approximately best available).

By modelling four levels of efficiency, it is then possible through interpolation to estimate energy demand associated with intermediate levels of efficiency if required.

**Table 8 Pool Pump – Modelled Efficiency Levels**

| End Use Type | Very Low Efficiency | Low Efficiency | Medium Efficiency | High Efficiency | Metric |
|---|---|---|---|---|---|
| All Pool Pumps | 1.5 | 4.0 | 6.5 | 9 | Stars |

**SPA PUMPS**

Whilst spa pumps can be rated under the GEMS scheme, the rating itself is based on the duty cycle of a pool pump rather than a spa pump, the two being quite different in nature. Because of the uncertainty around the applicability of GEMS ratings to actual spa pump performance, only a single level of performance for spa pumps was modelled in this study..

This performance level is based on that assumed in the BASIX scheme which assumes a certain pump power input (per KL of spa capacity). This value is applied to an assumed number of hours of operation per day (3.5 hours has been assumed in this study – see Appendix 1 – End Use Estimates Basis).

**Table 9 Spa Pump – Modelled Efficiency Levels**

| End Use Type | Average Efficiency | Metric |
|---|---|---|
| Spa | 0.4 | kW/KL (pump rating) |

# 5 Climate Zones and Jurisdictional Boundaries

Each of the eight NCC climate zones were modelled. However, in the interests of improved accuracy, some of these zones were represented by more than one NatHERS climate zone. In all, a total of 14 NatHERS climate zones were modelled (see Table 10) with two locations split into separate zone types; one assumed for Class 1, and a different zone assumed for Class 2 type dwellings. The differentiation between Class 1 and Class 2 dwellings in Sydney and Melbourne reflects the variation in the number of new housing builds in these two cities with Class 2 dwellings being more prevalent in inner city areas and Class 1 in the urban fringes

**Table 10: Climate Zones Modelled**

| NCC Climate Zone | Population centre | State | NatHERS Climate Zone |
|---|---|---|---|
| Climate zone 1 | Darwin | NT | 1 |
| | Cairns | Qld | 32 |
| Climate zone 2 | Brisbane | Qld | 10 |
| Climate zone 3 | Longreach | Qld | 3 |
| Climate zone 4 | Mildura | VIC | 27 |
| Climate zone 5 | Adelaide | SA | 16 |
| | Perth | WA | 13 |
| | Sydney | NSW | 56 for Class 2 |
| | | | 28 for Class 1 |
| Climate zone 6 | Melbourne | Vic | 60 for Class 1 |
| | | | 21 for Class 2 |
| Climate zone 7 | Canberra | ACT | 24 |
| | Hobart | Tas | 26 |
| Climate zone 8 | Thredbo | NSW | 69 (Class 1 only) |

It should be noted, however, that NCC climate zones often straddle multiple state and territory jurisdictions (see Figure 9). Using recent NatHERS portal data from 2016 to 2020 showing new constructions by NatHERS climate zone the estimated percentage new dwellings constructed within each BCA climate zone per jurisdiction was calculated (see Table 11 – Class 1 and Table 12 – Class 2).

For the purposes of this study, analysis was undertaken for each variant in Table 11 and Table 12 except those highlighted in red.  Those highlighted in red had less than 10 new builds on average per annum over the past five years. Together the variants modelled represent the majority of cases throughout Australia (including all capital cities). To the extent indicated by the analysis, whole-of-home requirements may need to be separately reported in NCC 2022 for each jurisdiction located within a single NCC climate zone.

**Figure 9 : NCC Climate Zone Map (NCC 2019)**

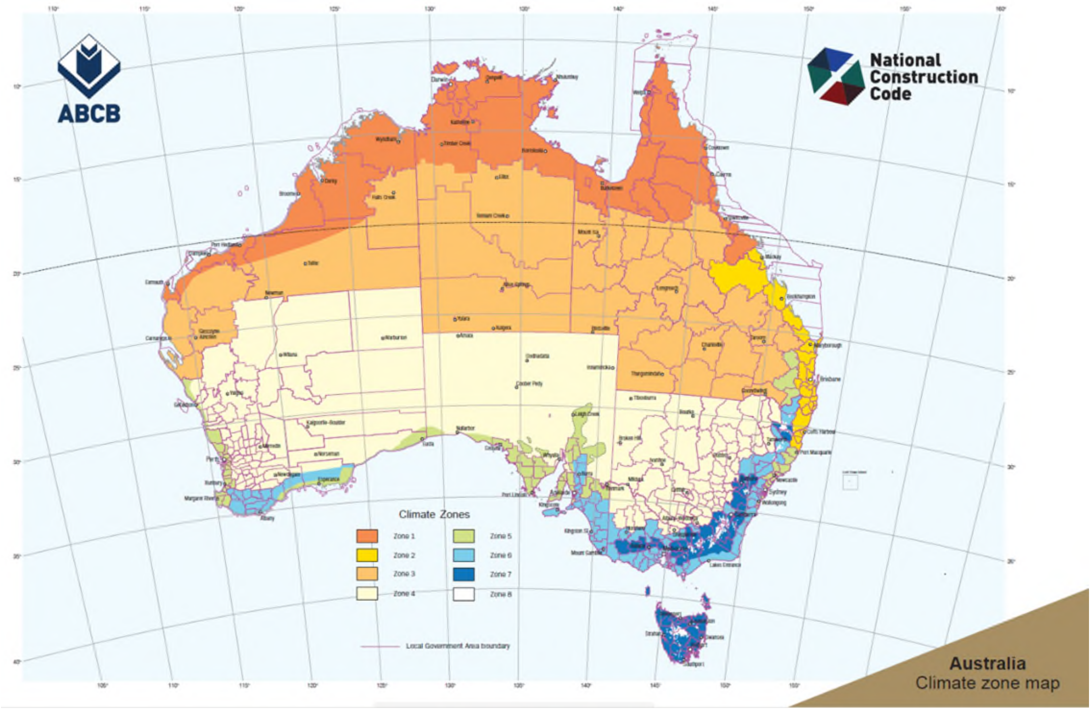



**Table 11: Estimated % new dwellings constructed within each NCC climate zone per jurisdiction – Class 1**

| BCA | NSW | VIC | QLD | SA | WA | TAS | NT | ACT |
|---|---|---|---|---|---|---|---|---|
| 1 | | | 11.22% | | 2.19% | | 83.90% | |
| 2 | 7.05% | 0.00% | 84.07% | 0.01% | | | | |
| 3 | | | 0.49% | | 0.40% | | 15.94% | |
| 4 | 3.80% | 2.08% | 0.00% | 13.07% | 6.50% | | | 0.03% |
| 5 | 34.85% | 0.00% | 4.20% | 80.17% | 86.17% | | | 0.03% |
| 6 | 49.05% | 87.37% | 0.02% | 6.75% | 4.73% | | 0.16% | 0.01% |
| 7 | 5.03% | 10.51% | 0.00% | | 0.01% | 99.96% | | 99.93% |
| 8 | 0.22% | 0.03% | | | | 0.04% | | |

**Table 12: Estimated % new dwellings constructed within each BCA climate zone per jurisdiction – Class 2**

| BCA | NSW | VIC | QLD | SA | WA | TAS | NT | ACT |
|---|---|---|---|---|---|---|---|---|
| 1 | | | 2.27% | | 0.11% | | 96.97% | |
| 2 | 1.02% | | 97.21% | | | | | |
| 3 | | | 0.16% | | | | 3.03% | |
| 4 | 0.23% | 0.03% | | 0.25% | | | | |
| 5 | 74.56% | 0.04% | 0.37% | 99.66% | 99.74% | | | 0.93% |
| 6 | 23.77% | 99.59% | | 0.08% | 0.16% | | | |
| 7 | 0.40% | 0.33% | | | | 100.00% | | 99.07% |
| 8 | 0.02% | | | | | | | |

# 6 Calculation Methods, Assumptions and Settings

## 6.1 Calculation Methods and Usage Profiles

For each end-use type, a method for calculating annual energy consumption, as well as a profile of usage over the course of a typical year, was determined. In the case of heating and cooling equipment, the profile of hourly usage was derived from the thermal performance simulation model, but for all other end uses the profile was determined via reference to available survey data.

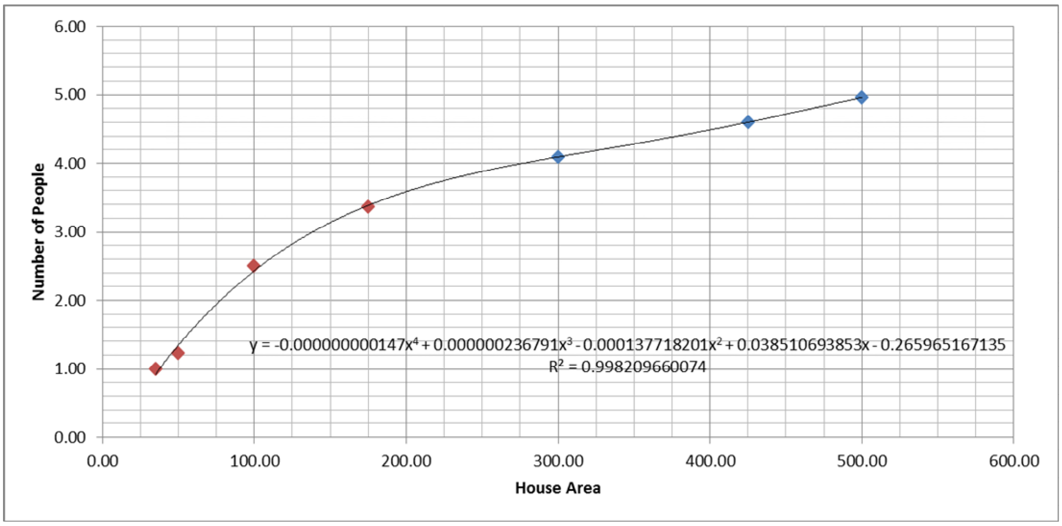
The details of calculation methods and usage profiles (as well as assumptions relating to product life) can be found in Appendix 1 – End Use Estimates Basis. These summary sheets have largely been taken from the documentation prepared for the Sustainability Victoria Zero Net Carbon (ZNC) model.

## 6.2 Household Numbers

Numbers of occupants within a dwelling can have a significant impact on the energy consumption of certain end uses. This is particularly true in relation to hot water usage.

Some whole-of-home models such as the Sustainability Victoria ZNC model assume a set number of occupants (4)[10] irrespective of floor area, whilst other models such as the Victorian Scorecard and the draft NatHERS Whole-of-Home Ratings and Assessment Framework assume a relationship between floor area and household numbers as per Figure 10.

**Figure 10: Relationship between floor area and number of occupants (ABS / Victorian Scorecard)***




* Note that the red dots represent the average number of occupants for 1, 2, 3 and 4 bedroom dwellings as found by the ABS.

[10] This is somewhat higher than the average (2.6) which increases energy estimates for hot water relative to the statistical average. By using a common number this means that all dwellings of a particular floor area are comparable on the same assumed level of service delivery. Note: For the purposes of this study areas of enclosed garages have been excluded from the assumed floor area of the dwelling.

For this study the relationship as shown in Figure 10 was adopted as the basis for determining household numbers as a function of total floor area. Noting that irrespective of how small a dwelling is the assumed minimum number of occupants equals 1.

## *6.3 Thermal Performance Modelling Assumptions*

Generally, the assumptions and settings relating to assumed occupant behaviour as used in NatHERS tools (such as CSIROs AccuRate Sustainability) were applied in the analysis.

There were two areas where alternative user behaviour assumptions were applied. These related to assumed thermostat settings adopted by users and assumed occupancy profiles. The reasoning behind these deviations from NatHERS and the actual settings adopted are detailed in the following two sub-sections.

#### 6.3.1.1 Thermostat settings

Thermostat settings specified in AccuRate are as follows:

Heating:

- Living zones = 20°C
- Bedroom zones = 18°C until midnight then 15°C overnight.

Cooling

- Varies by Climate zone : 23°C to 27°C

The thermostat setting adopted for use in this study were:

Heating:

- Living zones = 20°C
- Bedroom zones = 18°C until midnight then no overnight heating

Cooling

Cooling thermostat settings were lowered by approximately 1 – 1.5 $^{o}$C compared to those used in AccuRate. This reduction is intended to better reflect real life settings. Several studies have provided evidence to the effect that the AccuRate settings are too high. The relevant studies include:

- Energy Use in the Australian Residential Sector 1986-2020 published in 2008
- How Australians Operate Air Conditioning At Home – a CSIRO paper presented to the 2018 AIRAH conference.

Both studies acknowledge that further research in this area is warranted.

The CSIRO results are shown below in Table 13 below. From the far right-hand column of the table (off values) rounded values for a cooler climate (Melbourne 23C), a warmer climate (Adelaide 24C) and a hotter climate (Brisbane 25C) can be approximated. The 14 climates used in this study were categorised into one of these three broader categories (cool, warm hot) – see Table 14 below.

**Table 13: Thermostat setting comparison (CSIRO 2018)**

| City | Air conditioning turning on/off for space heating (°C) | | | Air conditioning turning on/off for space cooling (°C) | | |
|---|---|---|---|---|---|---|
| | The protocol | This study with 50% acceptability | This study with 80% acceptability | The protocol | This study with 50% acceptability | This study with 80% acceptability |
| Adelaide | 20/20 | 17.0/21.0 | 18.5/22.8 | 27.5/25.0 | 27.3/25.4 | 26.0/24.3 |
| Brisbane | 20/20 | 19.1/22.6 | 20.2/24.4 | 28/25.5 | 28.1/26.3 | 26.9/24.7 |
| Melbourne | 20/20 | 16.7/21.5 | 17.7/22.9 | 26.5/24 | 26.6/25.4 | 24.7/23.5 |
| Adelaide | 20/20 | 17.0/21.0 | 18.5/22.8 | 27.5/25.0 | 27.3/25.4 | 26.0/24.3 |

**Table 14: Cooling Thermostat Settings Adopted in this Study**

| BCA Climate Zone | Population centre | State | NatHERS Climate Zone | Cooling Thermostat Setting (°C) |
|---|---|---|---|---|
| Climate zone 1 | Darwin | NT | 1 | 25 |
| | Cairns | Qld | 32 | 25 |
| Climate zone 2 | Brisbane | Qld | 10 | 25 |
| Climate zone 3 | Longreach | Qld | 3 | 25 |
| Climate zone 4 | Mildura | VIC | 27 | 24 |
| Climate zone 5 | Adelaide | SA | 16 | 24 |
| | Perth | WA | 13 | 24 |
| | Sydney | NSW | 56 for Class 2 | 24 |
| | | | 28 for Class 1 | 24 |
| Climate zone 6 | Melbourne | Vic | 60 for Class 1 | 23 |
| | | | 21 for Class 2 | 23 |
| Climate zone 7 | Canberra | ACT | 24 | 23 |
| | Hobart | Tas | 26 | 23 |
| Climate zone 8 | Thredbo | NSW | 69 (Class 1 only) | 23 |

### *6.3.2 Occupancy profiles*

Using AccuBatch two main occupancy profiles were modelled:

- An “All day schedule”
- A “Workday schedule”

These two schedules were adopted based on research work published in the 2008 study, Energy Use in the Australian Residential Sector 1986 – 2020 (DEWHA 2008) with minor adjustments in line with the scheduling adopted in the Sustainability Victoria ZNC model.

The combination of thermostat settings, occupancy profiles and zonings are detailed in the following table (noting that the cooling thermostat settings shown are for the cooler type climates, for the warm and hot type climates the values as noted in Table 14 would be substituted for the 23°C value shown):

**Table 15: Modelled Thermostat Settings, Occupancy Profiles and Zonings**

**Zoned**

All day

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Living | Heating | | | | | | | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | | |
| | Cooling | | | | | | | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | | |
| Bed | Heating | 15 | 15 | 15 | 15 | 15 | 15 | 18 | 18 | 18 | | | | | | | | | 18 | 18 | 18 | 18 | 18 | | |
| | Cooling | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | | | | | | | | | 23 | 23 | 23 | 23 | 23 | 23 | 23 |

**Un-Zoned**

All day

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Living | Heating | | | | | | | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | | |
| | Cooling | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 |
| Bed | Heating | 15 | 15 | 15 | 15 | 15 | 15 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | | |
| | Cooling | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 |

**Zoned**

Work day

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Living | Heating | | | | | | | 20 | 20 | | | | | | | | | | 20 | 20 | 20 | 20 | 20 | 20 | |
| | Cooling | | | | | | | 23 | 23 | | | | | | | | | | 23 | 23 | 23 | 23 | 23 | 23 | |
| Bed | Heating | 15 | 15 | 15 | 15 | 15 | 15 | 18 | 18 | | | | | | | | | | 18 | 18 | 18 | 18 | 18 | 18 | |
| | Cooling | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | | | | | | | | | | 23 | 23 | 23 | 23 | 23 | 23 | 23 |

**Un-Zoned**

Work day

| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Living | Heating | | | | | | | 20 | 20 | | | | | | | | | | 20 | 20 | 20 | 20 | 20 | 20 | |
| | Cooling | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | | | | | | | | | | 23 | 23 | 23 | 23 | 23 | 23 | 23 |
| Bed | Heating | 15 | 15 | 15 | 15 | 15 | 15 | 18 | 18 | | | | | | | | | | 18 | 18 | 18 | 18 | 18 | 18 | |
| | Cooling | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | | | | | | | | | | 23 | 23 | 23 | 23 | 23 | 23 | 23 |

Note: Overnight heating of bedrooms as used in the AccuRate default mode (shown in grey) was not included

## 6.4 *Equipment Ownership Assumptions - General*

Energy use will depend on actual ownership of various forms of end-use equipment. For this study, a common ownership profile was assumed across all dwelling types. This profile is shown in Table 16. In this table those entries that are bolded constitute the end-uses that are assumed to be regulated end uses in the context of NCC 2022. The remaining end uses are non-regulated end uses and are therefore not included in the accounting of ZNRE. However, these other end uses are still important, as they are almost all electrical loads that tend to increase the proportion of PV generation used on site. This increases the economic returns to the householder who installs a PV system. If these other end-uses were ignored, then a significant proportion of on-site generation would be assumed to have been exported to the grid rather than used on-site, noting that exported returns are typically only one-third the returns associated the displacement of imported power by PV systems).

Table 16: Ownership assumptions

| END USE | INCLUSION | OWNERSHIP |
|---|---|---|
| **Heating - Living** | Yes* | 1 |
| **Cooling - Living** | Yes* | 1 |
| **Heating – Other areas** | Yes* | 1 |
| **Cooling – Other areas** | Yes* | 1 |
| **Water Heating** | Yes | 1 |
| Cook Top | Yes | 1 |
| Oven | Yes | 1 |
| **Lighting** | Yes | 1 |
| Refrigerator | Yes | 1 |
| Secondary Refrigerator | Yes | 35% |
| Freezer | Yes | 38% |
| Clothes Washer | Yes | 1 |
| Dishwasher | Yes | 1 |
| Clothes Dryer | Yes | 1 |
| Television (Main) | Yes | 1 |
| Television (Secondary) | Yes | 1 |
| **Pool pump** | Optional | 1 |
| **Spa Pump** | Optional | 1 |
| Standby Power | Yes | 1 |
| Other | Yes | 1 |

* Note: Heating and cooling ownership is subject to some special rules in this study (as is the case in most whole-of-home tools developed for use in Australia to date). The ownership assumptions relating to these end uses are covered in detail in the following Section 6.5.

For regulatory purposes in this study, in assessing what proportion of energy loads are required to be offset by a PV system (or other form of on-site renewable energy supply), only the regulated loads are considered. However, in assessing both the householder-level economic impacts and the societal level impacts of the proposed regulations, all end-uses are taken into account.

For the purposes of this study non regulated end-use electrical loads have been aggregated into a single load which varies by household size, this aspect is covered in detail in Section 6.7 (capacity assumptions) and Appendix 1 – End Use Estimates Basis (usage profiles).

## 6.5 Equipment Ownership – Heating and Cooling

Heating and cooling equipment ownership assumptions present a particular issue in relation to whole-of-home energy consumption assessment.

The basis of NatHERS calculations for heating and cooling loads includes an assumption that all households are both heated and cooled and that the entire floor area except some nominated utility areas are conditioned. Whilst this may be a higher-than-average level of service provision it does provide a common service provision level that enables valid comparison between dwellings.

With the overlay of heating and cooling equipment, the question arises as to what should be assumed in cases where only part of the dwelling is proposed to be serviced by a heater or cooler (e.g. a room heater is only available in the main living space) or where no wired-in heater and or cooler is provided.

Also, with limited-capacity (under-sized) heating/cooling equipment, the energy demand will appear relatively low (compared to a dwelling with whole-of-home heating/cooling as is assumed in NatHERS), and with no heating/cooling installed then the energy demand for those end-uses will be modelled as zero irrespective of the potential load.

This presents potential gaming issues whereby a developer could defer the installation of a heater or a cooler until post occupancy thereby avoiding the need to offset heating/cooling energy demands with PVs in a whole-of-home assessment.

Even in the case of cooling equipment where many new dwellings are built without such equipment, the reality is that in most climates in Australia householders choose to install a cooler post occupancy if one is not already present (approx. 75% of households in Australia own an air-conditioner of one form or another).

Existing Whole-of-Home tools, such as the SV ZNC tool and the CSIRO equivalent AusZEH, assume that all zones (except utility areas) will be heated and cooled. In the case of the CSIRO tool this assumption cuts-in where the load exceeds 20 $MJ/m^2$ for each separate zone, while in the case of the ZNC tool there is no lower limit.

The DELWP Scorecard tool is understood to be moving in a similar direction. If no heating is installed, the largest room is assumed to be heated with resistance electric heating. Future versions of Scorecard are proposing to assume a minimum heated and cooled area and that bedrooms are only cooled overnight.

The 20 $MJ/m^2$ CSIRO cut-in limit by zone adds significant complexity to the calculations, but makes little difference to the outcome. For example, a 20$m^2$ room would have an annual load of 400MJ (20 * 20) or 110 kWh per year assuming a worst-case resistance electric heater. This equates to less than 0.1 kW of additional PV capacity that might be required if the 20$MJ/m^2$ threshold were to be removed for simplicity.

In the CSIRO tool, where a heater type is not specified for any of the conditioned spaces, it is assumed that the space will be heated using a resistance electric heater.

For coolers, it is assumed to be a heat pump that just meets the current MEPS level. This approach is copied in the draft NatHERS Whole-of-Home Ratings and Assessment Framework.

In the ZNC tool the following rules are applied:

> …..If the specified equipment for the particular dwelling is just a room heater (or cooler) located in say the living area only then the modelling tool will assume that those system types are in fact installed in all spaces assumed to be conditioned when undertaking a ZNC rating (i.e. it is assumed that the owner could potentially duplicate the existing living room heating and cooling system in all other conditioned rooms in the dwelling). There are some rules around this assumption and these are as follows:
>
> a) If a house has a heater or cooler in the primary or secondary zone (but not both) then for modelling purposes the same type and specification system must be input into the other zone.
> b) If a house only has central heating (of any type) and no cooling, then a ducted refrigerative AC (AEER = 3.6 – 2.7Stars) must be assumed to cool all zones and the zoned/unzoned setting must match that of the ducted heater.
> c) If the house only has a room heater (of any type) and no cooling, then a split system refrigerative AC (3.1 Star rated) must be assumed to cool all zones.
> d) If the house has no heater or cooler then the heating system will be assumed to be Central Gas (3.5 stars) or if no gas is available Central HP (ACOP 3.7 – 2.9 Stars). Cooling will be assumed to be Central ducted unzoned Heat Pump (AEER = 3.6 – 2.7Stars).

For this study, the approach used in the SV ZNC model has largely been adopted. Whilst the assumption that an occupant would simply use resistance electric heating is possibly sound in rental accommodation, where a split incentive exists, such an assumption is considered to be economically irrational in the case of an owner occupier (majority of dwellings in Australia). Such an assumption is also considered to place an overly onerous burden on owners and developers of houses where partial heating is the preferred option.

**The adopted approach in this study is as follows:**

For cooling, it is assumed that the un-serviced areas, irrespective of load size, are cooled using a cooler of the same type as used in serviced areas. Where there is no cooler present at all, a MEPS level heat pump cooler is to be assumed. MEPS levels vary according to type and size from 1.3 stars to 2.88 stars. Consequently, for simplicity it has been assumed that a heat pump cooler of 1.5 stars is installed.

For heating, it is assumed that the un-serviced areas, irrespective of load size, are heated using a heater of the same type as used in serviced areas, and where there is no heater present at all, a MEPS-level heat pump is to be assumed. MEPS levels vary according to type and size from 1.3 stars to 2.88 stars, consequently for simplicity it has been assumed that a heat pump heater of 1.5 stars is installed.

## 6.6 Equipment Type/Performance Assumptions

As noted in the previous sections, a range of end-use equipment is assumed to be installed within each dwelling. In the case of equipment that may be regulated under the NCC, a range of representative types and performance levels have been selected for modelling purposes (refer Section 4.2). In the case of all other end-uses, a set of assumptions had to be made regarding the type and performance of that equipment (mostly plug loads). These assumptions - intended to be representative of the market average - were based on market data analysis undertaken for Sustainability Victoria for their ZNC model (see EES 2018).

**Table 17: Assumed Types and Performance of Un-regulated End Uses**

| End Use | Type | Performance Rating[3] |
|---|---|---|
| Cooktop | Gas[1] | N/A |
| Oven (assumed to be electric) | Resistance Electric[1] | N/A |
| Refrigerator | Group 5T | 2.95 |
| Secondary Refrigerator | Group 5T | 2.95 |
| Freezer | Group 6c | 2.8 |
| Clothes Washer | Top Loader | 2.3 |
| Dishwasher | Standard | 3.21 |
| Clothes Dryer | Resistance Electric | 2.35 |
| Television (Main) | Standard LED | 5.27 |
| Television (Secondary) | Standard LED | 5.27 |
| Standby Power | As per ZNC model[2] | N/A |
| Other | As per ZNC model[2] | N/A |

Notes:

1. This combination of gas cooktop and electric oven is the most common combination (EES 2008). Because the cooktop is assumed to be gas and it is unregulated in terms of the NCC it is effectively ignored in the analysis. The oven being electric will impact on the utilization of on-site generated renewable energy and will therefore influence the householder and societal cost benefit equation.
2. Standby power and other end use power consumption has been based on the analysis undertaken for the Sustainability Victoria ZNC model (see Appendix 2 – Usage Profile Data Tables)
3. GEMS star rating

## 6.7 Equipment Capacity Assumptions

The following sub-sections detail the capacity assumptions associated with the various end uses. The capacity/usage associated with several of the end-uses is dependent on the household size which, as noted in Section 6.1, has been correlated with floor area.

**HEATING AND COOLING EQUIPMENT**

Required capacity for heating and cooling equipment is simply based on the heating and cooling loads as derived from the thermal simulation tool AccuRate. The key factors determining load is the NatHERS performance rating of the dwelling, the building design (insofar as it impacts its heating and its cooling load intensity outcomes), and the floor area of the dwelling.

**HOT WATER SYSTEMS**

In terms of demand for hot water, a common assumption across all households has been made. It is assumed that there is a fixed amount of hot water consumption per day (10 litres) plus a variable amount of consumption of 40 litres per occupant per day (for the derivation of the number of occupants see Section 6.2). This value was originally derived from work undertaken by Dr George Wilkenfeld for the study Energy Use in the Australian Residential Sector 1986 – 2020 (EES 2008). This value also reflects the general consensus amongst those that have produced whole-of-house tools in recent years and is supported by various survey data sets.

**LIGHTING EQUIPMENT**
Lighting capacity is typically measured in terms of lumen output, however for this study lighting capacity has been simply gauged in terms of its power density ($W/m^2$ of floor area). Under the current provisions of the NCC this is the metric used and this is capped at 5 $W/m^2$ (with some dispensations for various technologies such as dimmers)[11]. The actual stock average lighting power density modelled in this study (4 $W/m^2$) is detailed in Section 4.2.

**POOL PUMPS**
Pool pump capacity is matched to the volumetric capacity of the swimming pool it serves. Based on research undertaken by the BASIX team in NSW, this averages approximately 40,000 litres. In the modelling undertaken for this project, this average capacity of 40,000 litres was used. For regulatory purposes, it is expected that actual capacity of the installed pool will be used to scale the results obtained at 40,000 litres in a linear fashion.

**SPA PUMPS**
Spa pump capacity is matched to the volumetric capacity of the spa it serves. Based on research undertaken by the BASIX team in NSW, this averages approximately 4,000 litres. In the modelling undertaken, this average capacity of 4,000 litres was used. For regulatory purposes it is expected that actual capacity of the installed spa will be used to scale the results obtained at 4,000 litres in a linear fashion.

**NON-REGULATED ELECTRICAL EQUIPMENT**
The combined loads associated with all of the non-regulated electrical equipment assumed to be present within a household have been set based on estimates made within the Sustainability Victoria ZNC tool under its “market average” scenario (i.e. the average of newly purchased equipment, see also Appendix 1 – End Use Estimates Basis). This load covers the following end-uses and varies according to the number of occupants:

- Oven (assumed to be electric)
- Refrigerator
- Secondary Refrigerator (ownership is assumed to be <1)
- Freezer (ownership is assumed to be <1)
- Clothes Washer
- Dishwasher
- Clothes Dryer
- Television (Main)
- Television (Secondary)
- Standby Power
- Other (miscellaneous electrical equipment e.g. vacuums, coffee makers, etc.).

[11] This means that if the installed lighting equipment had an efficacy of say 50 lumens/Watt then the capacity of the system would be 50 lumens/Watt * 5 $Watts/m^2$ i.e. 250 $lumens/m^2$

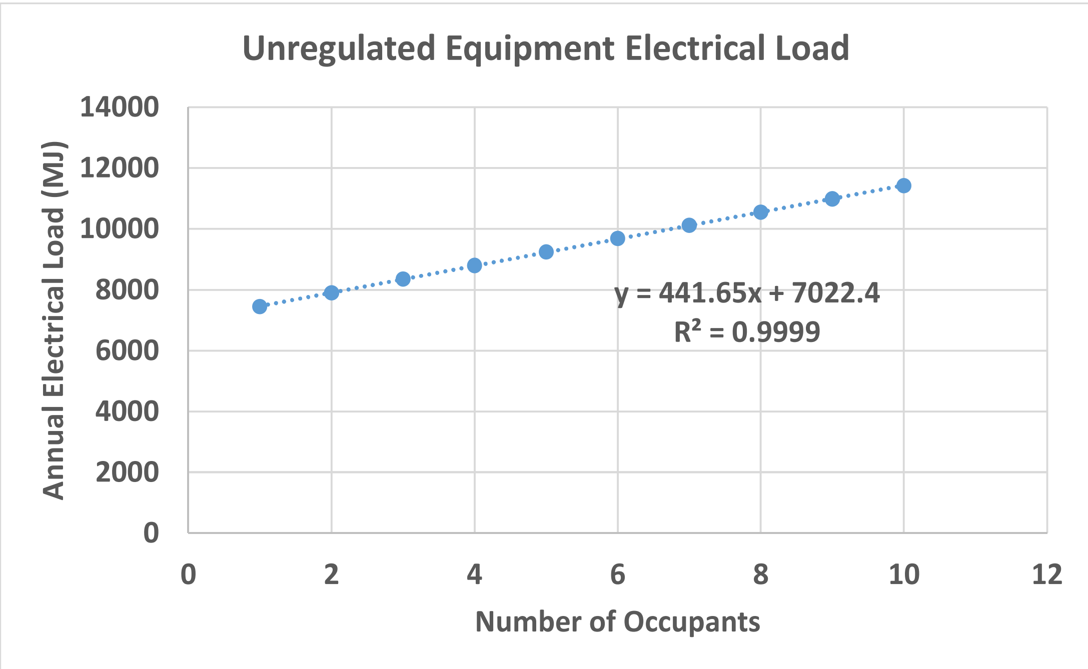
The non-regulated electrical equipment load by occupant number according to the Sustainability Victoria ZNC tool is as per Table 18. When plotted (see Figure 11) this shows an almost perfectly linear relationship between number of occupants and load ($R^2$ = 0.9999).

**Table 18: Annual non-regulated electrical equipment load (SV – ZNC Model)**

| No. of Occupants | Annual Load (MJ) |
|---:|---:|
| 1 | 7441 |
| 2 | 7899 |
| 3 | 8353 |
| 4 | 8801 |
| 5 | 9245 |
| 6 | 9686 |
| 7 | 10123 |
| 8 | 10558 |
| 9 | 10990 |
| 10 | 11419 |

Consequently the linear regression formula (7022.4 + 441.65 x No. of occupants) has been used in the model to estimate the annual non-regulated electrical equipment load for any sized dwelling.

**Figure 11: Annual non-regulated electrical equipment load (SV – ZNC Model)**



## 6.8 Photovoltaics

Roof-mounted PV cells are assumed to be the most likely form of renewable energy employed as a means for offsetting household energy consumption in order to achieve a specified ZNRE or part ZNRE target.

### 6.8.1 Calculation of Output

Estimates of expected PV array outputs for the 14 representative climate zones were prepared by ITP Renewables and were based on the specifics of the weather files as used in the NatHERS based thermal performance simulations. Outputs were estimated for each hour of the year and for each of 4 orientations.

### 6.8.2 Assumptions and Settings

**ORIENTATION OF PVS**
PVs could be installed on any orientation of a roof. However, to maximise returns installers tend to locate on the North, East or West Quadrants, depending on availability. South-facing PVs on gently sloping roofs can also provide reasonable returns but less than for the other orientations, so this orientation tends to be avoided unless there is no alternative.

For modelling purposes an assumption was made regarding the likely distribution of PVs on an average dwelling as this will impact on system outputs – see Table 19.

**Table 19: Assumed Distribution of PVs by orientation**

| Quadrant | % of PVs facing Quadrant |
|---|---|
| North | 35% |
| East | 30% |
| West | 30% |
| South | 5% |

**MAXIMUM CAPACITY OF PVs**
Whilst installations up to 10kW are not unknown on a detached dwelling, most systems do not exceed 7kW. In the case of Class 2 dwellings capacity limitations are expected to be more severe, particularly in high rise apartments with a very low roof area to floor area ratios.

The analysis in this study is in part intended to deliver a finding as to the required renewable capacity needed to achieve a NZRE rating (or part ZNRE rating) but the capacity requirement must also be practical to achieve and therefore practical limits (at least for common sizes of dwellings) need to be assumed in relation to likely available PV capacity.

For an average sized Class 1 dwelling of 200 – 250 m$^2$ a system size larger than about 7 kW is currently relatively uncommon[12]. For significantly larger dwellings

[12] Noting however, with expected future increases in the uptake of batteries, electric vehicles, solar diverters for hot water systems and demand side management capabilities within dwellings the capacity of PV systems installed in dwellings with these types of emerging technologies might be expected to rise further.

larger systems are possible (even exceeding 10kW if multi-phase power is available and with approval of the supply authority). The modelling tool has been configured to model sizes between 0 and 10kW in 1 kW increments.

For Class 2 dwellings that are on average significantly smaller than Class 1 dwellings the PV requirement is likely to be less. The 10 kW modelling limit is considered more than adequate for an average sized Class 2 dwelling however this provision is for a single unit and the requirement for all units in a block will be significantly higher. For high rise units with a low roof area to total floor area ratio this is likely to present an issue; i.e., insufficient roof space to accommodate a PV installation that can offset the regulated energy use of the block as a whole (this aspect is discussed in more detail elsewhere in this report).

**CAPS ON EXPORT TO GRID**

Supply authorities typically apply a cap on the amount of power that a dwelling can export to the grid. Often this is in the order of 5kW per phase. This means that PV installations over 5kW for a single dwelling with single phase power may have reduced returns in the form of export credits compared to a case where no cap is applied. Such reductions are typically quite modest where the PV capacity is only a kW or two over the 5kW limit as exports in such cases will rarely exceed 5kW. For very large dwellings, or dwellings with power hungry equipment (e.g. slab heating) it is reasonable to assume that multi-phase power supply will be used which means that the 5kW inverter cap noted above can be exceeded (in most cases) by splitting the PV output across more than one phase.

**INVERTER CAPACITY LIMITS**

Standard practice is to install inverters that are approximately 85% of the rated PV capacity[13]. For example, for a 6kW rated PV array typically a 5kW inverter would be installed.

This tends to marginally limit the available power for use or export at times of maximum production where the PV arrays output exceeds the rated capacity of the inverter. Such reductions in usable power are however typically very modest.

For this study it has been assumed that the inverter capacity is capped at 85% of the PV rated capacity.

## *6.9 Financial Settings and Assumptions*

The model has been developed to allow the user to select a number of pre-set financial setting options or, alternatively, use an override function to apply a particular setting of their choosing for sensitivity analysis purposes. The key financial settings available within the analysis tool and the available default settings are detailed in the following sub-sections.

### *6.9.1 Evaluation period*

The regulations are assumed to commence in 2022 (although this setting can be varied in the model if required).

[13] This values is however trending downwards but cannot generally go below 75% which is the required minimum of the Clean Energy Regulator.

Costs and savings can be estimated over any period by the model. For the purposes of this study the evaluation period has been set to 40 years in line with directions from ABCB.

Each improvement measure is assigned an assumed lifetime (see Appendix 1 – End Use Estimates Basis). For example, PV inverters are assumed to have a lifetime of 10 years. As noted earlier, the model factors in replacements of each improvement measure over the evaluation period.

Note that the model is set up such that the user can apply any regulation commencement year (post 2020) and any economic evaluation period of their choosing.

### *6.9.2 Discount rate*

The discount rate is used to determine the net present value of a future stream of energy cost savings resulting from a nominated set of improvement measures and the net present value of those improvement measures (including any future replacement costs as applicable). Following advice from OBPR (via ABCB) the default discount rate is assumed to be 7% (very conservative in the current economic climate). For the purposes of sensitivity analysis, a user can manually set any discount rate of their choosing.

### *6.9.3 Real rates of increase in fuel costs*

Recent historical trends suggest that fuel costs are likely to increase in real terms over coming years, noting however that there is significant uncertainty around this aspect. For modelling purposes, a default conservative assumption of zero net real increase in fuel costs over the study period was assumed. For the purposes of sensitivity analysis, a user can manually set any rate of their choosing.

### *6.9.4 Learning rates and equipment costs*

“Learning rates” refers to the assumed rate of reduction over time in the real incremental cost of undertaking a particular improvement as a function of the cumulative volume of production over time. As technologies develop and as demand for a particular energy efficiency measure increases, the real incremental cost of that measure tends to decrease as manufacturing techniques improve and material costs fall.

In the case of improvement measures that have been the subject of mature energy efficiency programs, such as the GEMS program (particularly where minimum levels of efficiency have been mandated), the real prices are expected to change only slowly in the future as these are mature technologies and total cumulative volumes of production is increasing slowly.

In the case of newer technologies with rapidly increasing market uptake (e.g. high performance glazing.) the price falls can be significant as the cumulative market volumes are still relatively low.

The model allows for the application of learning rates to the following costs:

- Building shell upgrades
- Heating and Cooling equipment
- Water heating equipment
- Lighting equipment
- Pool pumps

- Spa pumps
- PVs.

By default, learning rates if applied are conservatively assumed to persist for 10 years.

As noted earlier in this report, by default, learning rates for all costs have been set at a conservative 1% per annum (Houston Kemp 2017). Building and Equipment cost estimates are taken as an average over an assumed 10 year life of regulations starting in 2022 i.e. costs are in present day dollars based on estimated costs mid-term of the regulations, an approximate assumed real cost reduction of 5% on year 1 costs across the life of the regulations.

For the purposes of the RIS analysis (by others), learning rates were set to zero such that the RIS modelling team could apply their own preferred rates for sensitivity analysis

### *6.9.5 Rebates*

The key form of rebate to be considered are those associated with the supply and installation of PVs.

From a householder's perspective, it makes sense to factor into the cost of a PV installation the value of any rebates. From a societal perspective, such rebates should be ignored as they are a financial transfer from one group of energy users (those without PV) to others (those with). The net change in social value associated with a transfer is zero.

## *6.10 Fuels and Tariff Assumptions*

### *6.10.1 Fuels examined*

The model developed for this project has been set-up so as to be able to model a total of three fuel types as follows:

- Electricity
- Mains Gas
- Firewood (or solid fuels)

Electricity and mains gas are by far the most significant with firewood holding onto a moderate market share in regional areas of the southern states.[14]

### *6.10.2 Electricity Tariff Structures*

Three forms of electricity tariff can be examined by the model as follows:

- Single or Flat rate
- Flexible or TOU rate
- Controlled load (for some hot water and slab heating applications).

For other than controlled loads, three different levels of tariff can be set over a 24 hour period, nominally these are called:

- Peak

[14] Note: LPG has limited market share (mainly due to cost) and is increasingly being supplanted by heat pump technologies for heating and hot water applications.

- Shoulder
- Off-peak.

The model allows the user to set any tariff value against each of the three tariff levels and also set the hours of the day (for both weekdays and weekends) at which each tariff level applies. In the case of a single or flat rate tariff all hours of the day are simply set to a single tariff (peak).

In the case of electricity usage (unlike other fuels) the real cost of such usage varies according to the time of use. At certain times of the day when demand is high (e.g. late afternoon / early evening when cooling is required) the cost is high and at other times when the demand is low (e.g. overnight) the cost is lower. Consequently, the model is set up such that the energy cost uses different factors to account for the different impacts of electricity usage on the network at peak, shoulder and off-peak times.

For modelling purposes the adopted time blocks for peak, shoulder and off-peak has been set as per Table 20. This construct is an attempt to represent an Australia wide time of use structure designed to reflect real costs. In reality each jurisdiction and even individual electricity retailers within a jurisdiction have set up their own TOU structures which can vary by both time of day and day of week (see examples in Table 21). The scope and time available for this project did not allow for a complete analysis of wholesale and network costs by time of use across the range of Australian networks. The values in Table 20 are simply an attempt to reconcile all these differing structures into a single structure.

**Table 20: Electricity Usage – Timing for categories of usage**

| Hour | Hour span | Weekday |
|---|---|---|
| 1 | 24-1 | Off peak |
| 2 | 1-2 | Off peak |
| 3 | 2-3 | Off peak |
| 4 | 3-4 | Off peak |
| 5 | 4-5 | Off peak |
| 6 | 5-6 | Off peak |
| 7 | 6-7 | Off peak |
| 8 | 7-8 | Peak |
| 9 | 8-9 | Peak |
| 10 | 9-10 | Shoulder |
| 11 | 10-11 | Shoulder |
| 12 | 11-12 | Shoulder |
| 13 | 12-13 | Shoulder |
| 14 | 13-14 | Shoulder |
| 15 | 14-15 | Shoulder |
| 16 | 15-16 | Shoulder |
| 17 | 16-17 | Peak |
| 18 | 17-18 | Peak |
| 19 | 18-19 | Peak |
| 20 | 19-20 | Peak |
| 21 | 20-21 | Shoulder |
| 22 | 21-22 | Shoulder |
| 23 | 22-23 | Off peak |
| 24 | 23-24 | Off peak |

**Table 21: Examples of TOU structures by Jurisdiction**

| | | NSW | | VIC | | QLD | | SA | |
|---|---|---|---|---|---|---|---|---|---|
| Hour | Hour span | Weekday | Weekend | Weekday | Weekend | Weekday | Weekend | Weekday | Weekend |
| 1 | 24-1 | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak |
| 2 | 1-2 | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak |
| 3 | 2-3 | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak |
| 4 | 3-4 | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak |
| 5 | 4-5 | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak |
| 6 | 5-6 | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak |
| 7 | 6-7 | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak |
| 8 | 7-8 | Shoulder | Shoulder | Peak | Off peak | Shoulder | Shoulder | Peak | Off peak |
| 9 | 8-9 | Shoulder | Shoulder | Peak | Off peak | Shoulder | Shoulder | Peak | Off peak |
| 10 | 9-10 | Shoulder | Shoulder | Peak | Off peak | Shoulder | Shoulder | Peak | Off peak |
| 11 | 10-11 | Shoulder | Shoulder | Peak | Off peak | Shoulder | Shoulder | Peak | Off peak |
| 12 | 11-12 | Shoulder | Shoulder | Peak | Off peak | Shoulder | Shoulder | Peak | Off peak |
| 13 | 12-13 | Shoulder | Shoulder | Peak | Off peak | Shoulder | Shoulder | Peak | Off peak |
| 14 | 13-14 | Shoulder | Shoulder | Peak | Off peak | Shoulder | Shoulder | Peak | Off peak |
| 15 | 14-15 | Peak | Shoulder | Peak | Off peak | Shoulder | Shoulder | Peak | Off peak |
| 16 | 15-16 | Peak | Shoulder | Peak | Off peak | Shoulder | Shoulder | Peak | Off peak |
| 17 | 16-17 | Peak | Shoulder | Peak | Off peak | Peak | Shoulder | Peak | Off peak |
| 18 | 17-18 | Peak | Shoulder | Peak | Off peak | Peak | Shoulder | Peak | Off peak |
| 19 | 18-19 | Peak | Shoulder | Peak | Off peak | Peak | Shoulder | Peak | Off peak |
| 20 | 19-20 | Peak | Shoulder | Peak | Off peak | Peak | Shoulder | Peak | Off peak |
| 21 | 20-21 | Shoulder | Shoulder | Peak | Off peak | Shoulder | Shoulder | Peak | Off peak |
| 22 | 21-22 | Shoulder | Shoulder | Peak | Off peak | Shoulder | Shoulder | Off peak | Off peak |
| 23 | 22-23 | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak |
| 24 | 23-24 | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak |

| | | WA | | TAS | | NT | | ACT | |
|---|---|---|---|---|---|---|---|---|---|
| Hour | Hour span | Weekday | Weekend | Weekday | Weekend | Weekday | Weekend | Weekday | Weekend |
| 1 | 24-1 | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak |
| 2 | 1-2 | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak |
| 3 | 2-3 | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak |
| 4 | 3-4 | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak |
| 5 | 4-5 | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak |
| 6 | 5-6 | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak |
| 7 | 6-7 | Off peak | Off peak | Off peak | Off peak | Peak | Off peak | Off peak | Off peak |
| 8 | 7-8 | Shoulder | Shoulder | Peak | Off peak | Peak | Off peak | Peak | Peak |
| 9 | 8-9 | Shoulder | Shoulder | Peak | Off peak | Peak | Off peak | Peak | Peak |
| 10 | 9-10 | Shoulder | Shoulder | Peak | Off peak | Peak | Off peak | Shoulder | Shoulder |
| 11 | 10-11 | Shoulder | Shoulder | Off peak | Off peak | Peak | Off peak | Shoulder | Shoulder |
| 12 | 11-12 | Shoulder | Shoulder | Off peak | Off peak | Peak | Off peak | Shoulder | Shoulder |
| 13 | 12-13 | Shoulder | Shoulder | Off peak | Off peak | Peak | Off peak | Shoulder | Shoulder |
| 14 | 13-14 | Shoulder | Shoulder | Off peak | Off peak | Peak | Off peak | Shoulder | Shoulder |
| 15 | 14-15 | Shoulder | Shoulder | Off peak | Off peak | Peak | Off peak | Shoulder | Shoulder |
| 16 | 15-16 | Shoulder | Shoulder | Off peak | Off peak | Peak | Off peak | Shoulder | Shoulder |
| 17 | 16-17 | Peak | Shoulder | Peak | Off peak | Peak | Off peak | Shoulder | Shoulder |
| 18 | 17-18 | Peak | Shoulder | Peak | Off peak | Peak | Off peak | Peak | Peak |

| | | WA | | TAS | | NT | | ACT | |
|---|---|---|---|---|---|---|---|---|---|
| 19 | 18-19 | Peak | Shoulder | Peak | Off peak | Off peak | Off peak | Peak | Peak |
| 20 | 19-20 | Peak | Shoulder | Peak | Off peak | Off peak | Off peak | Peak | Peak |
| 21 | 20-21 | Peak | Shoulder | Peak | Off peak | Off peak | Off peak | Shoulder | Shoulder |
| 22 | 21-22 | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Shoulder | Shoulder |
| 23 | 22-23 | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak |
| 24 | 23-24 | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak | Off peak |

### *6.10.3 Fuel costs*

**ELECTRICITY**

Electricity pricing data is somewhat difficult to determine following the privatisation and de-regulation of most of Australia's electricity markets. The Australian Energy Market Commission (AEMC) publishes estimates of electricity costs by state and territory on an annual basis (the latest publication is from December 2019).

The AEMC estimates cover only an average price for an average-sized household in each jurisdiction. There is no detail relating to time of use rates (peak shoulder and off peak) and also no detail in relation to controlled load rates (controlled and uncontrolled loads are simply aggregated). In addition, their estimates do not include GST but do factor in supply charges into an overall estimate of c/kWh (advice from Vanti at AEMC – March 2020). To allow for GST costs the AEMC values can be increased by 10% and to remove the supply charges (network costs) from the rates the values were then reduced by 20% (this is an estimate only based on assumed supply charges being in the range of $0.90 – $1.10 per day which is typical of most jurisdictions except the NT where it is somewhat lower). This then gives an approximate rate per jurisdiction (see Table 22 column 2).

To help fill in some of the knowledge gaps (TOU rates, controlled load rates versus uncontrolled rates, solar feed in tariffs), reference was made to a number of comparison sites (primarily, www.energymadeeasy.gov.au/ and compare.energy.vic.gov.au) that display offerings from a range of energy companies.

For Western Australia and NT, where prices are regulated, reference was made to the relevant government website (for WA) and direct to suppliers websites (for the NT), . Generally, three major retailers in each jurisdiction were assessed, with the results averaged. The results are presented in Table 22 columns 3 – 6).

In the analysis model these rates are adjusted according to the assumed real rate of increase in fuel costs over time (assumed to be zero by default). These rates can easily be altered by the user from the dashboard of the modelling tool.

**Table 22: Electricity Tariffs by Jurisdiction (c/kWh incl. GST)**

| Jurisdiction | AEMC estimate for 2018-19 (prepared Dec 2019) | Uncontrolled Load (EES Market Research March 2020) | Controlled Load (EES Market Research March 2020) | Solar Feed In (EES Market Research March 2020) |
|---|---|---|---|---|
| **NSW** | 27.02 | 27.66 | 12.99 | 8.67 |
| **VIC** | 25.84 | 26.48 | 19.27 | 12 |
| **QLD** | 26.58 | 23.11 | 15.63 | 10.05 |
| **SA** | 32.62 | 36.18 | 19.79 | 11.23 |
| **WA** | 28.33 | 28.82 | 11.84 | 7.1 |
| **TAS** | 21.22 | 21.25 | 13.29 | 9.35 |
| **NT** | 23.34 | 26.05 | N/A | 26.0 |
| **ACT** | 23.84 | 24.05 | 14.62 | 8.83 |

An effort was also made to try and discern the rates associated with time of use tariffs in each state via reference to a number of comparison sites as previously described earlier in this section. Generally, three major retailers in each jurisdiction were assessed with the results averaged, noting that there can be significant variation between individual retailers. The results are presented in Table 23 (TOU Tariffs).

**Table 23: TOU Tariffs by Jurisdiction c/kWh incl. GST (approximation only)**

| Jurisdiction | Peak | Shoulder | Off-peak |
|---|---|---|---|
| **NSW** | 47 | 22 | 16 |
| **VIC** | 28 | N/A* | 19 |
| **QLD** | 33 | 22 | 19 |
| **SA** | 44 | 26 | 26 |
| **WA** | 55 | 29 | 15 |
| **TAS** | 33 | N/A* | 15 |
| **NT** | 31 | N/A* | 23 |
| **ACT** | 30 | 21 | 17 |

** Generally, in these jurisdictions there is only a peak and an off-peak rate applied.*

Averaging across the various providers and jurisdictions it as found that compared to the average price for electricity, the cost during peak times was 140% of the average, the cost during shoulder times was 90% and the cost during off-peak times was 70%.

Applying these percentages to the average electricity prices as determined in Table 22, the values in Table 24 were derived and adopted.

**Table 24 : Electricity Costs Adopted in this study (cents/kWh – 2020)**

| Tariff type | NSW | VIC | QLD | SA | WA | TAS | NT | ACT |
|---|---|---|---|---|---|---|---|---|
| Electricity - Peak | 38.72 | 37.07 | 32.35 | 50.65 | 40.35 | 29.75 | 36.47 | 33.67 |
| Electricity Shoulder | 24.89 | 23.83 | 20.80 | 32.56 | 25.94 | 19.13 | 23.45 | 21.65 |
| Electricity - Off peak | 19.36 | 18.54 | 16.18 | 25.33 | 20.17 | 14.88 | 18.24 | 16.84 |
| Electricity - Cont. Load | 12.99 | 19.27 | 15.63 | 19.79 | 11.84 | 13.29 | 26.05 | 14.62 |
| Electricity – PV Export | 9 | 12 | 10 | 11 | 7 | 9.5 | 26 | 9 |

## MAINS GAS TARIFFS

For gas tariffs, reference was made to a survey undertaken by Oakley Greenwood in 2017. This data, although comprehensive is now somewhat dated, consequently a number of energy comparison sites (primarily, www.energymadeeasy.gov.au/ and compare.energy.vic.gov.au) that display offerings from a range of energy companies were reviewed. For Western Australia where prices are regulated reference was made to the relevant WA government website.

Generally, three major retailers in each jurisdiction were assessed, with the results averaged. The results are presented in Table 25. It should be noted that these tariffs can vary according to the amount of gas used. Generally, an average of tier 1 and tier 2 rates were assumed, noting that the building shells and equipment being used can be assumed to be relatively efficient (i.e. relatively low heating loads).

**Table 25: Gas Tariffs by Jurisdiction (c/MJ incl. GST)**

| Jurisdiction / City | Oakley Greenwood 2017 prices (c/MJ) | Market Search (June 2018) (c/MJ) | Market Search (June 2020) (c/MJ) |
|---|---|---|---|
| NSW / Sydney | 3.45 | 4.00 | 3.38 |
| Victoria | 2.35 | 2.26 | 2.36 |
| Qld / Brisbane | 6.4 | 5.58 | 4.88 |
| SA / Adelaide | 4.53 | 4.03 | 4.23 |
| WA / Perth | 4.12 | 4.08 | 4.01 |
| ACT / Canberra | 3 | 3.68 | 3.56 |

## FIREWOOD TARIFFS

There is significant variability and uncertainty in the cost of firewood. Price will vary greatly depending on the location (metro or non-metro) and the degree to which self-collection takes place.

In rural areas where firewood use is most common, firewood costs typically range from \$200 - \$300 per tonne (based on limited phone surveying by EES in 2018). Assuming an energy intensity of 16MJ per kg this equates to 1.25 to 1.875 c/MJ. On this basis a conservative value of 1.85 c/MJ was adopted.

## 6.11 Greenhouse Gas Intensity Assumptions

Estimating of greenhouse gas emissions associated with the import of mains gas, electricity and or firewood, and the estimating of greenhouse gas emission abatement associated with the export of electricity from a PV system (where installed), is simply estimated by multiplying the energy consumed or exported by the greenhouse gas emission intensity factor by year, for the particular fuel type concerned.

Emission factors have been based on the following:

**Electricity**
National Greenhouse Account Factors 2019 Scope 2 + 3 (Table 44)

| Jurisdiction | Factor (kg/GJ) | Rate of Change/Year* (kg/GJ) |
|---|---|---|
| NSW | 250 | -2.3 |
| VIC | 311 | -4.4 |
| QLD | 257 | -2.9 |
| SA | 148 | -9.4 |
| WA | 205 | -5.8 |
| TAS | 48 | Varies (-2 to +2) – assume static |
| NT | 197 | -2.7 |
| ACT | ? | ? |
| AUS | 244 | -3.5 |

* Based on trend in preceding 10 years (2006/7 to 2016/17)

**Natural Gas**
National Greenhouse Account Factors 2019 Scope 1 (Table 2) + Scope (Table 41)

Scope 1 = 51.53 kg/GJ (all jurisdictions)

Scope 3: as per table below

| Jurisdiction | Scope 3 Factor (kg/GJ) | Scope 1 + 3 (kg/GJ) |
|---|---|---|
| NSW | 12.8 | 64.33 |
| VIC | 3.9 | 55.43 |
| QLD | 8.7 | 60.23 |
| SA | 10.4 | 61.93 |
| WA | 4.0 | 55.53 |
| TAS | N/A | N/A |
| NT | N/A | N/A |
| ACT | 12.8 | 64.33 |
| AUS | N/A | N/A |

**Firewood (slow combustion)**

A value of 5 kg/GJ has been adopted based on estimates prepared by George Wilkenfeld and Associates for the Commonwealth.

## 6.12 Societal Cost of fuels

Societal costs, used for undertaking cost benefit analysis, are simply the combined cost of fuel costs (see Section 6.10) and the costs associated with the greenhouse gas emissions of each fuel type. Greenhouse gas emission costs are simply calculated by multiplying the energy use by the greenhouse gas intensity of the fuel (see Section 6.11) then by a dollar value per tonne of greenhouse gas emissions ($CO_{2\text{-}e}$).

For this study a default carbon price of $12/tonne was used. $12/tonne[15] represents the average price paid by the Government for each tonne of abatement purchased through the Emissions Reduction Fund auctions, over 10 auctions.

The societal cost of fuels derived in this manner are reported in Table 26.

**Table 26 : Fuel Societal Costs Adopted in this Study (2020)**

| Tariff type | NSW | VIC | QLD | SA | WA | TAS | NT | ACT |
|---|---|---|---|---|---|---|---|---|
| Electricity – Peak (c/kWh) | 39.80 | 38.42 | 33.46 | 51.29 | 41.23 | 29.96 | 37.32 | 33.88 |
| Electricity Shoulder (c/kWh) | 25.97 | 25.18 | 21.91 | 33.20 | 26.82 | 19.33 | 24.30 | 21.85 |
| Electricity - Off peak (c/kWh) | 20.44 | 19.88 | 17.29 | 25.97 | 21.06 | 15.08 | 19.09 | 17.04 |
| Electricity– Cont. Load (c/kWh) | 14.07 | 20.61 | 16.74 | 20.43 | 12.73 | 13.50 | 26.90 | 14.83 |
| Natural Gas (c/MJ) | 3.48 | 2.47 | 4.97 | 4.27 | 4.07 | 3.78 | 3.78 | 3.68 |
| Firewood (c/MJ) | 1.87 | 1.87 | 1.87 | 1.87 | 1.87 | 1.87 | 1.87 | 1.87 |
| Electricity – PV Export (c/kWh) | 10.08 | 13.34 | 11.11 | 11.64 | 7.89 | 9.71 | 26.85 | 9.21 |

## 6.13 Other Technical Settings and Assumptions

The following technical settings are applied by default in the model.

**Table 27: Other Technical Settings**

| Parameter | Setting | Notes |
|---|---|---|
| Assumed duct losses | 15% | For simplicity, hydronic heating systems are assumed to suffer similar losses. |
| Assumed Slab heating losses | 20% | This is considered a conservative (low) estimate, particularly for any slabs without edge insulation. |

[15] Advice received from Emissions Reduction Fund Policy Section, Climate Change Division, Department of Industry, Science, Energy and Resources. May 2020. See also : http://www.cleanenergyregulator.gov.au/ERF/Auctions-results/march-2020

# 7 Improvement Cost Accounting

## 7.1 Overview

Gauging the cost of regulation involved assessing two main elements:

- The cost of upgrading the building shell performance from a 6 star NatHERS performance level to a NatHERS 7 star performance level.
- The cost of installing sufficient on-site renewable energy supply to meet the proposed whole-of-home performance standard.

In addition to these costs, there is also a potential cost associated with alterations to installed equipment specifications. However, as noted earlier, whilst regulations are likely to mandate changes to the building shell performance and also in many cases the provision of PV systems as a means for offsetting other energy consumption, there is no proposal to alter regulations in respect of the minimum performance standards for installed equipment. This means that in general terms there is no expectation that builders will alter the types and efficiencies of the equipment currently being installed unless in their view it will be beneficial for them to so do.

The proposed regulations will allow a builder/designer to continue to use their preferred regulated equipment choices and simply install the required level of PV panels or alternatively, choose more efficient equipment and reduce PV system capacity requirement. In the case of Option 2 (Part NZRE), more efficient appliances would reduce the installed capacity of renewable energy systems, or allow them to be avoided altogether.

The following three sections detail the underlying assumptions and basis used for cost accounting in relation to the building shell, PVs and equipment.

## 7.2 Building Shell Improvement Costs

Details in relation to the costing of building shell upgrades can be found in the companion report to this report called “NatHERS solutions and Costs”

As noted previously, whilst only a single dwelling type was used for establishing heating and cooling load profiles a broader range of dwellings types and sizes were modelled so as to establish representative costs associated with meeting the new building shell performance target.

**Class 1 Dwellings**

Costings for Class 1 dwellings were based on 13 modelled types in each climate zone modelled. The 13 types included 4 small dwellings, 4 mid-sized dwellings, 4 large dwellings and one semi-detached dwelling covering a range of representative construction formats applicable to the particular location. The costs for each of the 3 sets of differently sized detached dwellings were weighted equally. In addition, within each size range the timber floored examples and the concrete floored examples of the detached dwellings were weighted in accordance with the CSIRO data portal statistics available at: https://ahd.csiro.au/dashboards/construction/floors/.

The resultant cost structures are detailed in Table 28 below.

**Table 28: Class 1 Dwellings – Building Shell Improvement Costs (6 to 7 Stars)**

| NatHERS Climate Zone | Location | Improvement Cost ($/m$^2$) |
|---|---|---|
| 1 | Darwin | $ 7.34 |
| 3 | Longreach | $ 6.05 |
| 10 | Brisbane | $ 6.51 |
| 13 | Perth | $ 7.31 |
| 16 | Adelaide | $ 8.68 |
| 24 | Canberra | $ 14.73 |
| 26 | Hobart | $ 14.18 |
| 27 | Mildura | $ 11.48 |
| 28 | Sydney 1 | $ 11.35 |
| 32 | Cairns | $ 3.93 |
| 60 | Melbourne 1 | $ 10.04 |
| 69 | Thredbo | $ 8.89 |

**Class 2 Dwellings**
Costings for Class 2 dwellings were based on 24 modelled types in each climate zone modelled. The 24 types included examples of middle and corner units on ground floors, intermediate floors and uppermost floors across the 4 main orientations. The costs for each of the 24 dwellings were weighted equally. The resultant cost structures are detailed in Table 28 and Table 29 below.

**Table 29: Class 2 Dwellings – Building Shell Improvement Costs (6 to 7 Stars Average)**

| NatHERS Climate Zone | Location | Improvement Cost ($/m$^2$) |
|---|---|---|
| 1 | Darwin | 5.14 |
| 3 | Longreach | 5.45 |
| 10 | Brisbane | 6.74 |
| 13 | Perth | 5.27 |
| 16 | Adelaide | 8.82 |
| 21 | Melbourne 2 | 5.8 |
| 24 | Canberra | 12.25 |
| 26 | Hobart | 4.91 |
| 27 | Mildura | 4.43 |
| 32 | Cairns | 3.16 |
| 56 | Sydney 2 | 8.69 |

## *7.3 Photovoltaic Costs*

Costs associated with the supply and installation of PV panels and associated inverters were determined by IT Power Renewable Energy Consulting (ITP). ITP gathered data from www.solarchoice.net.au which takes data from its installer network database to find average prices for PV systems in Australia (Refer Appendix 4 – PV and Inverters – Basis for Cost Estimates).

For the first half of 2020, the average installed price for varying system sizes by jurisdiction are shown in Table 30 below. These prices include GST and are after the STC discount has been applied. The average cost of inverters alone is shown in the last row of the table below.

The model separately accounts for:

- The cost of PVs alone without STC rebates
- The cost of inverters alone
- The value of STC rebates.

By accounting for each of these items separately it is possible to model PV costs using differing assumptions in relation to the number of STCs applicable per kW of installed capacity and the monetary value of those STCs. In this way it is possible to model a scenario that includes no government rebates (this is the default assumption used in the modelling at an economy wide level in the RIS) or alternatively with rebates[16] as would be applicable to modelling at a household level.

Another important reason for disaggregating the costs and rebates associated with PV systems is that the lifespan of PVs is approximately double that of inverters, hence a new inverter is assumed to be installed approximately once every 10 years, whereas the PV panels are assumed to be replaced approximately once every 20 years. In addition, whilst rebates in the form of STC credits can, if required, be factored into the estimates in relation to the initial installation of the PV system, for replacement systems it is assumed that, in line with current government policy, no further rebates apply would apply under any circumstances.

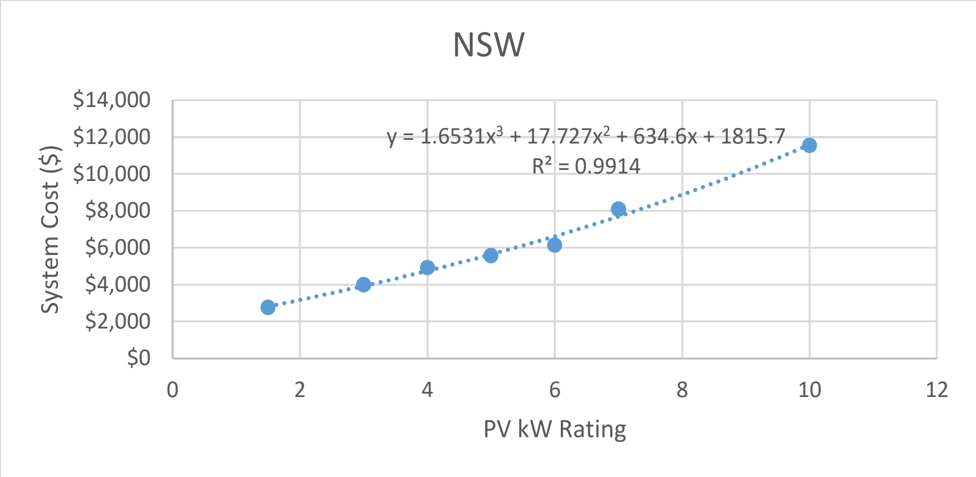
**Table 30: PV System Costs – including GST ($) (Solar Choice 2020)**

| | PV Capacity (kW) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1.5 | 3 | 4 | 5 | 6 | 7 | 10 |
| NSW | 2756 | 3999 | 4923 | 5568 | 6133 | 8088 | 11553 |
| VIC | 3288 | 4431 | 5357 | 5863 | 6429 | 8444 | 12822 |
| QLD | 3026 | 4399 | 5503 | 6418 | 7283 | 8848 | 13373 |
| SA | 3536 | 4819 | 5473 | 6218 | 7173 | 8628 | 13213 |
| WA | 2516 | 3379 | 4283 | 4758 | 5593 | 7348 | 12933 |
| TAS | 3148 | 4501 | 5747 | 7033 | 8409 | 9954 | 13422 |
| NT | 6101 | 7588 | 8859 | 10570 | 10981 | 12243 | 15006 |
| ACT | 2756 | 3949 | 5343 | 5958 | 6603 | 8568 | 11493 |
| Inverter (All States) | 806 | 1076 | 1256 | 1436 | 1616 | 1796 | 2336 |

Using the cost data from Table 30, a function relating PV cost with installed capacity was determined for each jurisdiction – See Figure 12 (NSW example). The polynomial equation shown within this figure was used to determine the cost of a PV installation of any given installed capacity. Added to this was the cost of the inverter at $536.20 + $180 per kW of installed capacity.

[16] Where rebates are to be accounted for (i.e. in a household level analysis) then an average level of rebate over a 10 year regulatory period starting 2022 is assumed. In this case an average only 4 years of credits are applied.

**Figure 12 Cost Curve Analysis – PV Only (NSW)**




The model allows the user to specify any number of STCs per kW of installed capacity and any value for each STC awarded. However, as noted earlier, for benefit/cost analysis at an economy wide level STCs values are set at zero.

## *7.4 Appliance improvement costs*

Default cost data for appliance costs loaded into the model has been drawn from a range of pre-existing sources used in the development of the Zero Net Carbon Tool for Sustainability Victoria (this included some limited market research undertaken for Sustainability Victoria). Other sources included some limited 2021 market research undertaken in respect of water heater costs for this study.

Different appliance categories were assessed for improvement cost based on different data sets depending upon availability. Some data sets were relatively comprehensive such as those available for whitegoods (not the focus of this study however) whilst others were less robust, such as for space-conditioning equipment and water heaters. Often the relationship between cost and efficiency was found to be quiet weak, although generally there was some correlation between higher efficiency and higher cost. The following subsections detail the appliance improvement cost basis for the following categories of appliance type:

- Space Conditioning Equipment
- Water Heating
- Pool Equipment.

Because some of the available data (mainly space conditioning equipment) was derived from a Victorian source now 4 years old the Victorian values were all adjusted to take account of CPI increases. For other jurisdictions costs were adjusted by the applicable CPI rises since 2016 (based on ABS housing CPI data 2016 and 2020) as well as by the comparative construction costs by state and territory[17] - see

[17] https://www.budgetdirect.com.au/home-contents-insurance/guides/buying-house/cost-to-build-a-house.html

Table 31 . It should be understood that extrapolation of this Victorian based data to other jurisdictions is an approximation only.

**Table 31: Climate Zones Modelled – CPI Increases and Building Cost Indicies**

| Jurisdiction | CPI Increase 2016 - 2020 | Building Cost Index (Relative to Victoria) |
|---|---|---|
| NSW | 106% | 103% |
| VIC | 109% | 100% |
| QLD | 103% | 105% |
| SA | 106% | 92% |
| WA | 99% | 81% |
| TAS | 113% | 105% |
| NT | 95% | 99% |
| ACT | 113% | 100% |

### *7.4.1 Space Conditioning Equipment*

No current comprehensive survey data was readily available for this category of equipment. However, as part of an earlier study for Sustainability Victoria's zero net carbon model, EES contracted a space conditioning equipment supply and install company (Global Energy Solutions) to estimate costs across the range of space conditioning equipment covered by the model as well as across a range of efficiency levels (noting that some space conditioning equipment only comes in a single efficiency level (e.g. resistance electric heating).

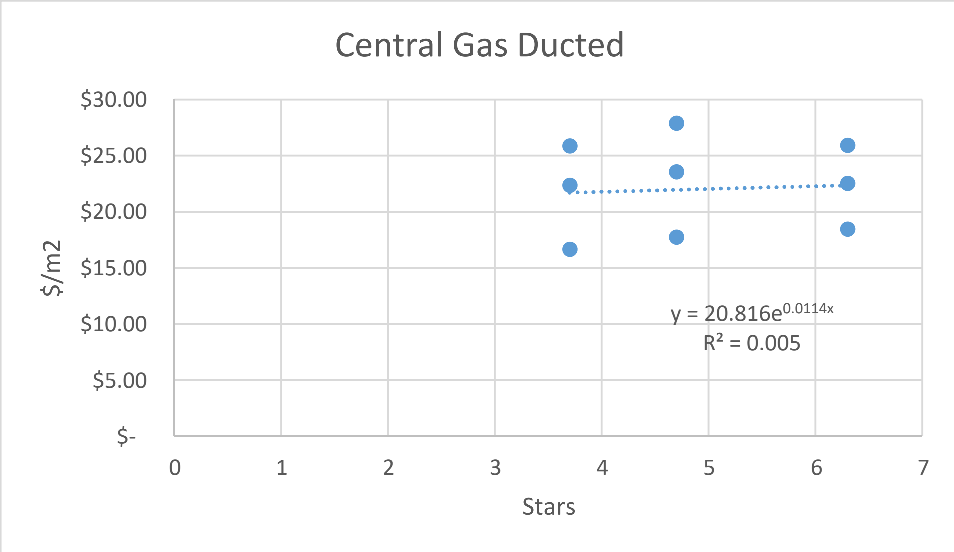
The results of that analysis are detailed in the following charts (see Figure 13) that include the specifications of the cost curves adopted in the model. These cost curves are couched in terms of the cost of supply and installation per $m^2$ of floor area serviced. Whilst more accurate plant sizing can be achieved by assessing actual loads, industry practice still tends to rely on simple rules of thumb based on the floor area to be conditioned (e.g. 100 W of capacity per $m^2$ for a 6 star rated dwelling)

In a couple of cases the cost curves were amended slightly to better reflect present day cost conditions. These changes are noted below the applicable charts that follow:

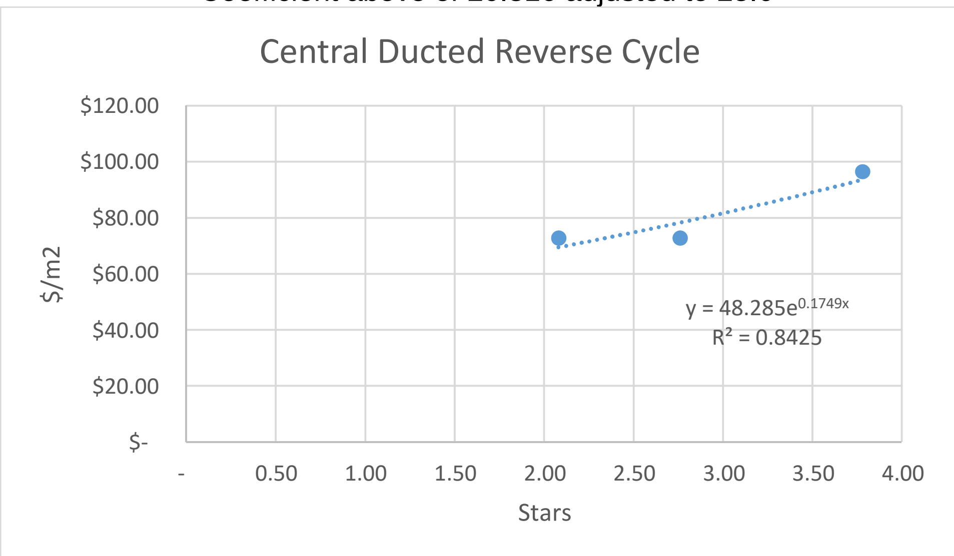
The following three space conditioning types were found to have a fixed cost per $m^2$:

Electric panel heating – \$22.27 / $m^2$
Floor slab heating – \$72.00 / $m^2$
Wood fired slow combustion heating – \$17.28 / $m^2$

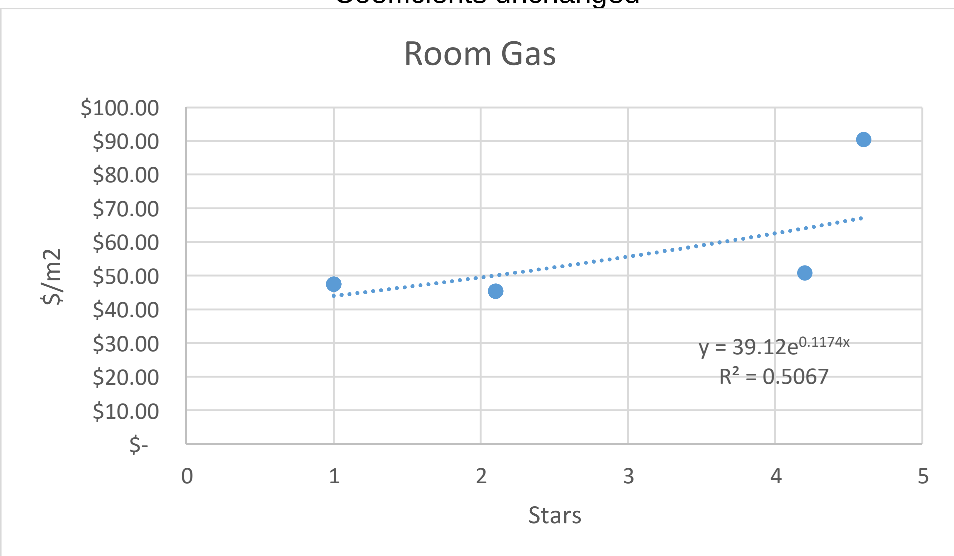
**Figure 13: Cost Curve Analysis for Selected Space Conditioning Equipment**



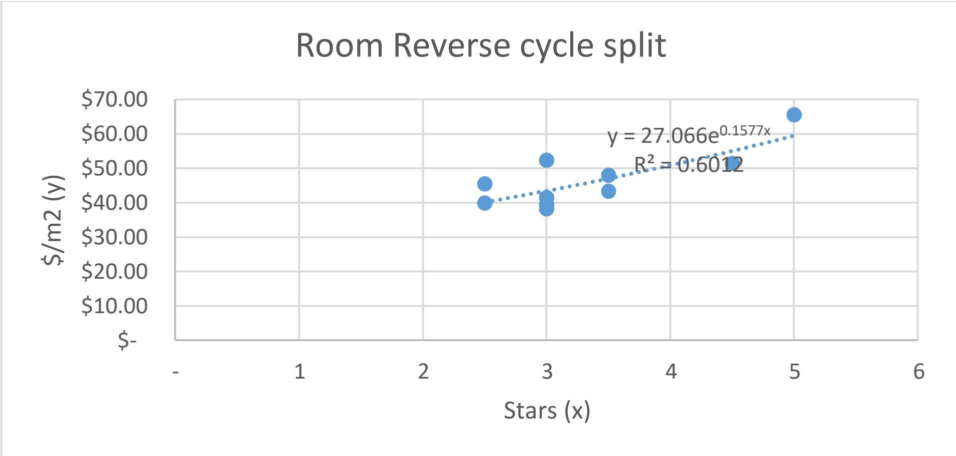

*Coefficient above of 20.816 adjusted to 25.0




*Coefficients unchanged




Coefficient of 39.12 adjusted to 35.0



*Coefficient of 27.066 adjusted to 30

### 7.4.2 Water Heating

No comprehensive survey data was readily available for this category of equipment. Whilst cost curve data was available from the 2016 Sustainability Victoria study for their Zero Net Carbon model this was found in some cases to be somewhat dated[18]. This was particularly true in respect of heat pump type water heaters where there has been downward pressure on costs due to the entry of new players into the market, particularly from China.

Consequently, EES undertook their own limited online survey in 2021 to determine representative costs for a typical class 1 dwelling and a typical class 2 dwelling hot water system for the most common types. Added to these unit costs were the installation costs (as derived in the ZNC study). Combined these provided a total installed cost – see Table 32.

These costs are exclusive of any rebates that are typically available in relation to solar and heat pump systems. Rebates in the form of RECs are not taken into account in any economy wide impacts analysis but would be applicable at the household level.

These estimated equipment costs (water heaters, space heaters and coolers) are of course only of relevance in circumstances where a builder elects to substitute equipment types as part of their response to regulations. In many cases, where a builder elects to maintain their original equipment choices and simply add PVs as required to meet the regulatory requirement, the equipment costs noted in the tables in this report (apart from PVs themselves) will be irrelevant.

[18] Also, whilst this data worked reasonably well in respect of class 1 dwellings (the primary focus of the initial ZNC study for Sustainability Victoria), it was found to be less applicable to class 2 dwellings with significantly lower floor areas and deemed number of occupants.

**Table 32: Estimated Relative Water Heater Costs ($)**

| **Water Heater Type** | **Class 1 (Nom. 3 to 4 people)** | | | **Class 2 ( Nom. 2-3 people)** | | |
|---|---|---|---|---|---|---|
| | **Unit** | **Install** | **Total** | **Unit** | **Install** | **Total** |
| Electric Storage (peak) | 1,140 | 510 | **1,650** | 840 | 510 | **1350** |
| Electric Storage (off peak) | 1,530 | 510 | **2,040** | 1270 | 510 | **1780** |
| Heat Pump (Standard) | 3,266 | 930 | **4,196** | 2940 | 930 | **3870** |
| Solar electric (Standard) | 4,490 | 1,780 | **6,270** | 3470 | 1780 | **5250** |
| Gas storage | 1,350 | 510 | **1,860** | 1140 | 510 | **1650** |
| Gas Instantaneous | 1,310 | 872 | **2,182** | 960 | 872 | **1832** |
| Solar Gas Instantaneous | 5,150 | 1,850 | **7,000** | 4200 | 1850 | **6050** |

# 8 Input into RIS Process

## 8.1 Overview

As part of the work undertaken for this study, an analysis of a selected representative sample of dwelling and equipment types was undertaken across the range of NCC climate zones and jurisdictions, so as to generate a data set suitable for input into the econometric model used for undertaking the regulatory impact analysis.

Modelling was conducted for both the business-as-usual case and the "with regulations" case (including a range of regulatory stringency options). The data set derived from this analysis provided data on energy consumption by end use and fuel type, as well as building cost data by component (building shell, Equipment and PV systems).

In addition to producing energy and cost input data sets for the purposes of the RIS, a range of other analyses was undertaken to assist the RIS process. In the main, the additional data related to estimates of the propensity of the various elements modelled, such that these could be weighted within the RIS modelling.

The following aspects were covered in this work to aid the RIS process:

- Options modelled (Dwelling classes, Dwelling performances Jurisdictions, Climate zones, Regulatory Stringencies)
- New housing – split between Class 1 and Class 2
- Representative equipment types modelled
- Propensity of Equipment Types
- BAU PV installations
- Thermal Bridging Impacts
- Pools and spas propensity
- Response to Regulation – Assumption basis

Each of these elements are described in detail in the following sub-sections.

## 8.2 Options modelled

For the purposes of the RIS analysis a specific set of options were modelled at the request of the RIS consulting firm in collaboration with the ABCB. These included:

**Dwelling classes**

- Class 1 (included detached and semi-detached dwellings)
- Class 2 (included flats and apartments).

**Dwelling thermal performances**

- BAU 6 Star NatHERS
- BAU 7 Star NatHERS
- With Regulations 7 Star NatHERS.

For the BAU case, both a 6 star and a 7 star version were modelled because data available from the CSIRO portal indicates that under BAU, a range of performance levels are currently being produced. Typically, at a minimum this is 6 stars but can range to 7 stars and even higher in a limited number of cases.

**Jurisdictions and Climate zones**

Data for the jurisdictions and climate zone combinations shown in Table 33 was generated for the RIS analysis.

**Table 33: Jurisdiction/Climate Zone Combinations modelled for the RIS**

| Class 1 | | | Class 2 | | |
|---|---|---|---|---|---|
| **Jurisdiction** | **NCC CZ** | **Propensity in Jurisdiction** | **Jurisdiction** | **NCC CZ** | **Propensity in Jurisdiction** |
| NSW | 2 | 7.05% | NSW | 2 | 1.02% |
| NSW | 4 | 3.80% | NSW | 4 | 0.23% |
| NSW | 5 | 34.85% | NSW | 5 | 74.56% |
| NSW | 6 | 49.05% | NSW | 6 | 23.77% |
| NSW | 7 | 5.03% | NSW | 7 | 0.40% |
| NSW | 8 | 0.22% | | | |
| | | | VIC | 6 | 99.59% |
| VIC | 4 | 2.08% | VIC | 7 | 0.33% |
| VIC | 6 | 87.37% | | | |
| VIC | 7 | 10.51% | QLD | 1 | 2.27% |
| VIC | 8 | 0.03% | QLD | 2 | 97.21% |
| | | | QLD | 5 | 0.37% |
| QLD | 1 | 11.22% | | | |
| QLD | 2 | 84.07% | SA | 5 | 99.66% |
| QLD | 3 | 0.49% | | | |
| QLD | 5 | 4.20% | WA | 5 | 99.74% |
| | | | | | |
| SA | 4 | 13.07% | TAS | 7 | 100.00% |
| SA | 5 | 80.17% | | | |
| SA | 6 | 6.75% | NT | 1 | 96.97% |
| | | | | | |
| WA | 1 | 2.19% | ACT | 7 | 99.07% |
| WA | 3 | 0.40% | | | |
| WA | 4 | 6.50% | | | |
| WA | 5 | 86.17% | | | |
| WA | 6 | 4.73% | | | |
| | | | | | |
| TAS | 7 | 99.96% | | | |
| | | | | | |
| NT | 1 | 83.90% | | | |
| NT | 3 | 15.94% | | | |
| | | | | | |
| ACT | 7 | 99.93% | | | |

These combinations cover all jurisdiction/climate zone combinations where the number of new constructions undertaken per year over the past 5 years averaged 10 units or more. Those with less than 10 units built per annum were excluded as these were considered to be insignificant in the context of a RIS analysis. The propensity values were derived from data provided by CSIRO from their portal of NatHERS simulations. Whilst this portal data does not cover 100% of all new constructions it does cover a large majority of new constructions (> 80% in most jurisdictions) and is the only known available data source that disaggregates new dwellings by climate zone.

**Regulatory Stringencies**
For RIS modelling a total of three stringency levels were modelled:

**Option 1: 100% NZRE** i.e. irrespective of the installed equipment types the societal cost of operating that (regulated) equipment must be fully offset by the value of PV panel energy generation. The more efficient/less costly the regulated equipment is to operate, the less the renewable energy offset requirement.

**Option 2: Part NZRE** - In this option a benchmark equipment and building fabric performance level is set, and the societal cost of operating that (regulated) equipment is calculated. A compliant dwelling must have the same societal cost as a 7-star dwelling with specified benchmark heating, cooling and hot water appliances; i.e.,

- Building shell performance level: Equivalent to a 7 star NatHERS rated dwelling
- Heating: Equivalent to a 4.5 star rated (GEMS 2012) heat pump ducted heater (AEER = 4.5)[19]
- Cooling Equivalent to a 4.5 star rated (GEMS 2012) heat pump ducted cooler (ACOP = 4.5)[20]
- Water heater: Instantaneous gas.

**Option 1.5: 30% NZRE** - In this option a compliant dwelling must provide sufficient renewable energy to fully offset its regulated equipment societal cost less 70% of the renewable energy required to fully offset the societal cost of an equivalent dwelling having benchmark equipment and building fabric performance level (as specified in option 2 above). This option might be thought of as approximately 30% more stringent than the benchmark case when compared to the 100% NZRE case.

## *8.3 New housing – split between Class 1 and Class 2*

An analysis was undertaken on available ABS building approvals and building completions data so as to determine the relative split between Class 1 and Class 2 dwellings by year and by jurisdiction. Data was available up until 2020 with projections then made until 2031. The tabular results can be found in Table 34. For more detail regarding these estimates refer to Appendix 6 – Equipment Propensities.

[19] Under the latest 2019 GEMS determination, in terms of seasonal ratings, this would equate to 3 Stars i.e. A Heating Seasonal Performance Factor (HSPF) of 4.5
[20] Under the latest 2019 GEMS determination, in terms of seasonal ratings, this would equate to 3 Stars i.e. A Total Cooling Seasonal Performance Factor (TCSPF) of 4.5

Table 34: Proportion of New Housing that is Class 2 Type Housing

| Year | NSW | VIC | QLD | SA | WA | TAS | NT | ACT |
|---|---|---|---|---|---|---|---|---|
| **2000** | 25.6% | 14.9% | 19.5% | 6.6% | 10.1% | 7.7% | 16.6% | 18.7% |
| **2001** | 27.9% | 12.3% | 17.9% | 2.6% | 5.0% | 2.6% | 22.7% | 46.2% |
| **2002** | 32.2% | 16.3% | 22.0% | 5.5% | 5.7% | 1.3% | 24.6% | 28.6% |
| **2003** | 30.6% | 15.2% | 19.4% | 4.3% | 7.8% | 2.2% | 28.7% | 28.5% |
| **2004** | 30.6% | 11.5% | 22.2% | 6.4% | 9.4% | 0.6% | 43.0% | 61.1% |
| **2005** | 31.3% | 9.4% | 22.5% | 6.9% | 6.9% | 0.7% | 37.8% | 41.1% |
| **2006** | 29.0% | 10.1% | 17.3% | 8.1% | 8.1% | 1.9% | 25.1% | 27.3% |
| **2007** | 30.0% | 13.1% | 20.4% | 5.2% | 9.9% | 1.7% | 38.7% | 40.5% |
| **2008** | 30.1% | 11.7% | 19.3% | 5.9% | 13.7% | 4.4% | 13.2% | 37.4% |
| **2009** | 24.8% | 16.7% | 15.0% | 4.8% | 3.7% | 3.8% | 17.3% | 27.9% |
| **2010** | 35.3% | 25.9% | 18.9% | 6.0% | 7.8% | 7.3% | 41.7% | 46.6% |
| **2011** | 35.3% | 25.3% | 21.5% | 8.7% | 7.8% | 5.8% | 37.2% | 52.3% |
| **2012** | 43.1% | 32.8% | 17.2% | 5.8% | 12.8% | 11.2% | 56.0% | 42.3% |
| **2013** | 45.0% | 29.2% | 26.7% | 10.1% | 10.7% | 10.4% | 38.6% | 50.1% |
| **2014** | 43.7% | 32.3% | 28.6% | 14.5% | 15.8% | 8.3% | 39.6% | 45.3% |
| **2015** | 48.7% | 34.5% | 37.7% | 14.2% | 15.7% | 6.9% | 30.2% | 51.8% |
| **2016** | 48.6% | 30.4% | 29.9% | 15.8% | 18.7% | 1.8% | 17.5% | 54.3% |
| **2017** | 43.9% | 27.8% | 20.6% | 13.1% | 16.8% | 3.5% | 7.6% | 54.7% |
| **2018** | 38.6% | 22.9% | 21.4% | 14.2% | 11.3% | 0.5% | 0.3% | 62.2% |
| **2019** | 35.3% | 22.3% | 20.7% | 11.6% | 16.4% | 3.5% | 5.1% | 50.6% |
| **2020** | 29.6% | 18.4% | 15.7% | 6.8% | 11.8% | 0.8% | 15.6% | 46.5% |
| **2021** | 29.1% | 18.0% | 15.3% | 6.6% | 11.5% | 0.8% | 14.5% | 45.8% |
| **2022** | 28.7% | 17.7% | 15.0% | 6.5% | 11.2% | 0.8% | 13.5% | 45.2% |
| **2023** | 28.2% | 17.4% | 14.6% | 6.3% | 10.9% | 0.8% | 12.4% | 44.5% |
| **2024** | 27.8% | 17.0% | 14.2% | 6.1% | 10.7% | 0.8% | 11.4% | 43.9% |
| **2025** | 27.3% | 16.7% | 13.9% | 5.9% | 10.4% | 0.8% | 10.3% | 43.2% |
| **2026** | 26.8% | 16.3% | 13.5% | 5.7% | 10.1% | 0.8% | 9.2% | 42.6% |
| **2027** | 26.4% | 16.0% | 13.1% | 5.5% | 9.8% | 0.7% | 8.2% | 41.9% |
| **2028** | 25.9% | 15.7% | 12.7% | 5.4% | 9.6% | 0.7% | 7.1% | 41.3% |
| **2029** | 25.5% | 15.3% | 12.4% | 5.2% | 9.3% | 0.7% | 6.1% | 40.6% |
| **2030** | 25.0% | 15.0% | 12.0% | 5.0% | 9.0% | 0.7% | 5.0% | 40.0% |
| **2031** | 24.5% | 14.7% | 11.6% | 4.8% | 8.7% | 0.7% | 3.9% | 39.4% |

## *8.4 Representative equipment types modelled*

In the main part of this study, over 600 combinations of heating, cooling and hot water equipment were modelled. Whilst such a large number of combinations is useful when framing deemed-to-satisfy requirements, in terms of calculating impacts for a RIS, such a large number of options is unwieldy and also unnecessary given that many of the options would have little or no market penetration.

For the purposes of RIS modelling, a representative sample of equipment options were selected. This includes 6 heater types (including no heating) combined with four cooler types (including no cooling) and seven water heater types. A total of 77 combinations were modelled, noting that not all heater types were combined with all cooler types (e.g. a central heat pump heater was only ever paired with a central heat pump cooler). In total, ten heater/cooler combinations were combined with each of the seven water heater types.

The range of equipment types modelled are detailed below.

**Heater Types**

1. Central Gas (ducted)
2. Room Gas
3. Central HP (ducted)
4. Room HP
5. Firewood
6. No Heating

**Cooling Types**

1. Central HP (ducted)
2. Room HP
3. Central evaporative (ducted)
4. No cooling

**Water Heater Types**

1. Electric Storage (continuous)
2. Electric Storage (controlled)
3. Heat Pump
4. Solar electric
5. Gas storage
6. Gas Instantaneous
7. Solar Gas

Details of the exact combinations modelled can be found in Section 8.5.

## *8.5 Propensity of Equipment Types*

In order that the various equipment combinations noted in Section could be properly weighted in the RIS modelling exercise, an analysis of the current market in terms of installations into new dwellings was carried out. This is a particularly difficult task as there is very limited data collection in relation to equipment choices in new housing and data relating to propensities of equipment types in the general stock have not been conducted since 2014 (ABS 4602). Various data sources were used to construct a profile of equipment combinations in new dwellings by State and by class of dwelling. This process is described in detail in Appendix 6 – Equipment Propensities and New Housing Stock Data.

The results of that analysis by jurisdiction can be found below in Table 35 (Class 1 housing) and Table 36 (Class 2 housing).

## Table 35: Equipment Propensities for New Class 1 Housing by Jurisdiction

| Appliance Combination | | | Class 1 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Heater Type** | **Cooler Type** | **Water Heater Type** | **NSW** | **VIC** | **QLD** | **SA** | **WA** | **TAS** | **NT** | **ACT** |
| Central Gas | Room HP (Cool) | Electric Storage (continuous) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | Room HP (Cool) | Electric Storage (controlled) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | Room HP (Cool) | Heat Pump (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | Room HP (Cool) | Solar electric (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | Room HP (Cool) | Gas storage | 0.01% | 0.21% | 0.00% | 0.13% | 0.18% | 0.14% | 0.00% | 0.48% |
| Central Gas | Room HP (Cool) | Gas Instantaneous | 0.26% | 0.72% | 0.01% | 1.13% | 0.60% | 0.57% | 0.00% | 1.72% |
| Central Gas | Room HP (Cool) | Solar Gas | 0.01% | 2.45% | 0.00% | 0.32% | 0.64% | 0.09% | 0.00% | 1.07% |
| Central Gas | Central evaporative | Electric Storage (continuous) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | Central evaporative | Electric Storage (controlled) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | Central evaporative | Heat Pump (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | Central evaporative | Solar electric (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | Central evaporative | Gas storage | 0.00% | 0.09% | 0.00% | 0.05% | 0.04% | 0.00% | 0.00% | 0.15% |
| Central Gas | Central evaporative | Gas Instantaneous | 0.01% | 0.29% | 0.00% | 0.48% | 0.13% | 0.01% | 0.00% | 0.53% |
| Central Gas | Central evaporative | Solar Gas | 0.00% | 1.01% | 0.00% | 0.14% | 0.14% | 0.00% | 0.00% | 0.33% |
| Central Gas | No cooling | Electric Storage (continuous) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | No cooling | Electric Storage (controlled) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | No cooling | Heat Pump (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | No cooling | Solar electric (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | No cooling | Gas storage | 0.00% | 0.03% | 0.00% | 0.01% | 0.02% | 0.12% | 0.00% | 0.20% |
| Central Gas | No cooling | Gas Instantaneous | 0.07% | 0.10% | 0.00% | 0.11% | 0.05% | 0.47% | 0.00% | 0.70% |
| Central Gas | No cooling | Solar Gas | 0.00% | 0.35% | 0.00% | 0.03% | 0.06% | 0.07% | 0.00% | 0.44% |
| Room Gas | Room HP (Cool) | Electric Storage (continuous) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Room Gas | Room HP (Cool) | Electric Storage (controlled) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Room Gas | Room HP (Cool) | Heat Pump (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Room Gas | Room HP (Cool) | Solar electric (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Room Gas | Room HP (Cool) | Gas storage | 0.05% | 0.10% | 0.05% | 0.91% | 2.45% | 0.20% | 0.00% | 0.15% |
| Room Gas | Room HP (Cool) | Gas Instantaneous | 2.50% | 0.32% | 0.27% | 8.19% | 8.19% | 0.79% | 0.00% | 0.52% |
| Room Gas | Room HP (Cool) | Solar Gas | 0.09% | 1.11% | 0.05% | 2.34% | 8.75% | 0.12% | 0.00% | 0.32% |
| Room Gas | No cooling | Electric Storage (continuous) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Room Gas | No cooling | Electric Storage (controlled) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Room Gas | No cooling | Heat Pump (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Room Gas | No cooling | Solar electric (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Room Gas | No cooling | Gas storage | 0.01% | 0.01% | 0.01% | 0.09% | 0.22% | 0.16% | 0.00% | 0.06% |
| Room Gas | No cooling | Gas Instantaneous | 0.65% | 0.05% | 0.08% | 0.83% | 0.75% | 0.66% | 0.00% | 0.21% |
| Room Gas | No cooling | Solar Gas | 0.02% | 0.16% | 0.01% | 0.24% | 0.80% | 0.10% | 0.00% | 0.13% |
| Central HP | Central HP (Cool) | Electric Storage (continuous) | 0.03% | 0.32% | 0.69% | 0.18% | 0.60% | 2.02% | 0.06% | 1.66% |
| Central HP | Central HP (Cool) | Electric Storage (controlled) | 0.03% | 1.27% | 2.76% | 1.59% | 0.07% | 2.02% | 0.00% | 2.49% |
| Central HP | Central HP (Cool) | Heat Pump (Standard) | 0.30% | 0.87% | 0.40% | 8.83% | 1.47% | 2.94% | 0.01% | 9.41% |
| Central HP | Central HP (Cool) | Solar electric (Standard) | 0.28% | 2.04% | 1.11% | 1.77% | 2.89% | 0.19% | 0.67% | 0.46% |
| Central HP | Central HP (Cool) | Gas storage | 0.05% | 0.53% | 0.01% | 0.24% | 0.18% | 0.11% | 0.00% | 0.59% |
| Central HP | Central HP (Cool) | Gas Instantaneous | 2.42% | 1.78% | 0.06% | 2.17% | 0.62% | 0.45% | 0.00% | 2.09% |
| Central HP | Central HP (Cool) | Solar Gas | 0.08% | 6.09% | 0.01% | 0.62% | 0.66% | 0.07% | 0.01% | 1.30% |
| Room HP | Room HP (Cool) | Electric Storage (continuous) | 0.73% | 1.79% | 9.89% | 0.63% | 4.37% | 18.17% | 7.85% | 6.64% |
| Room HP | Room HP (Cool) | Electric Storage (controlled) | 0.63% | 7.17% | 39.54% | 5.65% | 0.49% | 18.17% | 0.59% | 9.96% |
| Room HP | Room HP (Cool) | Heat Pump (Standard) | 6.76% | 4.95% | 5.66% | 31.31% | 10.80% | 26.48% | 1.70% | 37.63% |
| Room HP | Room HP (Cool) | Solar electric (Standard) | 6.44% | 11.55% | 15.90% | 6.26% | 21.17% | 1.75% | 82.46% | 1.86% |
| Room HP | Room HP (Cool) | Gas storage | 1.17% | 3.01% | 0.17% | 0.85% | 1.35% | 1.01% | 0.44% | 2.36% |
| Room HP | Room HP (Cool) | Gas Instantaneous | 55.02% | 10.09% | 0.91% | 7.69% | 4.52% | 4.03% | 0.56% | 8.36% |
| Room HP | Room HP (Cool) | Solar Gas | 1.92% | 34.53% | 0.17% | 2.20% | 4.83% | 0.60% | 0.85% | 5.20% |
| Wood Central | Room HP (Cool) | Electric Storage (continuous) | 0.01% | 0.05% | 0.09% | 0.04% | 0.15% | 1.55% | 0.01% | 0.08% |
| Wood Central | Room HP (Cool) | Electric Storage (controlled) | 0.01% | 0.20% | 0.37% | 0.35% | 0.02% | 1.55% | 0.00% | 0.12% |
| Wood Central | Room HP (Cool) | Heat Pump (Standard) | 0.09% | 0.14% | 0.05% | 1.91% | 0.38% | 2.26% | 0.00% | 0.44% |
| Wood Central | Room HP (Cool) | Solar electric (Standard) | 0.08% | 0.32% | 0.15% | 0.38% | 0.74% | 0.15% | 0.15% | 0.02% |
| Wood Central | Room HP (Cool) | Gas storage | 0.02% | 0.08% | 0.00% | 0.05% | 0.05% | 0.09% | 0.00% | 0.03% |
| Wood Central | Room HP (Cool) | Gas Instantaneous | 0.72% | 0.28% | 0.01% | 0.47% | 0.16% | 0.34% | 0.00% | 0.10% |
| Wood Central | Room HP (Cool) | Solar Gas | 0.03% | 0.94% | 0.00% | 0.13% | 0.17% | 0.05% | 0.00% | 0.06% |
| Wood Central | Central evaporative | Electric Storage (continuous) | 0.01% | 0.05% | 0.09% | 0.04% | 0.15% | 1.55% | 0.01% | 0.08% |
| Wood Central | Central evaporative | Electric Storage (controlled) | 0.01% | 0.20% | 0.37% | 0.35% | 0.02% | 1.55% | 0.00% | 0.12% |
| Wood Central | Central evaporative | Heat Pump (Standard) | 0.09% | 0.14% | 0.05% | 1.91% | 0.38% | 2.26% | 0.00% | 0.44% |
| Wood Central | Central evaporative | Solar electric (Standard) | 0.08% | 0.32% | 0.15% | 0.38% | 0.74% | 0.15% | 0.15% | 0.02% |
| Wood Central | Central evaporative | Gas storage | 0.02% | 0.08% | 0.00% | 0.05% | 0.05% | 0.09% | 0.00% | 0.03% |
| Wood Central | Central evaporative | Gas Instantaneous | 0.72% | 0.28% | 0.01% | 0.47% | 0.16% | 0.34% | 0.00% | 0.10% |
| Wood Central | Central evaporative | Solar Gas | 0.03% | 0.94% | 0.00% | 0.13% | 0.17% | 0.05% | 0.00% | 0.06% |
| Wood Central | No cooling | Electric Storage (continuous) | 0.01% | 0.05% | 0.09% | 0.04% | 0.15% | 1.55% | 0.01% | 0.08% |
| Wood Central | No cooling | Electric Storage (controlled) | 0.01% | 0.20% | 0.37% | 0.35% | 0.02% | 1.55% | 0.00% | 0.12% |
| Wood Central | No cooling | Heat Pump (Standard) | 0.09% | 0.14% | 0.05% | 1.91% | 0.38% | 2.26% | 0.00% | 0.44% |
| Wood Central | No cooling | Solar electric (Standard) | 0.08% | 0.32% | 0.15% | 0.38% | 0.74% | 0.15% | 0.15% | 0.02% |
| Wood Central | No cooling | Gas storage | 0.02% | 0.08% | 0.00% | 0.05% | 0.05% | 0.09% | 0.00% | 0.03% |
| Wood Central | No cooling | Gas Instantaneous | 0.72% | 0.28% | 0.01% | 0.47% | 0.16% | 0.34% | 0.00% | 0.10% |
| Wood Central | No cooling | Solar Gas | 0.03% | 0.94% | 0.00% | 0.13% | 0.17% | 0.05% | 0.00% | 0.06% |
| No Heating | No cooling | Electric Storage (continuous) | 0.18% | 0.02% | 2.76% | 0.06% | 1.66% | 0.13% | 0.35% | 0.05% |
| No Heating | No cooling | Electric Storage (controlled) | 0.15% | 0.10% | 11.05% | 0.52% | 0.18% | 0.13% | 0.03% | 0.07% |
| No Heating | No cooling | Heat Pump (Standard) | 1.64% | 0.07% | 1.58% | 2.87% | 4.09% | 0.19% | 0.08% | 0.26% |
| No Heating | No cooling | Solar electric (Standard) | 1.56% | 0.16% | 4.44% | 0.57% | 8.02% | 0.01% | 3.70% | 0.01% |
| No Heating | No cooling | Gas storage | 0.28% | 0.04% | 0.05% | 0.08% | 0.51% | 0.01% | 0.02% | 0.02% |
| No Heating | No cooling | Gas Instantaneous | 13.33% | 0.14% | 0.25% | 0.70% | 1.71% | 0.03% | 0.03% | 0.06% |
| No Heating | No cooling | Solar Gas | 0.47% | 0.47% | 0.05% | 0.20% | 1.83% | 0.00% | 0.04% | 0.04% |

## Table 36: Equipment Propensities for New Class 2 Housing by Jurisdiction

| Appliance Combination | | | Class 2 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Heater Type** | **Cooler Type** | **Water Heater Type** | **NSW** | **VIC** | **QLD** | **SA** | **WA** | **TAS** | **NT** | **ACT** |
| Central Gas | Room HP (Cool) | Electric Storage (continuous) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | Room HP (Cool) | Electric Storage (controlled) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | Room HP (Cool) | Heat Pump (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | Room HP (Cool) | Solar electric (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | Room HP (Cool) | Gas storage | 0.09% | 1.17% | 0.00% | 0.08% | 0.09% | 0.04% | 0.00% | 0.19% |
| Central Gas | Room HP (Cool) | Gas Instantaneous | 0.59% | 2.29% | 0.00% | 0.45% | 0.49% | 0.15% | 0.00% | 1.08% |
| Central Gas | Room HP (Cool) | Solar Gas | 0.00% | 0.05% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.05% |
| Central Gas | Central evaporative | Electric Storage (continuous) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | Central evaporative | Electric Storage (controlled) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | Central evaporative | Heat Pump (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | Central evaporative | Solar electric (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | Central evaporative | Gas storage | 0.00% | 0.01% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | Central evaporative | Gas Instantaneous | 0.00% | 0.01% | 0.00% | 0.01% | 0.01% | 0.00% | 0.00% | 0.02% |
| Central Gas | Central evaporative | Solar Gas | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | No cooling | Electric Storage (continuous) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | No cooling | Electric Storage (controlled) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | No cooling | Heat Pump (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | No cooling | Solar electric (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Central Gas | No cooling | Gas storage | 0.01% | 0.01% | 0.00% | 0.01% | 0.02% | 0.04% | 0.00% | 0.10% |
| Central Gas | No cooling | Gas Instantaneous | 0.04% | 0.02% | 0.00% | 0.08% | 0.09% | 0.16% | 0.00% | 0.54% |
| Central Gas | No cooling | Solar Gas | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.02% |
| Room Gas | Room HP (Cool) | Electric Storage (continuous) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Room Gas | Room HP (Cool) | Electric Storage (controlled) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Room Gas | Room HP (Cool) | Heat Pump (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Room Gas | Room HP (Cool) | Solar electric (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Room Gas | Room HP (Cool) | Gas storage | 0.01% | 0.02% | 0.02% | 0.94% | 1.68% | 0.15% | 0.00% | 0.19% |
| Room Gas | Room HP (Cool) | Gas Instantaneous | 0.05% | 0.04% | 0.10% | 5.33% | 9.49% | 0.61% | 0.00% | 1.09% |
| Room Gas | Room HP (Cool) | Solar Gas | 0.00% | 0.00% | 0.02% | 0.03% | 0.08% | 0.01% | 0.00% | 0.05% |
| Room Gas | No cooling | Electric Storage (continuous) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Room Gas | No cooling | Electric Storage (controlled) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Room Gas | No cooling | Heat Pump (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Room Gas | No cooling | Solar electric (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Room Gas | No cooling | Gas storage | 0.00% | 0.00% | 0.01% | 0.16% | 0.30% | 0.16% | 0.00% | 0.10% |
| Room Gas | No cooling | Gas Instantaneous | 0.00% | 0.00% | 0.05% | 0.90% | 1.73% | 0.65% | 0.00% | 0.55% |
| Room Gas | No cooling | Solar Gas | 0.00% | 0.00% | 0.01% | 0.00% | 0.02% | 0.02% | 0.00% | 0.02% |
| Central HP | Central HP (Cool) | Electric Storage (continuous) | 0.19% | 0.38% | 0.82% | 0.72% | 0.59% | 2.97% | 0.47% | 3.31% |
| Central HP | Central HP (Cool) | Electric Storage (controlled) | 0.62% | 0.07% | 1.23% | 1.68% | 0.07% | 1.27% | 0.04% | 2.20% |
| Central HP | Central HP (Cool) | Heat Pump (Standard) | 0.02% | 1.26% | 0.16% | 0.31% | 0.04% | 0.40% | 0.00% | 1.33% |
| Central HP | Central HP (Cool) | Solar electric (Standard) | 0.01% | 0.06% | 0.21% | 0.06% | 0.08% | 0.05% | 0.22% | 0.08% |
| Central HP | Central HP (Cool) | Gas storage | 0.47% | 4.14% | 0.01% | 1.47% | 0.54% | 0.22% | 0.01% | 0.92% |
| Central HP | Central HP (Cool) | Gas Instantaneous | 3.19% | 8.14% | 0.07% | 8.32% | 3.06% | 0.89% | 0.01% | 5.23% |
| Central HP | Central HP (Cool) | Solar Gas | 0.02% | 0.16% | 0.01% | 0.04% | 0.03% | 0.02% | 0.00% | 0.23% |
| Room HP | Room HP (Cool) | Electric Storage (continuous) | 3.63% | 2.17% | 21.96% | 4.08% | 7.88% | 46.49% | 57.10% | 20.30% |
| Room HP | Room HP (Cool) | Electric Storage (controlled) | 12.07% | 0.40% | 32.94% | 9.52% | 0.88% | 19.92% | 4.30% | 13.54% |
| Room HP | Room HP (Cool) | Heat Pump (Standard) | 0.31% | 7.21% | 4.24% | 1.75% | 0.51% | 6.33% | 0.55% | 8.17% |
| Room HP | Room HP (Cool) | Solar electric (Standard) | 0.27% | 0.33% | 5.55% | 0.33% | 1.11% | 0.74% | 26.53% | 0.51% |
| Room HP | Room HP (Cool) | Gas storage | 9.26% | 23.59% | 0.33% | 8.32% | 7.18% | 3.47% | 0.97% | 5.67% |
| Room HP | Room HP (Cool) | Gas Instantaneous | 62.22% | 46.42% | 1.87% | 47.17% | 40.68% | 13.89% | 1.45% | 32.10% |
| Room HP | Room HP (Cool) | Solar Gas | 0.35% | 0.94% | 0.29% | 0.23% | 0.36% | 0.34% | 0.27% | 1.41% |
| Wood Central | Room HP (Cool) | Electric Storage (continuous) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Wood Central | Room HP (Cool) | Electric Storage (controlled) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Wood Central | Room HP (Cool) | Heat Pump (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Wood Central | Room HP (Cool) | Solar electric (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Wood Central | Room HP (Cool) | Gas storage | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Wood Central | Room HP (Cool) | Gas Instantaneous | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Wood Central | Room HP (Cool) | Solar Gas | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Wood Central | Central evaporative | Electric Storage (continuous) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Wood Central | Central evaporative | Electric Storage (controlled) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Wood Central | Central evaporative | Heat Pump (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Wood Central | Central evaporative | Solar electric (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Wood Central | Central evaporative | Gas storage | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Wood Central | Central evaporative | Gas Instantaneous | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Wood Central | Central evaporative | Solar Gas | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Wood Central | No cooling | Electric Storage (continuous) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Wood Central | No cooling | Electric Storage (controlled) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Wood Central | No cooling | Heat Pump (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Wood Central | No cooling | Solar electric (Standard) | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Wood Central | No cooling | Gas storage | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Wood Central | No cooling | Gas Instantaneous | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| Wood Central | No cooling | Solar Gas | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% | 0.00% |
| No Heating | No cooling | Electric Storage (continuous) | 0.27% | 0.03% | 9.85% | 0.46% | 3.09% | 0.51% | 5.05% | 0.25% |
| No Heating | No cooling | Electric Storage (controlled) | 0.90% | 0.01% | 14.77% | 1.07% | 0.34% | 0.22% | 0.38% | 0.17% |
| No Heating | No cooling | Heat Pump (Standard) | 0.02% | 0.10% | 1.90% | 0.20% | 0.20% | 0.07% | 0.05% | 0.10% |
| No Heating | No cooling | Solar electric (Standard) | 0.02% | 0.00% | 2.49% | 0.04% | 0.43% | 0.01% | 2.35% | 0.01% |
| No Heating | No cooling | Gas storage | 0.69% | 0.33% | 0.15% | 0.93% | 2.82% | 0.04% | 0.09% | 0.07% |
| No Heating | No cooling | Gas Instantaneous | 4.66% | 0.64% | 0.84% | 5.29% | 15.97% | 0.15% | 0.13% | 0.39% |
| No Heating | No cooling | Solar Gas | 0.03% | 0.01% | 0.13% | 0.03% | 0.14% | 0.00% | 0.02% | 0.02% |

## 8.6 BAU PV installations

A proportion of new housing is currently constructed with a PV installation included as part of the initial build. Naturally, with the potential introduction of Whole-of-House energy-based regulations in 2022, such dwellings may already have sufficient PVs installed so as to meet in full or in part the NCC 2022 performance requirement.

In order that the impact on this cohort of dwellings could be assessed, a separate modelling run was undertaken where the BAU case included a PV installation and the with regulations case included any additional requirements over and above the level of PVs installed under the BAU case.

This raised two questions. What is the average capacity of PVs installed in new dwellings and what proportion of new dwellings would be fitted with PV at time of construction?

Reference was made to the Centre for New Energy Technologies (C4NET) study entitled “Australian Building Codes Board electricity data assessment: Victorian Data Assessment”. This study only covered housing built in Victoria. Their results are shown below in Table 37.

**Table 37: PV Installations in Victoria (C4NET)**

| Year | Average System Size – All housing surveyed (kW) | Average % of installation after 1 year |
|---|---|---|
| 2003 | 3.84 | 2% |
| 2004 | 3.83 | 3% |
| 2005 | 3.79 | 3% |
| 2006 | 3.79 | 3% |
| 2007 | 3.81 | 4% |
| 2008 | 3.98 | 1% |
| 2009 | 3.89 | 1% |
| 2010 | 3.94 | 1% |
| 2011 | 4.11 | 5% |
| 2012 | 4.34 | 5% |
| 2013 | 4.63 | 3% |
| 2014 | 4.45 | 5% |
| 2015 | 4.94 | 5% |
| 2016 | 5.07 | 5% |
| 2017 | 5.33 | 6% |
| 2018 | 5.47 | 10% |
| 2019 | 5.58 | 13% |
| 2020 | 5.67 | N/A |

The last data point in relation to number of installations within 1 year of construction indicates that 13% of new dwellings included PV within the first year. Whilst some would have installed their system post occupancy, many would have included the PVs as part of the construction contract. The only other data on this aspect comes from BASIX in NSW. The BASIX database records an average of 16.7% of new constructions being fitted with PVs. In the case of NSW and the BASIX scheme a credit is provided under the scheme for those who install PVs. This credit would be expected to drive a higher-than-average installation rate of PVs into new dwellings in NSW compared to the rest of Australia where such credits are not offered under the building approval process.

In terms of the average capacity of PV systems being installed the data suggests that this now sits at a little over 5kW. For the purposes of the RIS analysis it was agreed with the ABCB that an average system size of 5kW would be assumed for new housing. This is slightly less than the average for all housing but takes into account the fact that those installing PVs as part of the initial construction are likely to be more financially constrained.

## *8.7 Thermal Bridging Impacts*

The proposal to address issues relating to thermal bridging under the NCC 2022 regulations will primarily impact on metal-framed dwellings. At present, the NatHERS thermal simulation tools as used for the majority of building approvals does not take into account the added heat losses and heat gains due to thermal bridging.

This means that, particularly for steel-framed buildings, the current NatHERS tools generally under-estimate thermal loads. Consequently, the assumed performance of the BAU case for these dwellings (notionally 6 stars) understates the heating and in most cases the cooling loads. Required measures under the proposed NCC 2022 to address thermal bridging will mean that the added heat losses and gains applicable to the business-as-usual case will no longer apply to the “with regulations” (NCC 2022) case.

In terms of modelling steel framed dwellings for the RIS process it is therefore necessary to scale up the heating and cooling loads associated with the BAU case, thereby increasing the savings associated with shifting from a BAU 6 star case with thermal bridging to a “with regulations” 7 star case without bridging (i.e. increased benefits). At the same time, in relation to steel framed buildings it is also necessary to increase the cost for the “with regulations” case to account for the added cost of addressing the thermal bridging issues (i.e. increased costs).

The impact of the thermal bridging on the heating and cooling loads and costs was assessed by Tony Isaacs Consulting (see separate report on this aspect). The results of that assessment are detailed below in Table 38 (Class 1 dwellings) and Table 39 (Class 2 dwellings). These increases in heating and cooling loads and costs are indicative of dealing with thermal bridging across walls and ceilings as this constitutes the majority of cases in relation to new dwellings.

**Table 38: Thermal Bridging Factors – Class 1 Dwellings**

| NatHERS CZ | Location | Added Cooling (%) | Added Heating (%) | Added Cost ($) |
|---|---|---|---|---|
| 1 | Darwin | 2.5% | 0.0% | $1,060 |
| 32 | Cairns | 0.9% | 0.0% | $939 |
| 10 | Brisbane | 1.1% | 32.0% | $1,514 |
| 3 | Longreach | 1.9% | 9.6% | $875 |
| 27 | Mildura | 4.6% | 18.8% | $1,682 |
| 28 | W. Sydney | 3.3% | 22.3% | $1,669 |
| 13 | Perth | 2.7% | 9.9% | $879 |
| 16 | Adelaide | 9.1% | 27.4% | $1,747 |
| 60 | Melbourne | 1.3% | 26.5% | $1,670 |
| 26 | Hobart | -15.7% | 20.5% | $1,681 |
| 24 | Canberra | -5.3% | 25.1% | $1,689 |
| 69 | Thredbo | 10.7% | 30.6% | $1,680 |

**Table 39: Thermal Bridging Factors – Class 2 Dwellings**

| NatHERS CZ | Location | Added Cooling (%) | Added Heating (%) | Added Cost ($) |
|---|---|---|---|---|
| 1 | Darwin | 0.4% | 0.0% | $141 |
| 3 | Longreach | 0.9% | 4.7% | $118 |
| 10 | Brisbane | 0.6% | 8.0% | $99 |
| 13 | Perth | 0.5% | 0.7% | $133 |
| 16 | Adelaide | 0.9% | 4.2% | $156 |
| 21 | Melbourne | 0.9% | 2.0% | $126 |
| 24 | Canberra | 0.9% | 2.2% | $160 |
| 26 | Hobart | -1.2% | 3.5% | $110 |
| 27 | Mildura | 0.9% | 3.1% | $137 |
| 32 | Cairns | 0.6% | 0.0% | $130 |
| 56 | Sydney | 0.6% | 5.6% | $160 |

## *8.8 Pools and Spas propensity*

Limited analysis was undertaken in relation to dwellings with either a pool or a spa installed at time of initial construction. To enable application of this analysis into the RIS modelling, data relating to the propensity of ownership was sought.

No data could be found on the percentage of new dwellings that are constructed with a swimming pool as part of the initial build. Building approvals records should contain such data, but no one appears to aggregate the individual records on this aspect.

Reference was made to possibly the best publicly-available source of buildings approval data, the Victorian Building Authorities unit records for building approvals, but this did not include any data relating to swimming pools.

The only data that is available is ownership data for the entire stock. It is postulated that the rate of pool ownership for new builds would be less (probably significantly less) than for the general population because of the significant cost impost of installing a pool at a time when most people's budgets are stretched. In addition, compared to the stock of housing, new housing tends to include higher proportions of Class 2 dwellings and also more Class 1 dwellings built on small blocks with little available outdoor living space to accommodate a pool. Both of these factors would further reduce the likelihood that a new home builder would install a pool at time of construction.

It should also be recognised that a proportion of those new home-owners who do intend to construct a pool or a spa may decide after 2022 that they will postpone construction of the pool or spa until after the issue of the certificate of occupancy as a means for avoiding the need to factor in a pool pump into their whole-of-home compliance calculations.

**Available Data**

A number of sources put the current ownership of swimming pools at just over the 1 million households mark. The only data source that provides a time series and a split by jurisdiction is the ABS 4602 series (Environmental Issues: Energy Use and Conservation). The latest version of this was published in 2014 but this version did not contain information relating to swimming pools. The only versions that did contain swimming pool data were published in:

- 1994
- 1998
- 2001
- 2004.

An analysis of this data was conducted by George Wilkenfeld and Associates for The Department of Environment, Water, Heritage and the Arts (DEWHA) in the study – Energy Use in the Australian Residential Sector 1986 – 2020 (DEWHA 2008). This analysis came up with estimates and projections as per Table 40 (also shown graphically in Figure 14).

The Decision Regulation Impact Statement: Swimming pool pumps 2018, E3, September 2018 reported that there are approximately 1.1 million residential pools in Australia and further that the stock of pool pumps is growing by approximately 1.5 per cent per year.

These values are broadly consistent with those reported in the earlier 2008 DEWHA study, noting that the estimated number of pools in the RIS was 1.1 million compared to the DEWHA studies estimate for 2017 of 1.2 million. No source is provided in the RIS document for their estimate.

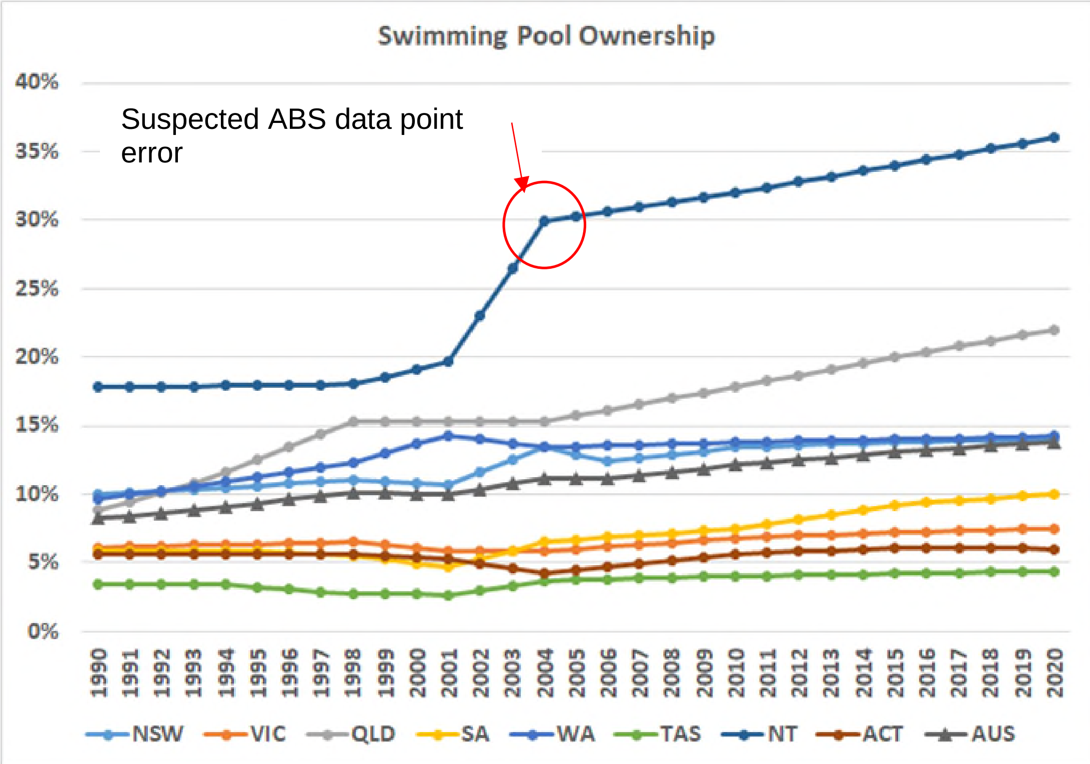
**Table 40: Swimming Pool Ownership by Year and Jurisdiction (DEWHA 2008)**

| Year | NSW | VIC | QLD | SA | WA | TAS | NT | ACT | AUS |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 10.0% | 6.1% | 8.8% | 5.9% | 9.7% | 3.4% | 17.8% | 5.6% | 8.2% |
| 1991 | 10.1% | 6.2% | 9.4% | 5.9% | 10.0% | 3.4% | 17.8% | 5.6% | 8.4% |
| 1992 | 10.3% | 6.2% | 10.1% | 5.9% | 10.3% | 3.4% | 17.9% | 5.6% | 8.6% |
| 1993 | 10.4% | 6.3% | 10.8% | 5.9% | 10.6% | 3.4% | 17.9% | 5.6% | 8.9% |
| **1994** | **10.5%** | **6.3%** | **11.6%** | **5.9%** | **10.9%** | **3.4%** | **17.9%** | **5.6%** | **9.1%** |
| 1995 | 10.6% | 6.4% | 12.5% | 5.8% | 11.3% | 3.2% | 17.9% | 5.6% | 9.3% |
| 1996 | 10.8% | 6.4% | 13.5% | 5.7% | 11.6% | 3.1% | 18.0% | 5.6% | 9.6% |
| 1997 | 10.9% | 6.5% | 14.4% | 5.6% | 12.0% | 2.9% | 18.0% | 5.6% | 9.9% |
| **1998** | **11.0%** | **6.5%** | **15.3%** | **5.5%** | **12.3%** | **2.7%** | **18.0%** | **5.6%** | **10.1%** |
| 1999 | 10.9% | 6.3% | 15.3% | 5.2% | 13.0% | 2.7% | 18.5% | 5.5% | 10.1% |
| 2000 | 10.8% | 6.1% | 15.3% | 5.0% | 13.6% | 2.7% | 19.1% | 5.4% | 10.0% |
| **2001** | **10.6%** | **5.8%** | **15.3%** | **4.7%** | **14.3%** | **2.7%** | **19.6%** | **5.3%** | **10.0%** |
| 2002 | 11.6% | 5.8% | 15.3% | 5.3% | 14.0% | 3.0% | 23.0% | 4.9% | 10.4% |
| 2003 | 12.5% | 5.8% | 15.3% | 5.9% | 13.7% | 3.4% | 26.5% | 4.6% | 10.7% |
| **2004** | **13.4%** | **5.8%** | **15.3%** | **6.5%** | **13.4%** | **3.7%** | **29.9%** | **4.2%** | **11.1%** |
| 2005 | 12.9% | 6.0% | 15.7% | 6.7% | 13.5% | 3.8% | 30.3% | 4.4% | 11.1% |
| 2006 | 12.4% | 6.1% | 16.1% | 6.8% | 13.5% | 3.8% | 30.6% | 4.7% | 11.1% |
| 2007 | 12.6% | 6.3% | 16.6% | 7.0% | 13.6% | 3.9% | 31.0% | 4.9% | 11.4% |
| 2008 | 12.9% | 6.5% | 17.0% | 7.2% | 13.7% | 3.9% | 31.3% | 5.1% | 11.6% |
| 2009 | 13.1% | 6.6% | 17.4% | 7.3% | 13.7% | 4.0% | 31.7% | 5.4% | 11.9% |
| 2010 | 13.4% | 6.8% | 17.8% | 7.5% | 13.8% | 4.0% | 32.0% | 5.6% | 12.1% |
| 2011 | 13.5% | 6.9% | 18.2% | 7.8% | 13.8% | 4.0% | 32.4% | 5.7% | 12.3% |
| 2012 | 13.6% | 7.0% | 18.7% | 8.2% | 13.9% | 4.1% | 32.8% | 5.8% | 12.5% |
| 2013 | 13.6% | 7.0% | 19.1% | 8.5% | 13.9% | 4.1% | 33.2% | 5.9% | 12.7% |
| 2014 | 13.7% | 7.1% | 19.6% | 8.9% | 14.0% | 4.2% | 33.6% | 6.0% | 12.9% |
| 2015 | 13.8% | 7.2% | 20.0% | 9.2% | 14.0% | 4.2% | 34.0% | 6.1% | 13.1% |
| 2016 | 13.8% | 7.3% | 20.4% | 9.4% | 14.0% | 4.2% | 34.4% | 6.1% | 13.2% |
| 2017 | 13.9% | 7.3% | 20.8% | 9.5% | 14.1% | 4.3% | 34.8% | 6.1% | 13.4% |
| 2018 | 13.9% | 7.4% | 21.2% | 9.7% | 14.1% | 4.3% | 35.2% | 6.0% | 13.5% |
| 2019 | 14.0% | 7.4% | 21.6% | 9.8% | 14.2% | 4.4% | 35.6% | 6.0% | 13.7% |
| 2020 | 14.0% | 7.5% | 22.0% | 10.0% | 14.2% | 4.4% | 36.0% | 6.0% | 13.8% |

Note 1: Bolded Values represent ABS 4602 survey data points, intervening years are interpolated and extrapolations were used post 2004

Note 2: The 2004 ABS data point for NT looks to be an error. If this is the case then current ownership levels would be expected to be closer to 25% rather than 36%

**Figure 14: Swimming Pool Ownership by Year and Jurisdiction (DEWHA 2008)**




## 8.9 *Assumed Response to Regulation*

As part of the modelling process for the RIS, it is necessary to make a range of assumptions relating to what the most likely response will be from the industry to the new regulations. In the case of a whole-of-home energy requirement, responses could be many and varied. Some may choose to maintain their current equipment selections and simply apply as much renewable energy (PVs) as required, noting of course that there would be practical limits to how much PV can be provided. Others may see value in shifting from their current equipment selections to ones that necessitate a lesser PV capacity, this would be particularly true in circumstances where only limited or no PV can practically be installed (e.g. on heavily shaded blocks).

A performance based regulation as is proposed provides great flexibility to building designers but at the same time produces significant complexity and uncertainty with respect to impacts analysis[21]. Industry responses are expected to take one of three main forms each with potentially different outcomes. These are:

- Least change to existing practices approach
- Least cost approach
- Most cost effective from the owners perspective approach

[21] A prescriptive approach such as a simple requirement that all dwellings must have installed a minimum of 3kW of PV for instance would have a far more certain outcome from a modelling perspective.

The following sub-sections detail the main response types assumed in particular settings considered within the RIS analysis.

### 8.9.1 Dwellings without PV included in the BAU case

For those dwellings with good solar access but would not have otherwise installed PVs at the time of construction, the lowest capital cost pathway was selected. This could either be:

1. Retaining the BAU equipment selection and applying as much PV as is required to meet the particular regulatory stringency level (option 1, 1.5 or 2)
2. Altering the equipment selection only (i.e. no added PV – this option is possible in the case of stringency option 2 and in selected cases under option 1.5 but not possible in relation to option 1 where some PV will always be required).
3. Altering the equipment selection plus adding as much PV as is required to meet the particular regulatory stringency level (option 1, 1.5 or 2).

Where equipment changes were assumed, there would be an almost limitless number of options and permutations that could be selected. For the purposes of this study, it was assumed that:

- If replacing a central conditioning system of any type, then a minimum 2.25 star rated (2019 Zoned rating) reverse cycle ducted air-conditioner would be installed in combination with an average efficiency heat pump type water heater. This equipment combination is now quite common as a central system and in the context of a societal cost metric provides a better outcome than most other available technologies. Also being an all-electric combination, this option would be available in all settings throughout Australia[22].
- If replacing room-type conditioning system/s, then a minimum 2.25 star rated (2019 Zoned rating) reverse cycle air-conditioner/s would be installed in combination with an average efficiency heat pump type water heater. This equipment combination is now quite common and in the context of a societal cost metric provides a better outcome than most other available technologies. Also, being an all-electric combination this option would be available in all settings throughout Australia.[23]

If the lowest capital cost option required more than 7.5 kW of PV for a Class 1 dwelling or more than 4kW of PV for a Class 2 dwelling then it was assumed that the next lowest cost option that required less than the noted PV capacity limits would be selected. Whilst larger PV systems are feasible (particularly on above average sized dwellings) for many, these values are likely to be at the upper limit of practicality.

### 8.9.2 Dwellings with PV in the BAU case

For dwellings that under the BAU case would have had PVs fitted in any case, a slightly different response is envisaged. In this case, if the dwelling with its BAU equipment selection in combination with the BAU level of PV already meets or exceeds the NCC 2022 performance requirement, then that BAU equipment combination is assumed to be adopted (noting that even if the PV provision under the

[22] In very hot climates such as Darwin a cooling only central air-conditioner might be selected instead. Likewise in a very cold alpine region a heating only system may be selected instead.
[23] In very hot climates such as Darwin a cooling only room air-conditioner might be selected instead. Likewise in a very cold alpine region a heating only system may be selected instead.

BAU case exceeds the requirement under NCC 2022 the PV capacity would not be assumed to be reduced down from the capacity installed in the BAU case).

If the BAU equipment selection in combination with the BAU level of PV does not meet the NCC 2022 performance requirement then it is assumed that the PV provision would be increased as required to meet the regulation. If the PV requirement were to exceed 10kW (generally only occurs under option 1 in the most extreme cold climates with certain heater types. Never exceeds 7.5kW under option 1.5) then the least cost approach noted in Section 8.9.1 is assumed to be applied. This would involve changes to equipment selections.

### *8.9.3 Dwellings where PVs are not practical to install*

In circumstances where the provision of PV is not possible or practical (e.g. on heavily shaded blocks), then the following response is assumed:

1. If, to meet the particular stringency level without resorting to the use of any PVs, no change to the BAU equipment selection is required, then this is the assumed case (mostly applies to stringency option 2) unless the equipment selections noted in option 2 below are less expensive than the BAU equipment selections and the result is one that requires no PV's, in this case option 2 would be selected.
2. If the BAU equipment selection will require PVs to achieve compliance, then the equipment type is assumed to be upgraded as follows:
    a. If replacing a central conditioning system of any type, then a minimum 2.25 star rated (2019 Zoned rating) reverse cycle ducted air-conditioner would be installed in combination with an average efficiency heat pump type water heater. This equipment combination is now quite common and in the context of a societal cost metric provides a better outcome than most other available technologies. Being an all-electric combination this option would be available in all settings throughout Australia.
    b. If replacing room type conditioning system/s, then a minimum 2.25 star rated (2019 Zoned rating) reverse cycle air-conditioner would be installed in combination with an average efficiency heat pump type water heater. This equipment combination is now quite common and in the context of a societal cost metric provides a better outcome than most other available technologies. Being an all-electric combination this option would be available in all settings throughout Australia.
3. If after upgrading the equipment as per option 2 above, some PV capacity is still required to achieve compliance, then the equipment selection is further upgraded to a minimum 3.75 star rated (2019 Zoned rating) reverse cycle non ducted air-conditioner (approximately 6 stars under the old GEMS 2013 determination) in combination with an average efficiency heat pump type water heater. This option is in some respects less than ideal but was the only one of the options modelled for this study that was likely to achieve compliance with stringency levels 1.5 or 2 in all cases where PVs were not a practical option. This option is potentially less than ideal because the availability of high-performance heat pump equipment (particularly in the GEMS cold zone) is at present fairly limited and where available, typically they are only available in very small capacities, requiring multiple installations, particularly for dwellings that are intended to have whole-of-home conditioning. Other solutions such as opting for an 8 or 9 star rated building

shell could well prove more cost effective and practical for fully shaded blocks but these options were not modelled as part of this study.

In cases where this option has been selected as a means for compliance the assumed increased system costs over and above the costs associated with the installation of a split system heat pump to service living areas only have been roughly approximated follows:

For Class 1 dwellings the cost has been doubled where room type heating/cooling is used and tripled where central heating/cooling is used. These approximate cost increases account for the fact that high efficiency heat pumps generally only come in small capacities (2 – 4 kW) and therefore multiple units (with increased installation costs) rather than a single unit would be required for space conditioning. For central conditioning cases, further additional units would be required to cover the increased floor area required to be serviced compared to the living areas only case.

For Class 2, due to the lesser average floor area compared to Class 1 the need for additional units to be installed would be expected to be less pronounced and as such the cost multiplier was set at 1.5 in all cases

As noted, alternative approaches to those suggested above would also be possible. This might include options such as opting for a higher than minimum efficiency building shell performance (8,9 or 10 stars) or use of a super-efficient heat pump water heater (e.g. using $CO_2$ type refrigerants) or use of in-line gas boosted solar water heaters (where gas is available). Further research in this area is warranted.

Note: Whilst the approaches noted above offer workable solutions for stringency options 1.5 and 2, in the case of stringency level 1, at least some PVs will always be required to be installed.

### *8.9.4 Dwellings with Pools*

For dwellings with swimming pools more limited modelling only was possible. For the BAU case the heating and cooling equipment was fixed as being a 2.25 star rated (2019 Zoned rating) reverse cycle air-conditioner. A ducted-type system was modelled, but the results could also be applied to a non-ducted system (such a system would be more efficient than a ducted system due to the lack of duct losses, consequently the assumed savings based on a ducted system would be conservative in relation to a non-ducted system). The water heater was assumed to be a heat pump type water heater of average efficiency and the pool pump was assumed to be of average efficiency, 4 stars (as tested to AS 5102.1-2009).

For those dwellings with good solar access, the lowest capital cost pathway was selected as the most likely response. This could either be:

1. Retaining the BAU equipment selection and applying as much PV as is required to meet the particular regulatory stringency level (option 1, 1.5 or 2)
2. Replacing the pool pump with a moderately high efficiency (6.5 star) pool pump and applying as much PV as is required to meet the particular regulatory stringency level (option 1, 1.5 or 2)
3. Replacing the pool pump with a very high efficiency (9 star) pool pump and applying as much PV as is required to meet the particular regulatory stringency level (option 1, 1.5 or 2).

If the lowest capital cost option above required more than 7.5 kW of PV, then it was assumed that the next lowest cost option that required less than the noted PV capacity limits would be selected.

For blocks where use of PVs is not practical the same logic as above was used to determine the lowest cost option that required no PV (noting however that this is never possible in the case of stringency option 1).

In cases where even using the 9 star rated pool pump option still required the use of PV then a high efficiency heat pump non ducted air-conditioner (3.75 star rated - 2019 Zoned rating) was also used[24]. This combination of high efficiency heating/cooling and pool pump removed the need for PVs in all cases in relation to option 2 and most but not all cases in relation to option 1.5. Other strategies such as use of higher efficiency building shells (not modelled in this study however) would make it possible to remove the need for any PV to be installed in the case of stringency level option 1.5.

[24] Note: Specific whole-of-home modelling of this option was not carried out as part of this study. Instead, a proxy for this was used. The costs and savings associated with a change from a 2.25 star rated heat pump to a 3.75 star rated heat pump (zoned rating) in a dwelling without a pool were applied to the dwelling with pool case where a 9 star rated pool pump was used. This approach therefore represents an approximation of the case of a dwelling with a pool, a 3.75 star rated heat pump and a 9 star rated pool pump.

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# 10 Appendices

## 10.1 Appendix 1 – End Use Estimates Basis

## Space Conditioning

### Basis for Energy Consumption Estimates

All space conditioning estimates were based on an assumed heating or cooling load determined through the use of thermal simulation modelling (see Section 2.2).

For a given heating or cooling load the following equation was used to estimate annual energy consumption by the selected end use equipment:

$$E = (((L / (1-Lo)) / E) *Z) + A$$

Where:
L = The heating or cooling load as applicable
Lo = Any system losses (e.g. from ductwork)
E = The efficiency of the space conditioning equipment
Z = The zoning constraint factor
A = Ancillary electrical energy consumption in the case of gas heaters (e.g. for electric fans)

### Key Assumptions and Adjustment Factors

- Heating and cooling loads - based on AccuRate thermal simulations
- System losses – Assumed to be 15% for ducted systems and 20% for floor slab heating (can be varied from the dashboard)
- Efficiency – see Table 41
- Ancillaries (electric fans for air distribution)
    - For ducted gas, assumed to be 2.5% of total energy consumption
    - For room gas, assumed to be 1% of total energy consumption

**Table 41 : Basis for Efficiency Estimates – Space Conditioning Equipment***

| Type | Efficiency estimate basis |
|---|---|
| Central Gas | Based on star rating = 50% plus 10% for each star > 1 star |
| Central HP | Based on star rating = 275% + 50% for each star > 1 star |
| Room Gas | Based on star rating = 61% plus 6% for each star > 1 star |
| Room HP | Based on star rating = 275% + 50% for each star > 1 star |
| Central Elec Panels | Assumed to be 100% efficient |
| Wood Central | Assumed to be 70% efficient |
| Wood Room | Assumed to be 70% efficient |
| Slab | Assumed to be 100% efficient |

* Does not include system losses

| Type | Efficiency estimate basis |
| --- | --- |
| No cooling | Not applicable |
| Central HP (Cool) | Based on star rating = 275% + 50% for each star > 1 star |
| Central evaporative | Based on empirical estimates – 1500% (EES 2008) |
| Room HP (Cool) | Based on star rating = 275% + 50% for each star > 1 star |

* Does not include system losses

Product life will vary to some degree according to the technology applied. For the purposes of this model an average lifetime of 12 years has been assumed (noting that this may be a little conservative in the case of certain technologies).

### Usage Profile

Usage profiles have been determined from the AccuRate hourly output files of heating and cooling load. Operation of space conditioning equipment is limited to certain hours according to the particular occupancy profile assumed (see Table 15).

# Water Heaters

### Basis for Energy Consumption Estimates

Energy consumption estimates for water heaters have been based on the methodology used in the SV Cost calculator model prepared by Energy Efficient Strategies for Sustainability Victoria in 2015.

The methodology and underlying assumptions are quiet complex and as such the detailed methodology prepared for the cost calculator has been reproduced in this report as an Appendix – see Appendix 3 – Water Heaters – Basis for Energy Estimates.

### Lifespan

There is little data available on the expected lifespan of water heaters and in any case this will vary depending on the quality of materials used and the type of water supply. The SV Cost calculator study assumed an average life of 15 years for water heaters. This may be reasonable for a stainless steel tank but probably too long for a more standard electric or gas water heater. For this model the average life for a water heater has been assumed to be a more conservative 12 years.

### Usage Profile

For off peak electric type water heaters usage has been based on availability of power supply on the dedicated circuit (generally overnight).

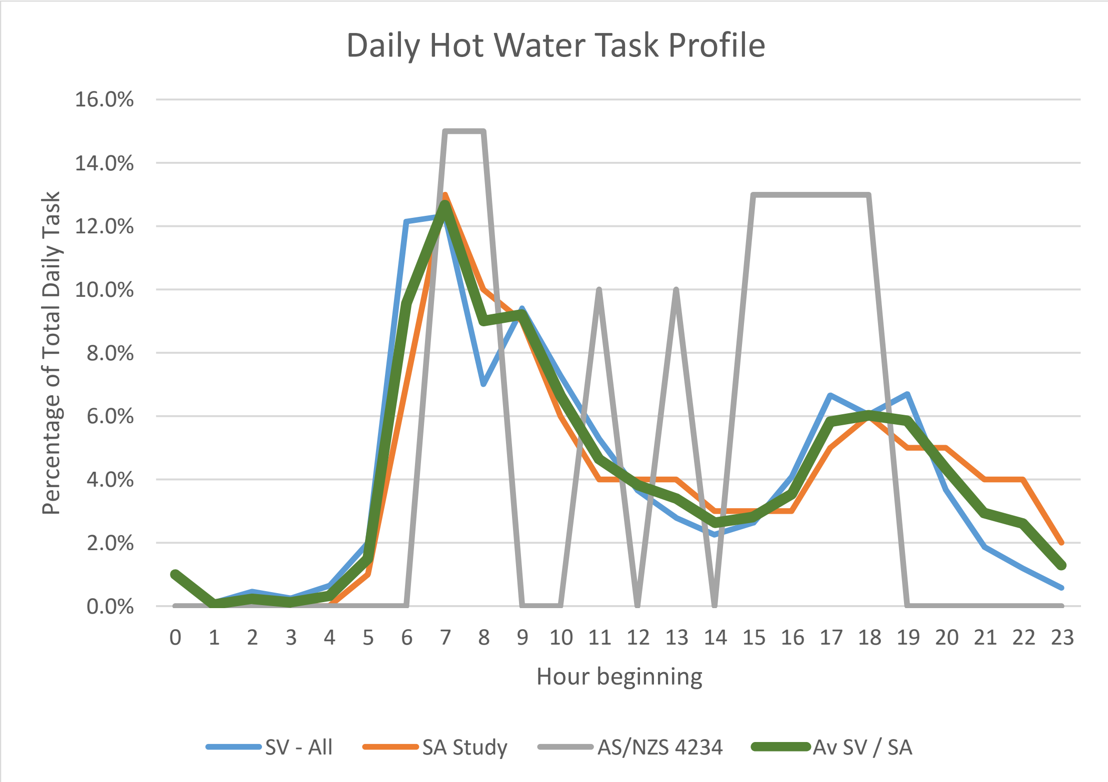
For all other systems, a number of data sources were considered. Firstly there are assumptions regarding the draw-off profile included in AS 4234:2008 Zones 1 -4 which included usage by time of day and by month of year (greater in colder months). Proportions of usage by time of year assumed in the standard are shown in Table 42.

**Table 42: Proportion of Hot Water Energy Use by Time of Year (AS 4234:2008 Zones 1 - 4)**

| Month | % |
|---|---|
| January | 6.6% |
| February | 6.8% |
| March | 8.0% |
| April | 8.2% |
| May | 8.9% |
| June | 9.1% |
| July | 9.4% |
| August | 9.4% |
| September | 9.1% |
| October | 8.9% |
| November | 8.2% |
| December | 7.5% |

Sustainability Victoria also provided metering data from both a Victorian study and a South Australian study. The results from those two studies for the daily hot water task profiles, plus the daily hot water task profile assumed in AS 4234:2008 Zones 1 -4 are shown in Figure 15. In addition, also included in this figure is an average of both the Victorian and South Australian profiles (which are very similar in any case).

**Figure 15: Daily hot Water Task Profiles (Various sources)**




For this study, the daily hot water task profile adopted was the average of both the Victorian and South Australian profiles (Green line in above chart). These values were applied month by month in accordance with the proportions shown in Table 42.

# Ovens

### Basis for Energy Consumption Estimates

.

For standard electric type ovens the assumed annual energy consumption was based on the Study: Energy Use in the Australian Residential Sector 1986-2020 section 6.6.4. In that study electric ovens were estimated to use 853 MJ/annum.

### Key Assumptions and Adjustment Factors

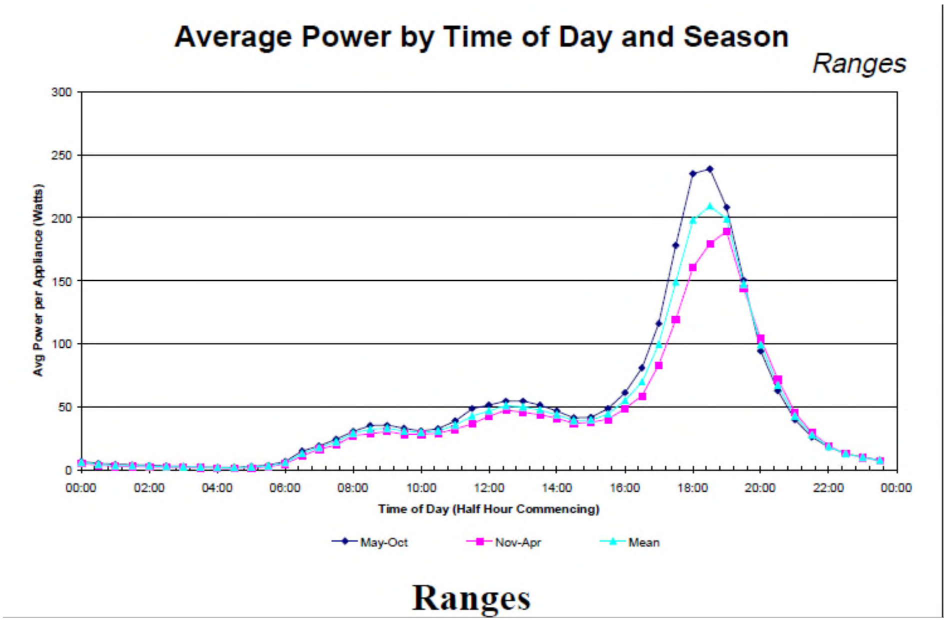
The only adjustments applied related to the size of the household. The reported average value (EES 2008) was assumed to relate to an average sized household (approximately 3 person). In line with the analysis in the EES study 50% of the energy use was assumed to be fixed and 50% was assumed to be dependent on the number of householders. Energy consumption for households of more or less than three persons were scaled on this basis.

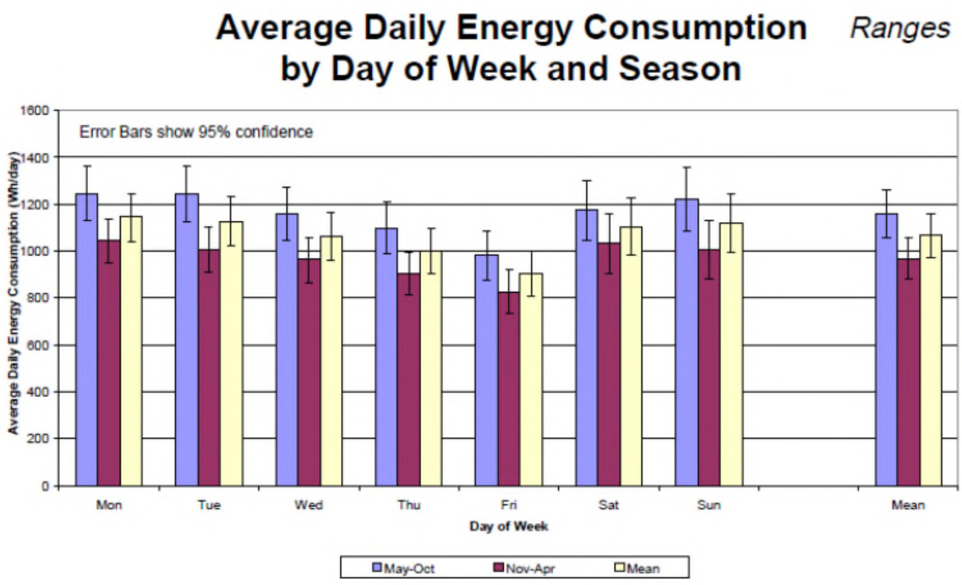
### Product Life

No data was readily available on this aspect. Consequently an informed estimate based on professional judgement of 15 years was used.

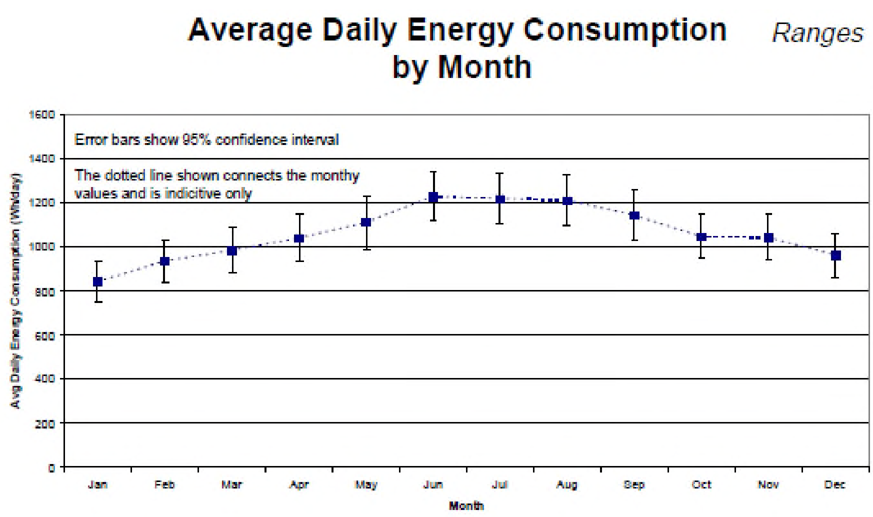
### Usage Profile

No oven specific data was readily available on the time of use profile for ovens, so the adopted usage profile in the model was based on Pacific Power survey data for "ranges", weighted according to the time of day profile, day of week profile and month of year profiles (see extracts from Pacific Power study below).






**Ranges**



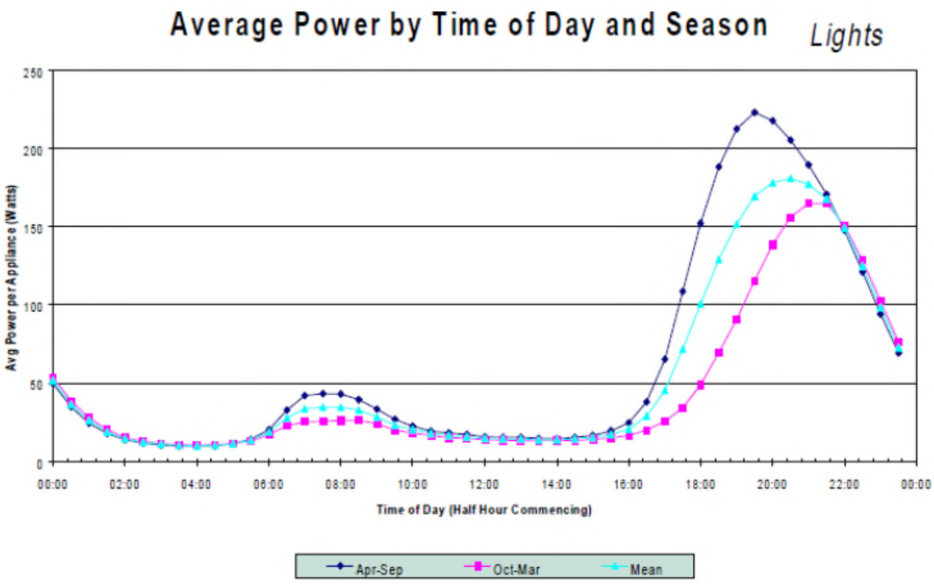

**Ranges**

## Lighting

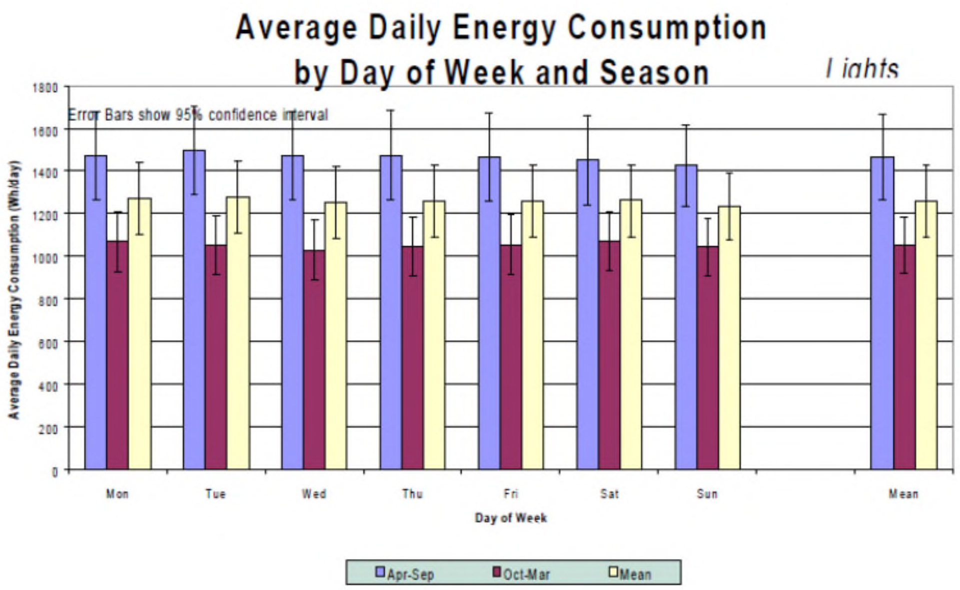
**Basis for Energy Consumption Estimates**
Estimates of energy consumption were based on the assumed power density of the installed system (W/m$^2$). This was simply multiplied by an assumed average daily duration of use which was set at 1.6 hours per day in accordance with the Proposed NatHERS Whole-of-Home Ratings and Assessment Framework. The 1.6 hours of use per day is an average figure across all lights in a dwelling and takes into account the fact that some spaces in a dwelling will be unlit for much of the time.

**Usage Profile**

The adopted usage profile in the model was based on Pacific Power survey data for "lights", weighted according to the time of day profile, day of week profile and month of year profiles (see extracts from Pacific Power study below). Note that the total energy consumed by lighting will be influenced by efficiency improvements and changes in floor area, but the overall shape is expected to remain reasonably consistent.




**Lights**



Average Daily Energy Consumption
by Day of Week and Season
Lights
Error Bars show 95% confidence interval
Average Daily Energy Consumption (Wh/day)
1800
1600
1400
1200
1000
800
600
400
200
0
Mon
Tue
Wed
Thu
Fri
Sat
Sun
Mean
Day of Week
Apr-Sep
Oct-Mar
Mean


**Lights**

# Refrigerators and Freezers

## Basis for Energy Consumption Estimates

Estimates for energy consumption are based on the star rating algorithm with adjustments as noted in the following sub-section. The star rating algorithm facilitates the calculation of the comparative annual energy consumption (CEC) by reverse engineering the following SRI equation:

$$SRI = 1 + \left[ \frac{\log_e\left(\frac{CEC}{BEC}\right)}{\log_e(1-ERF)} \right]$$

Where:

SRI is the star rating index (fractional star rating)
CEC is the comparative energy consumption (energy that appears on the energy label)
BEC is the base energy consumption – the equation that gives the CEC for a product with an SRI of 1.0, BEC = $C_f + (C_v \times (V_{adj\ tot})^{0.67})$
ERF is the energy reduction factor – reduction in CEC for each additional star
$V_{adj\ tot}$ = The total adjusted volume of all compartments in the refrigerator

**Table 43: Refrigerator and Freezer Star Rating Factors for the 2010 Labelling Algorithm**

| Appliance group | Group description | Fixed allowance factor ($C_f$) kWh/year | Variable allowance factor ($C_v$) kWh/year/L | Energy Reduction Factor (ERF) |
|---|---|---|---|---|
| 1 | All refrigerator | 200 | 4.0 | 0.23 |
| 2 | Refrigerator with ice maker | 200 | 4.0 | 0.23 |
| 3 | Refrigerator with short term freezer | 200 | 4.0 | 0.23 |
| 4 | Refrigerator with long term freezer | 150 | 8.8 | 0.23 |
| 5T | Top mounted frost free refrigerator-freezer | 150 | 8.8 | 0.23 |
| 5B | Bottom mounted frost free refrigerator-freezer | 150 | 8.8 | 0.23 |
| 5S | Side×side frost free refrigerator-freezer | 150 | 8.8 | 0.23 |
| 6C | Chest freezer | 150 | 7.5 | 0.23 |
| 6U | Manual defrost vertical freezer | 150 | 7.5 | 0.23 |
| 7 | Frost free vertical freezer | 150 | 7.5 | 0.23 |

## Key Assumptions and Adjustment Factors

Based on analysis of product registration data the expected share of freezer volume was assumed to be as per Table 44. Factors to account for climate and usage variations from the assumptions embodied within the test standard (AS/NZS 4474.2:2007) can also be found in Table 44.

**Table 44: Key Assumptions and Adjustment Factors by Group**

| Group | Climate and use factor | Share of freezer volume | Freezer adjustment factor |
|---|---|---|---|
| 1 | 0.75 | 0% | 1.0 |
| 2 | 0.80 | 3.0% | 1.2 |
| 5T | 0.85 | 28.4% | 1.6 |
| 5B | 0.85 | 32.5% | 1.6 |
| 5S | 0.85 | 37.9% | 1.6 |
| 6C | 0.80 | 100% | 1.6 |
| 6U | 0.80 | 100% | 1.6 |
| 7 | 0.80 | 100% | 1.6 |
| Wine | 0.70 | 0% | Overall 0.6 |

Note: Climate and use factors based on analysis for *Energy Use in the Australian Residential Sector 1986 – 2020*. More work on these factors is warranted.

The average lifetime assumed for this product type is 17 years for refrigerators and 21 years for freezers.

**Product Capacity**

Based on analysis of Gfk data (Sustainability Victoria 2016) the following average capacities for this product type were determined – see Table 45.

**Table 45: Average Capacity–Refrigerators/Freezers**

| Product Type | Capacity (Litres) | | | |
|---|---|---|---|---|
| | Group 1 | Group 5T | Group 5B | Group 5S |
| Refrigerators | 315 | 425 | 605 | 750 |

| Product Type | Capacity (Litres) | | | |
|---|---|---|---|---|
| | No Frez. | Group 6c | Group 6u | Group 7 |
| Freezers | 0 | 360 | 205 | 395 |

These average capacities were assumed to apply to a 3 person household (approximate average for the state). For households of other sizes, scaling was carried out according to the following equation:

$((O_A / O_{AV})-1) * SF$

Where:
$O_A$ = Actual number of occupants
$O_{AV}$ = Number of occupants in an average sized household rounded to nearest whole number (=3)
SF = Scaling factor (=0.33) i.e. assumes $^2/_3$ of capacity is fixed and $^1/_3$ varies by number of occupants. This is an estimate only. Note that for dwellings with very high

household numbers, rather than a single very high capacity appliance of this type there may be two smaller capacity appliances.

**Usage Profile**

Whilst refrigerator energy consumption will vary over time (particularly during defrost cycles) for the purposes of this study the usage is assumed to be continuous usage at a constant rate (i.e. Hourly consumption = Annual consumption/8760 hours).

# Clothes Washer

### Basis for Energy Consumption Estimates

Estimates for energy consumption are based on the star rating algorithm with adjustments as noted in the following sub-section. The star rating algorithm facilitates the calculation of the comparative annual energy consumption (CEC) by reverse engineering the following SRI equation:

$$SRI = 1 + \left[ \frac{\log_e\left(\frac{CEC + Em}{BEC + Eref}\right)}{\log_e(1 - 0.27)} \right]$$

where:

SRI is the star rating index (fractional star rating)
CEC is the comparative energy consumption (energy that appears on the energy label)
BEC is the base energy consumption – the equation that gives the CEC for a product with an SRI of 1.0, BEC = 115 × rated capacity

$$Em = \frac{F \times WEI \times RC \times 365}{1.08}$$

F = 0.1
WEI = water extraction index for the model (also called the spin index)

$$Eref = \frac{F \times WEI_{ref} \times RC \times 365}{1.08}$$

Where:
$WEI_{ref}$ = 1.03
WEI is usually in the range of 1.1 (maximum allowable) to about 0.55 (best on the market) and is the ratio of moisture remaining in the load compared to the bone dry mass of the test load (which is nominally the rated capacity / 1.08).

**Note:** Whilst the CW tab in the model calculates the total energy consumption associated with the clothes washer, that portion of energy used for heating water in a hot water heater for delivery into the clothes washer is exported to and accounted for, under the water heater section of the model rather than the clothes washer section.

### Key Assumptions and Adjustment Factors

**TOP LOADERS**
The overall approach to the calculation of **top loader washer** (non-drum) energy consumption was as follows:

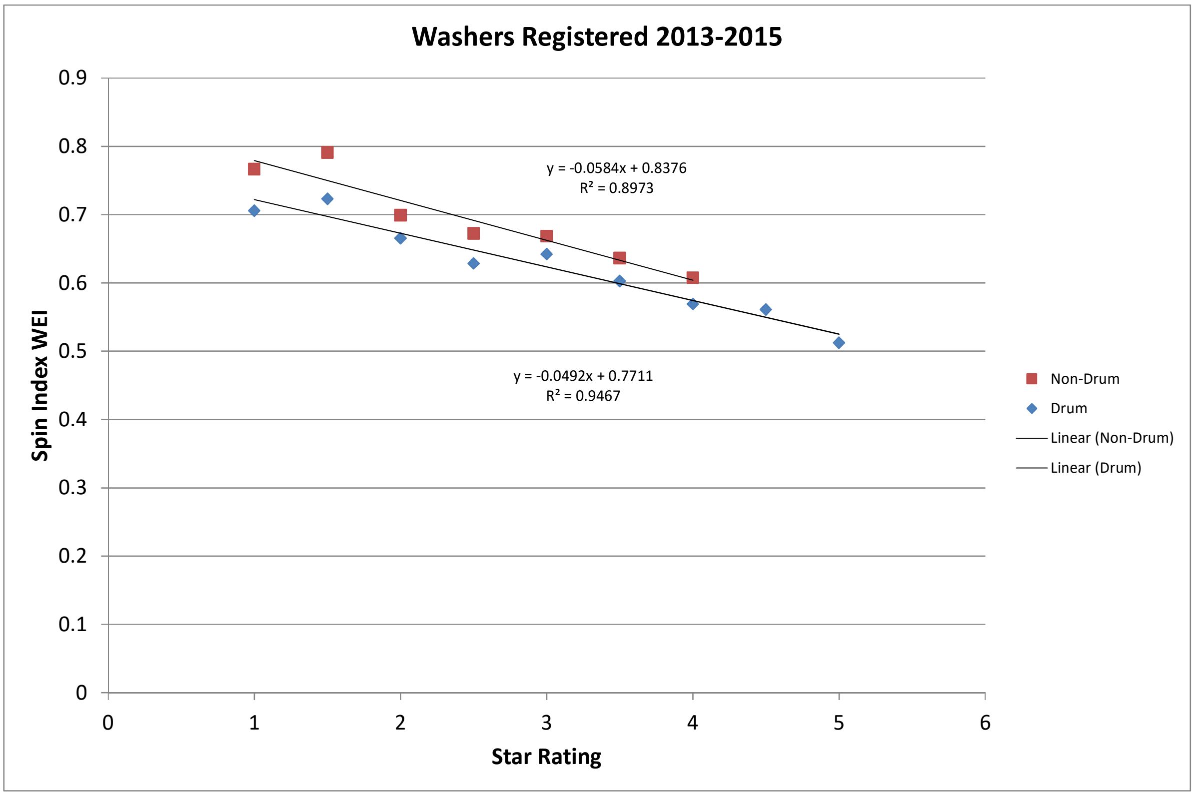
- Calculate CEC for rated capacity and standard conditions assuming reference WEI and WEI for the model based on star rating (see Figure 16)
- Subtract the standby energy based on the number of uses in the standard (365), the assumed cycle time and standby power
- Subtract the estimated mechanical energy based on the typical value per cycle for 365 cycles

- The remaining value is external hot water energy for 365 warm washes
- Calculate the hot water energy by scaling the hot water value by the number of uses per year divided by 365 (assumed usage in the standard) times the share of warm washes
- Calculate the electrical energy per year as the number of uses per year times the mechanical energy per cycle plus the standby power energy for the year (based on the number of uses per year, average cycle time and standby power)
- The assumed cycle time is 1.0 hours

Standby energy = (8760 – Uses × Program time) × Standby Power

Note that for top loaders the electrical energy scales with usage but remains constant by size and star rating. Hot water energy scales with usage and share of warm wash.

**Figure 16: Regression of star rating and WEI used to estimate a representative WEI for each sample calculation**




Notes: Analysis of energy labelling registrations for washers from 2013 to 2015 inclusive.

**FRONT LOADERS**

The overall approach for the calculation of **front loader washer** (drum) energy consumption was as follows:

- Calculate CEC for rated capacity and standard conditions assuming reference WEI and WEI for the model based on star rating (see Figure 16)
- Subtract the standby energy based on the number of uses in the standard (365), the assumed cycle time and standby power
- The remaining value is electrical plug load for 365 warm washes, which allows plug energy per warm wash to be calculated
- Calculate the cold wash energy from the table of cold water energy values by star rating (for 365 cold washes)
- Subtract the standby energy based on the number of uses in the standard (365), the assumed cycle time and standby power
- The remaining value is electrical plug load for 365 cold washes, which allows plug energy per cold wash to be calculated
- Calculate the electrical energy per year as the number of uses per year times the warm wash energy times the share of warm washes plus the number of uses per year times the cold wash energy times the share of cold washes plus the standby power energy for the year (based on the number of uses per year, average cycle time and standby power)

Standby energy = (8760 – Uses × Program time) × Standby Power

1 star cold CEC for front loaders is assumed to be 40 + 20 × Rated Capacity in kWh/year. Cold wash is assumed to reduce by 10% per star (ERF = 0.9).

Key Assumptions applied:

- Uses per year = 300
- Standby power = 0.5W
- Share of warm washes = 45%
- Water heater type – as selected
- Front loader cold wash type = semi cold (default) (applicable to front loading only.
- The assumed cycle time is 1.5 hours. The same cycle time is assumed for warm and cold wash.

Energy Use is further scaled according to the number of occupants. For 3 occupants there is no scaling, otherwise the scaling is carried out according to the following equation:

$((O_A / O_{AV})-1) * SF$

Where:
$O_A$ = Actual number of occupants
$O_{AV}$ = Number of occupants in an average sized household rounded to nearest whole number (=3)
SF = Scaling factor (=0.75) i.e. assumes 25% of usage is fixed and 75% varies by number of occupants

The resultant scaling factors are shown in the table below:

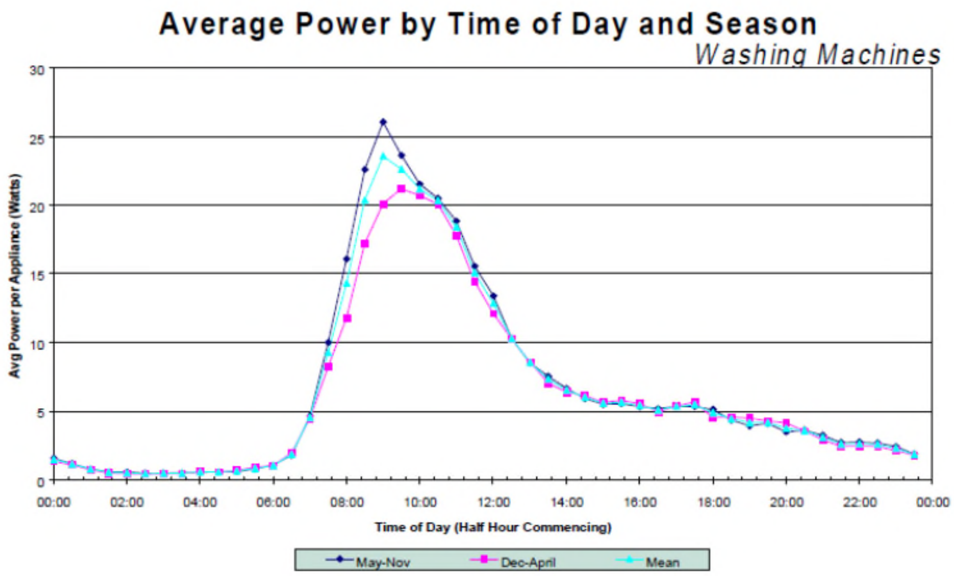
| Household size | Scaling Factor |
|---|---|
| 1 | 0.5 |
| 2 | 0.75 |
| 3 | 1 |
| 4 | 1.25 |
| 5 | 1.5 |
| 6 | 1.75 |
| 7 | 2 |
| 8 | 2.25 |
| 9 | 2.5 |
| 10 | 2.75 |

The average lifetime assumed for this product type was 12 years.

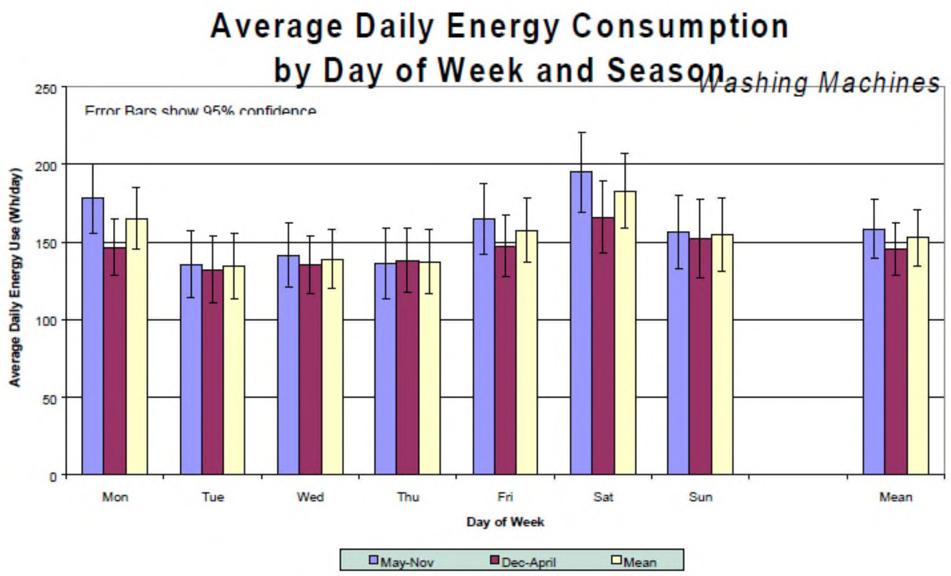
**Product Capacity**
Based on analysis of Gfk data (Sustainability Victoria 2016) the average capacity was determined to be 7kg. This value was not varied for differing household sizes. Instead the calculated energy consumption was simply adjusted (as noted in the previous section) to reflect the expected more or less frequent usage of this appliance type as applicable.

**Usage Profile**

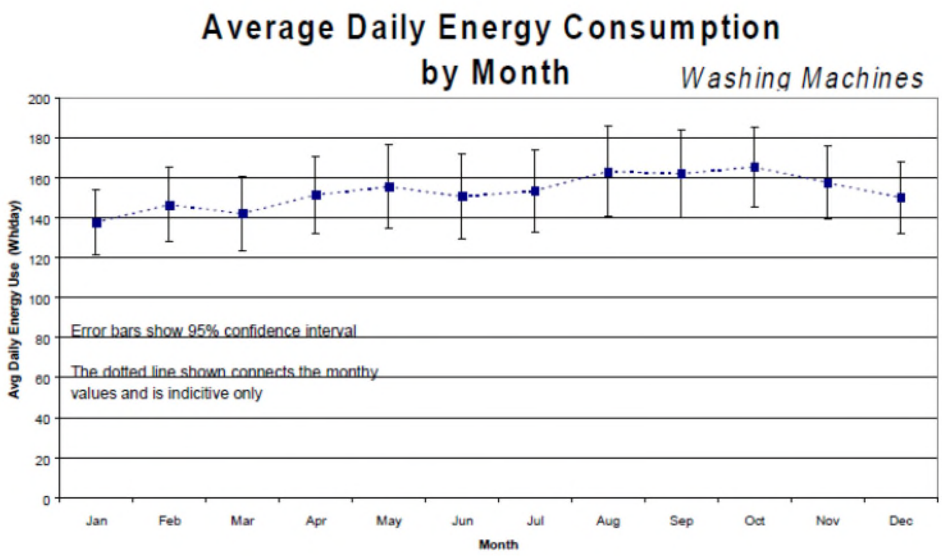
The adopted usage profile in the model was based on Pacific Power survey data for “washing machine”, weighted according to the time of day profile, day of week profile and month of year profiles (see extracts from Pacific Power study below). For the workday schedule the proportion of washing conducted on weekends was doubled, this meant that for the workday schedule the weekend accounted for about half of the total weekly wash. Time of use tariffs were not available at that time of the Pacific Power surveys, so where a TOU tariff is used, there is incentive to operate discretionary appliances like washers overnight and on weekends.




**Washing Machine**




**Washing Machine**




**Washing Machine**

# Dishwashers

Estimates for energy consumption are based on the star rating algorithm with adjustments as noted in the following sub-section. The star rating algorithm facilitates the calculation of the comparative annual energy consumption (CEC) by reverse engineering the following SRI equation:

$$SRI = 1 + \left[ \frac{\log_e \left( \frac{CEC}{BEC} \right)}{\log_e (1 - ERF)} \right]$$

Where:

SRI is the star rating index (fractional star rating)
CEC is the comparative energy consumption (energy that appears on the energy label)
BEC is the base energy consumption – the equation that gives the CEC for a product with an SRI of 1.0, BEC = 48 × place settings
ERF is the energy reduction factor – reduction in CEC for each additional star (0.3)

**Key Assumptions and Adjustment Factors**

The overall approach for the calculation of dishwasher energy was as follows:

- Calculate CEC for rated capacity and standard conditions
- Subtract the standby energy for the selected standby power value (default program time – see below)
- Scale this value by the number of uses per year divided by 365 (assumed usage in the standard)
- Add standby power energy for the year for the selected usage level

Standby energy = (8760 – Uses × Program time) × Standby Power.

Key Assumptions applied:

- Uses per year = 200
- Standby power = 0.5W
- The assumed cycle time is 1.5 hours

Energy Use is further scaled according to the number of occupants. For 3 occupants there is no scaling, otherwise the scaling is carried out according to the following equation:

$((O_A / O_{AV})-1) * SF$

Where:
$O_A$ = Actual number of occupants
$O_{AV}$ = Number of occupants in an average sized household rounded to nearest whole number (=3)

SF = Scaling factor (=0.75) i.e. assumes 25% of usage is fixed and 75% varies by number of occupants

The resultant scaling factors are shown in the table below:

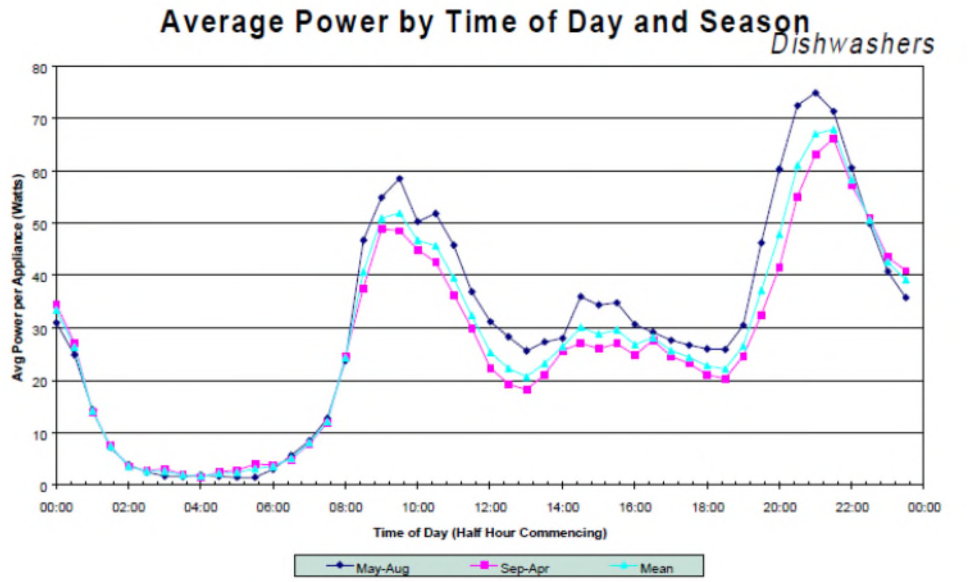
| Household size | Scaling Factor |
|---|---|
| 1 | 0.5 |
| 2 | 0.75 |
| 3 | 1 |
| 4 | 1.25 |
| 5 | 1.5 |
| 6 | 1.75 |
| 7 | 2 |
| 8 | 2.25 |
| 9 | 2.5 |
| 10 | 2.75 |

The average lifetime assumed for this product type is 12 years (refer).

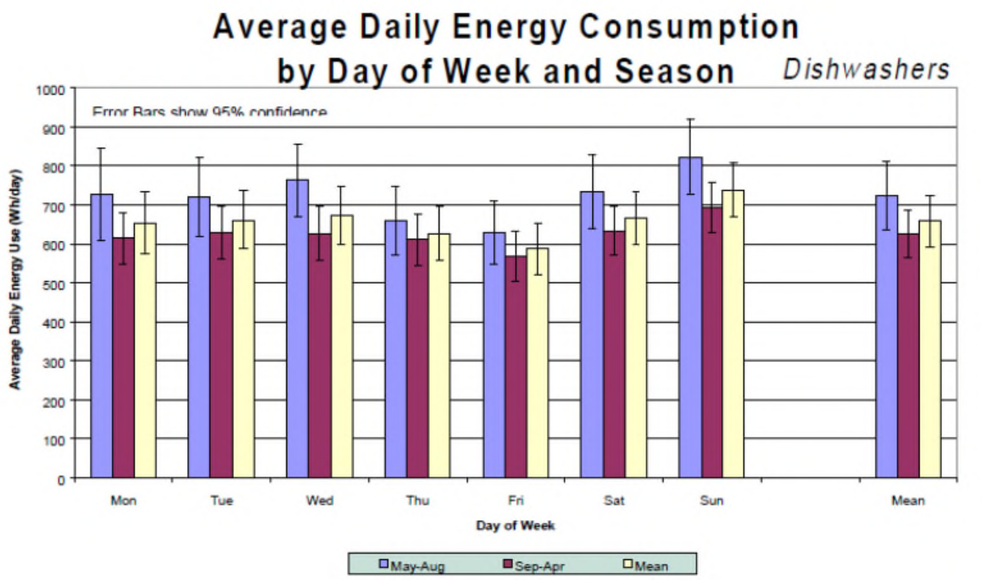
**Product Capacity**
Based on analysis of Gfk data (Sustainability Victoria 2016) the average capacity was determined to be 13 place settings. This value was not varied for differing household sizes. Instead the calculated energy consumption was simply adjusted (as noted in the previous section) to reflect the expected more or less frequent usage of this appliance type as applicable.

**Usage Profile**

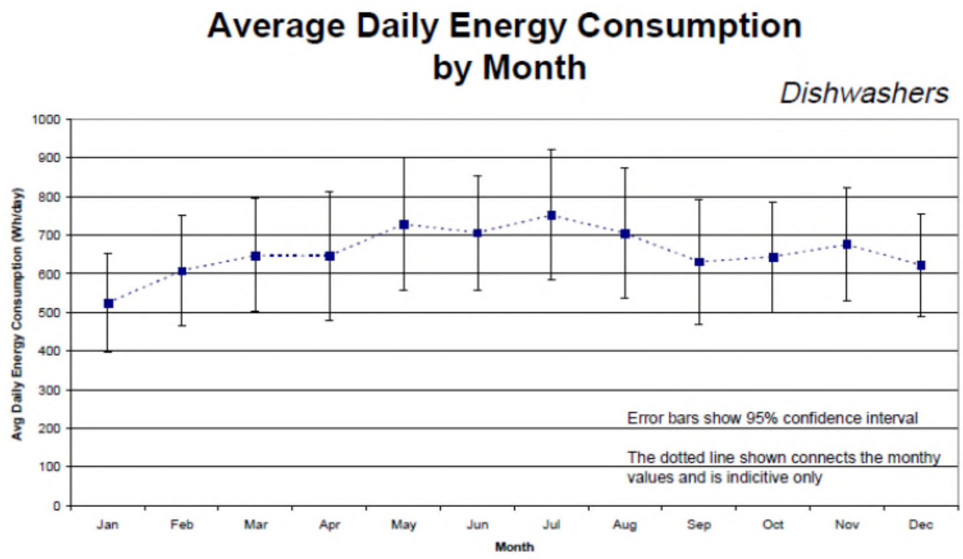
The adopted usage profile in the model was based on Pacific Power survey data for "dishwashers", weighted according to the time of day profile, day of week profile and month of year profiles (see extracts from Pacific Power study below below). Note that dishwashers have made considerable efficiency improvements since these measurements, so this data is used for load shape only and not energy.




**Dishwashers**




**Dishwashers**




**Dishwashers**

# Clothes Dryers

Estimates for energy consumption are based on the star rating algorithm with adjustments as noted in the following sub-section. The star rating algorithm facilitates the calculation of the comparative annual energy consumption (CEC) by reverse engineering the following SRI equation:

$$SRI \quad = \quad 1 + \left[ \frac{\log_e\left(\frac{CEC}{BEC}\right)}{\log_e\left(1 - ERF\right)} \right]$$

Where:

SRI is the star rating index (fractional star rating)
CEC is the comparative energy consumption (energy that appears on the energy label)
BEC is the base energy consumption – the equation that gives the CEC for a product with an SRI of 1.0, BEC = 53 x rated capacity
ERF is the energy reduction factor – reduction in CEC for each additional star (0.15).

### Key Assumptions and Adjustment Factors

The overall approach for the calculation of clothes dryer energy was as follows:

- Calculate CEC for rated capacity and standard conditions
- Scale this value by the number of uses per year divided by 52 (assumed usage in the standard)
- Scale this value by the effect of actual load size and the clothes washers assumed water extraction efficiency (WEI) on the dryer energy
- Add standby power energy for the year (note that for dryers the standby power is not included in the test procedure so effectively this is assumed to be 0 within the CEC energy value).

Standby energy = (8760 – Uses × Program time) × Standby Power

Key Assumptions applied:

- Uses per year = 52
- Cycle time = 1.5 hours
- Actual load = 70% of rated capacity (e.g. Rated 5kg = 3.5kg load)
- Standby power = 0.5W
- Water extraction index = imported from clothes washer calculations.

Energy Use is further scaled according to the number of occupants. For 3 occupants there is no scaling, otherwise the scaling is carried out according to the following equation:

$((O_A / O_{AV})-1) * SF$

Where:
$O_A$ = Actual number of occupants
$O_{AV}$ = Number of occupants in an average sized household rounded to nearest whole number (=3)
SF = Scaling factor (=0.75) i.e. assumes 25% of usage is fixed and 75% varies by number of occupants

The resultant scaling factors are shown in the table below:

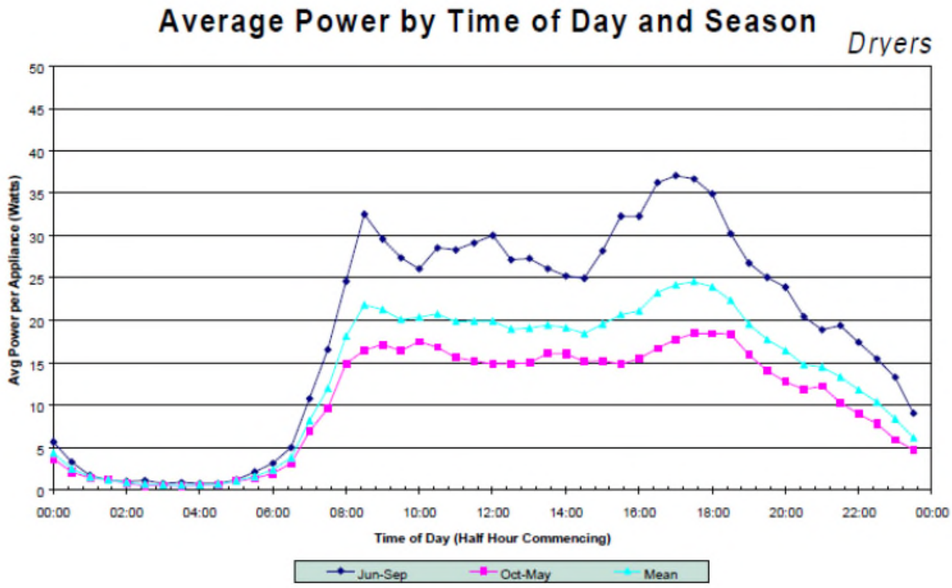
| Household size | Scaling Factor |
|---|---|
| 1 | 0.5 |
| 2 | 0.75 |
| 3 | 1 |
| 4 | 1.25 |
| 5 | 1.5 |
| 6 | 1.75 |
| 7 | 2 |
| 8 | 2.25 |
| 9 | 2.5 |
| 10 | 2.75 |

The average lifetime assumed for this product type is 12 years (Sustainability Victoria 2016).

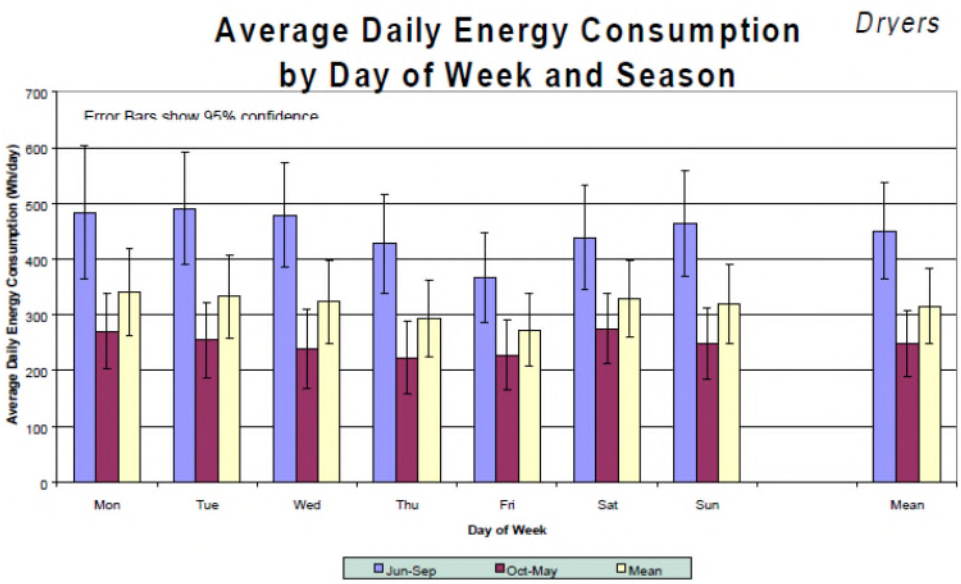
**Product Capacity**
Based on analysis of Gfk data the average capacity was determined to be 5kg. This value was not varied for differing household sizes. Instead the calculated energy consumption was simply adjusted (as noted in the previous section) to reflect the expected more or less frequent usage of this appliance type as applicable.

**Usage Profile**

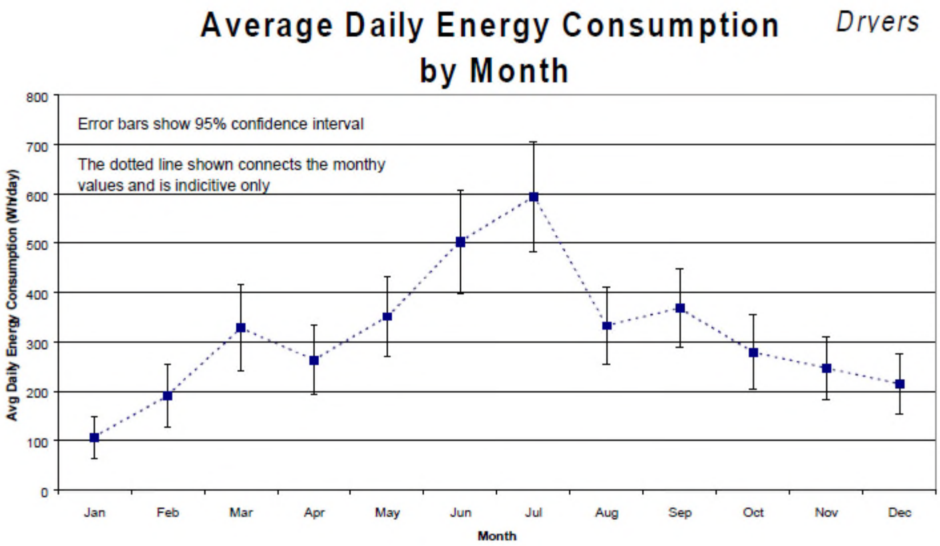
The adopted usage profile in the model was based on Pacific Power survey data for “dishwashers”, weighted according to the time of day profile, day of week profile and month of year profiles (see extracts from Pacific Power study below). Note that a recent review of all available dryer data found that the Pacific Power data appeared to be significantly lower than average for recently metered sites. This data is used for load shape only and not energy.




**Dryers**




**Dryers**


Average Daily Energy Consumption by Month
Dryers
Error bars show 95% confidence interval
The dotted line shown connects the monthy values and is indicitive only
Avg Daily Energy Consumption (Wh/day)
800
700
600
500
400
300
200
100
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

**Dryers**

# Televisions

Estimates for energy consumption are based on the star rating algorithm with adjustments as noted in the following sub-section. The star rating algorithm facilitates the calculation of the comparative annual energy consumption (CEC) by reverse engineering the following SRI equation:

$$SRI \quad = \quad 1 + \left[ \frac{\log_e\left(\frac{CEC}{BEC}\right)}{\log_e(1-ERF)} \right]$$

Where:

SRI is the star rating index (fractional star rating)
CEC is the comparative energy consumption (energy that appears on the energy label)
BEC is the base energy consumption – the equation that gives the CEC for a product with an SRI of 1.0, BEC = 65.408 + (0.09344 × screen area)
ERF is the energy reduction factor – reduction in CEC for each additional star (0.2).

### Key Assumptions and Adjustment Factors

The overall approach for the calculation of TV energy was as follows:

- Calculate CEC for screen area and standard conditions
- Subtract the standby energy for the selected standby power value for 24 – 10 (14) hours per day as nominated in the standard
- Scale this value by the actual assumed hours of use per day divided by 10 hours per day (assumed usage in the standard)
- Add standby power energy for the year for the selected usage level.

Standby energy = (24 – on hours) × Standby Power × 365

Key Assumptions applied:

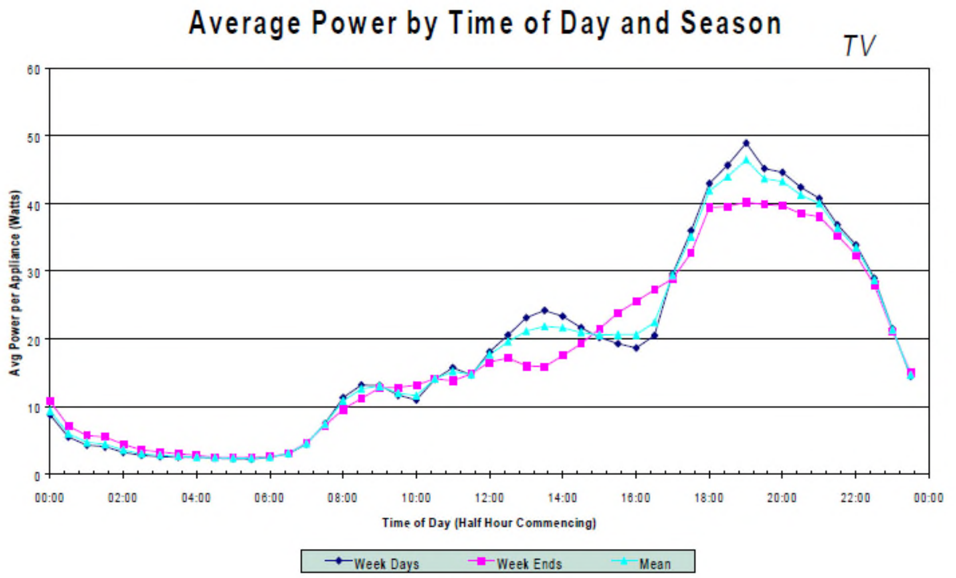
- Hours of use per day = 5.5 (main TV) or 2 (second TV)
- Standby power = 0.5W.

The average lifetime assumed for this product type is 10 years (refer Sustainability Victoria 2016).

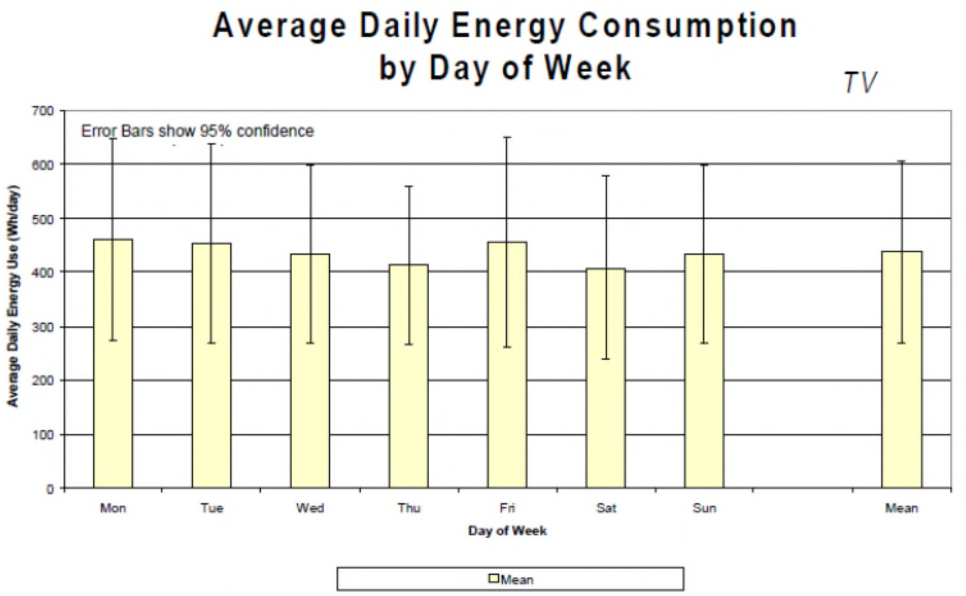
**Product Size**
Based on analysis of Gfk data  the average size of a TV was determined to be 110 diagonal cm.

## Usage Profile

The adopted usage profile in the model was based on Pacific Power survey data for “TVs”, weighted according to the time of day profile, day of week profile and month of year profiles (see extracts from Pacific Power study below). This data is used for load shape only and not energy.




**TV**




**TV (season estimate not possible)**

Note: Monthly data not available – assume constant over 12 months

# Pool pump

### Basis for Energy Consumption Estimates

Estimates for energy consumption are based on the star rating algorithm with adjustments as noted in the following sub-section. Based on the star rating algorithm, the efficiency of a pool pump was calculated using the following formula:

$$Efficiency = 9 \times (1.25)^{(SRI-1)}$$

Where:

Efficiency = Watthours per litre of water pumped
SRI = The star rating index of the pump

### Key Assumptions and Adjustment Factors

The overall approach for the calculation of pool pump energy was as follows:

- Divide the capacity of the pool (in litres) by the efficiency of the pool pump
- Multiply the resultant value by 365 (days) and divide by 1000 to determine annual energy consumption in kWh.

Key Assumptions applied:

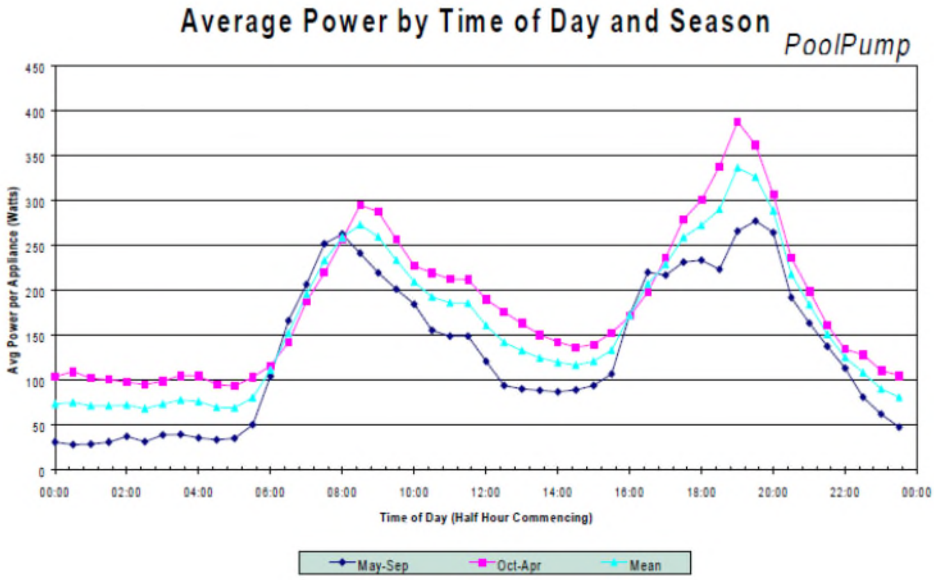
- Average size of a pool = 50,000 litres
- The average lifetime assumed for this product type was 10 years.

### Product Capacity

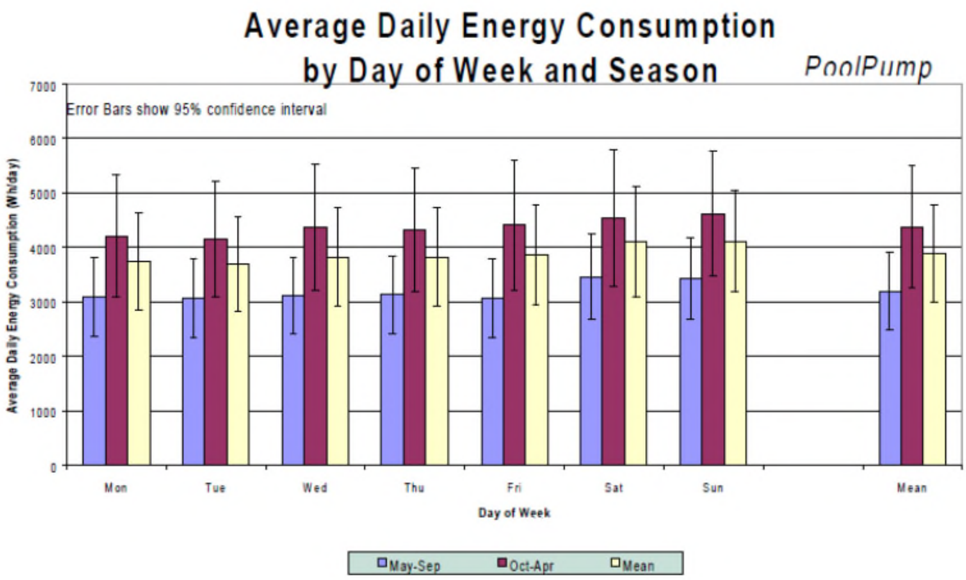
For this product type the relevant capacity is that of the pool that the pump services. Based on the assumptions within the relevant test standard it has been assumed that an average sized pool is 50,000 litres.

### Usage Profile

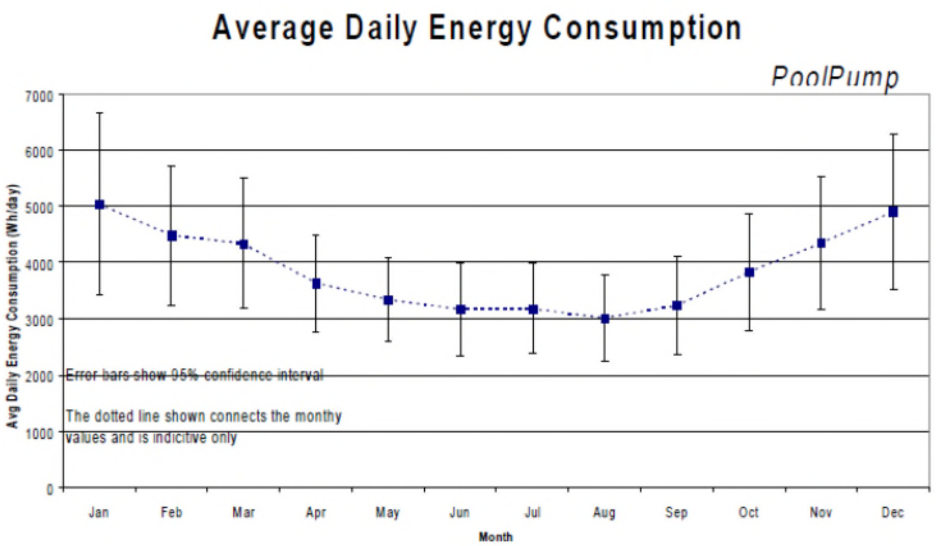
The adopted usage profile in the model was based on Pacific Power survey data for “pool pumps”, weighted according to the time of day profile, day of week profile and month of year profiles (see extracts from Pacific Power study below). Note that this equipment can be programmed to operate and any time, so the load shape in practice is highly flexible.




**Pool Pumps**




**Pool Pumps**


Average Daily Energy Consumption
PoolPump
Avg Daily Energy Consumption (Wh/day)
7000
6000
5000
4000
3000
2000
1000
0
Error bars show 95% confidence interval
The dotted line shown connects the monthy
values and is indicitive only
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month

**Pool Pumps**

# Spa pump

### Basis for Energy Consumption Estimates

Energy consumption estimates for Spa pumps is based on the formula applied under the BASIX scheme.

### Key Assumptions and Adjustment Factors

The overall approach for the calculation of the spa pump energy was as follows:

This performance level is based on that assumed in the BASIX scheme which assumes a certain pump power input (per KL of spa capacity). This value is applied to an assumed number of hours of operation per day

- Calculate the power input of the pump based on the volumetric capacity of the spa. The rate assumed is 0.4 kW/1000 litres capacity
- Multiply the power input by the assumed hours of operation per day.
- Multiply the resultant value by 365 (days) and divide by 1000 to determine annual energy consumption in kWh.

Key Assumptions applied:

- Average size of a spa = 4,000 litres
- Average hours of operation = 3.5 hours per day (Woolcott 2016 Research)
- The average lifetime assumed for this product type was 10 years.

### Product Capacity

For this product type the relevant capacity is that of the spa that the pump services..

### Usage Profile

The adopted usage profile in the model was based on Pacific Power survey data for “pool pumps”, weighted according to the time of day profile, day of week profile and month of year profiles (see pool pump section for details). Note that this equipment can be programmed to operate and any time, so the load shape in practice is highly flexible.

## Standby Power

### Basis for Energy Consumption Estimates

A fixed annual energy consumption due to standby power usage has been adopted in the model. The allowance for standby power consumption has been based on survey data from the study E3 Household Standby Audit: 2010 – 2011(DCCE 2011). That study found that on overage standby power consumption was in the order of 80W continuous throughout the year per household.

### Usage Profile

Assumed to be continuous.

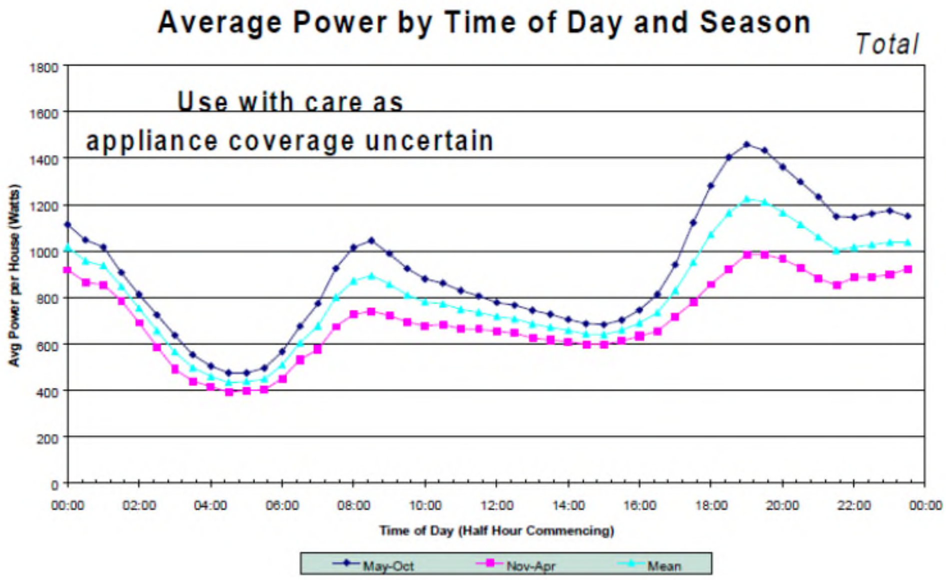
# Other Power

### Basis for Energy Consumption Estimates

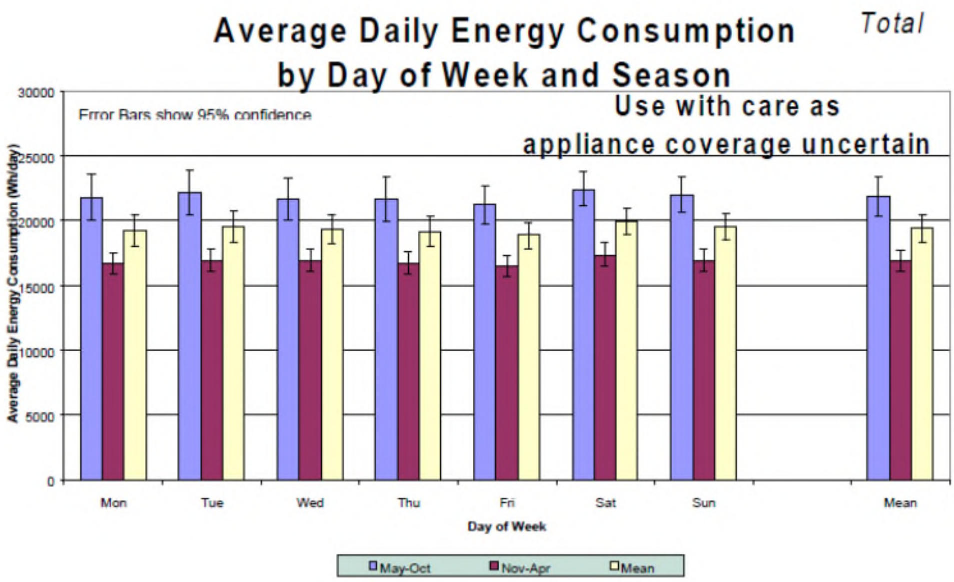
Other power consumption form miscellaneous equipment not explicitly modelled was estimated at approximately 250 kWh per annum based on the study “Energy Use in the Australian Residential Sector 1986-2020 (EES 2008).

### Usage Profile

The adopted usage profile in the model was based on Pacific Power survey data for “all”, weighted according to the time of day profile, day of week profile and month of year profiles (see extracts from Pacific Power study below below). No differentiation between all day and work day occupancies.

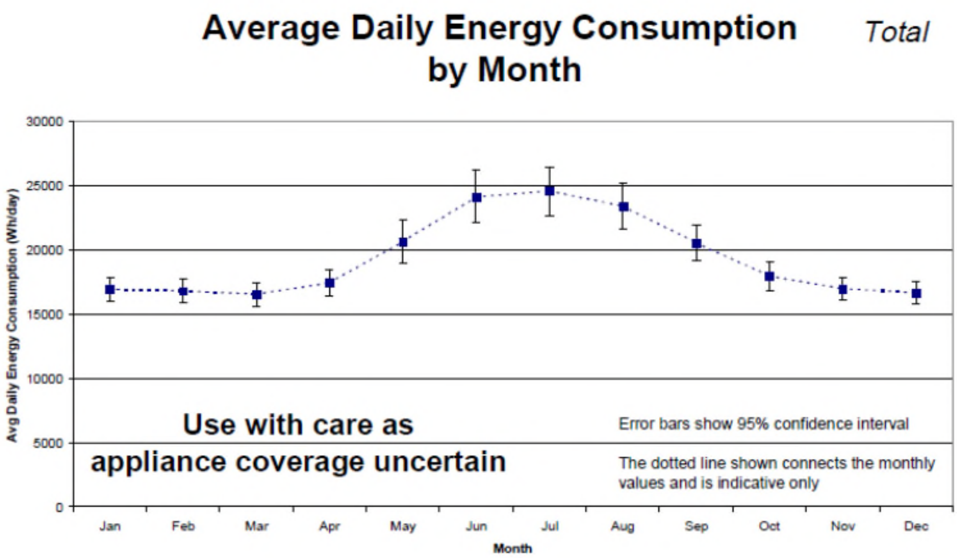



**Total**



Average Daily Energy Consumption by Day of Week and Season
Total
Error Bars show 95% confidence
Use with care as appliance coverage uncertain
Average Daily Energy Consumption (Wh/day)
30000
25000
20000
15000
10000
5000
0
Mon
Tue
Wed
Thu
Fri
Sat
Sun
Mean
Day of Week
May-Oct
Nov-Apr
Mean


**Total**



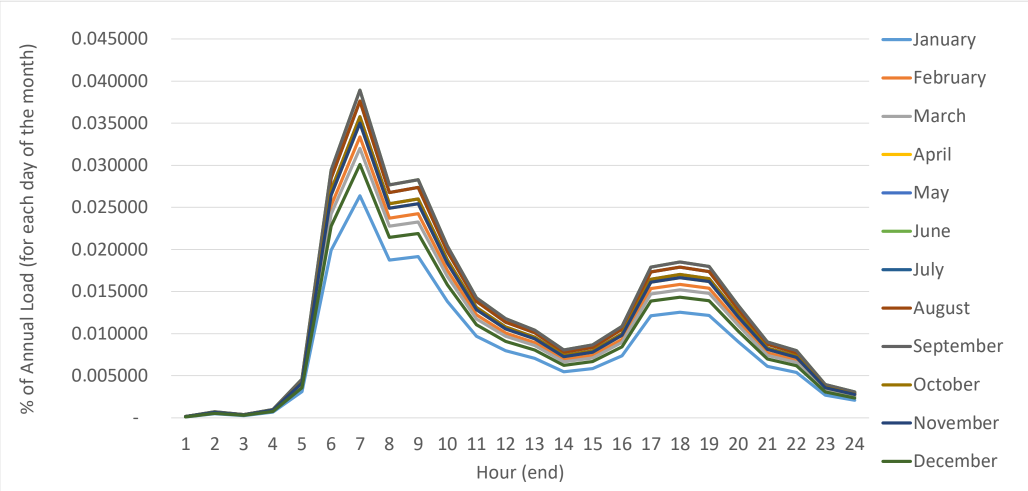
Average Daily Energy Consumption by Month
Total
Avg Daily Energy Consumption (Wh/day)
30000
25000
20000
15000
10000
5000
0
Use with care as appliance coverage uncertain
Error bars show 95% confidence interval
The dotted line shown connects the monthly values and is indicative only
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month


**Total**

## 10.2 Appendix 2 – Usage Profile Data Tables

## Hourly Load Percentage by hour of the day - for each day of the month

| Appliance Category | Water Heating | Appliance Type | Electric Storage (peak) | Occu-pancy | All day |
|---|---|---|---|---|---|

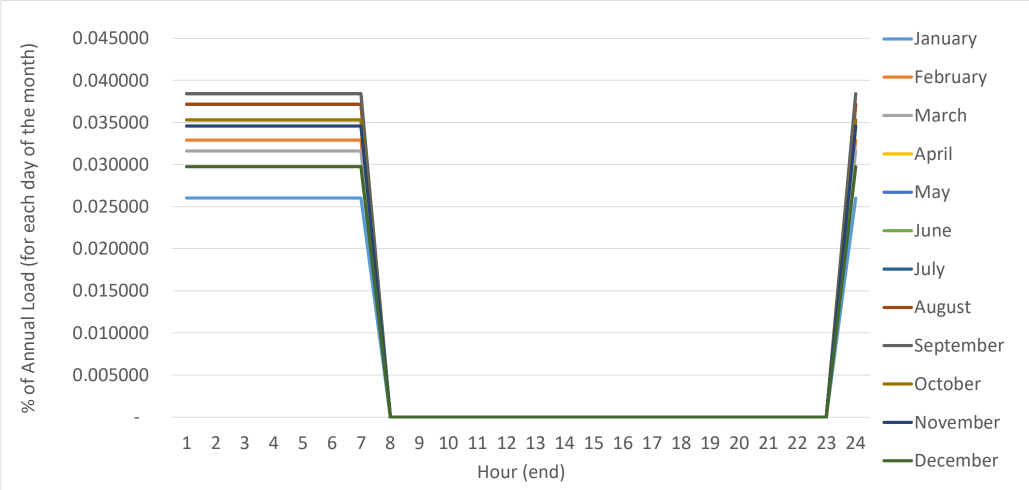



| Hour Ending | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.000107 | 0.000136 | 0.000130 | 0.000143 | 0.000146 | 0.000159 | 0.000153 | 0.000153 | 0.000159 | 0.000146 | 0.000143 | 0.000123 |
| 2 | 0.000477 | 0.000604 | 0.000579 | 0.000634 | 0.000648 | 0.000704 | 0.000682 | 0.000682 | 0.000704 | 0.000648 | 0.000634 | 0.000545 |
| 3 | 0.000254 | 0.000321 | 0.000308 | 0.000337 | 0.000345 | 0.000375 | 0.000363 | 0.000363 | 0.000375 | 0.000345 | 0.000337 | 0.000290 |
| 4 | 0.000669 | 0.000846 | 0.000812 | 0.000889 | 0.000908 | 0.000987 | 0.000956 | 0.000956 | 0.000987 | 0.000908 | 0.000889 | 0.000764 |
| 5 | 0.003108 | 0.003932 | 0.003774 | 0.004129 | 0.004218 | 0.004588 | 0.004440 | 0.004440 | 0.004588 | 0.004218 | 0.004129 | 0.003552 |
| 6 | 0.019922 | 0.025207 | 0.024191 | 0.026468 | 0.027037 | 0.029408 | 0.028460 | 0.028460 | 0.029408 | 0.027037 | 0.026468 | 0.022768 |
| 7 | 0.026357 | 0.033350 | 0.032005 | 0.035018 | 0.035771 | 0.038908 | 0.037653 | 0.037653 | 0.038908 | 0.035771 | 0.035018 | 0.030123 |
| 8 | 0.018737 | 0.023708 | 0.022752 | 0.024894 | 0.025429 | 0.027660 | 0.026767 | 0.026767 | 0.027660 | 0.025429 | 0.024894 | 0.021414 |
| 9 | 0.019148 | 0.024228 | 0.023251 | 0.025439 | 0.025986 | 0.028266 | 0.027354 | 0.027354 | 0.028266 | 0.025986 | 0.025439 | 0.021883 |
| 10 | 0.013829 | 0.017498 | 0.016792 | 0.018372 | 0.018768 | 0.020414 | 0.019755 | 0.019755 | 0.020414 | 0.018768 | 0.018372 | 0.015804 |
| 11 | 0.009664 | 0.012228 | 0.011734 | 0.012839 | 0.013115 | 0.014265 | 0.013805 | 0.013805 | 0.014265 | 0.013115 | 0.012839 | 0.011044 |
| 12 | 0.007964 | 0.010077 | 0.009670 | 0.010581 | 0.010808 | 0.011756 | 0.011377 | 0.011377 | 0.011756 | 0.010808 | 0.010581 | 0.009102 |
| 13 | 0.007065 | 0.008939 | 0.008579 | 0.009386 | 0.009588 | 0.010429 | 0.010093 | 0.010093 | 0.010429 | 0.009588 | 0.009386 | 0.008074 |
| 14 | 0.005469 | 0.006921 | 0.006641 | 0.007267 | 0.007423 | 0.008074 | 0.007814 | 0.007814 | 0.008074 | 0.007423 | 0.007267 | 0.006251 |
| 15 | 0.005856 | 0.007410 | 0.007111 | 0.007780 | 0.007947 | 0.008644 | 0.008366 | 0.008366 | 0.008644 | 0.007947 | 0.007780 | 0.006692 |
| 16 | 0.007365 | 0.009319 | 0.008944 | 0.009785 | 0.009996 | 0.010873 | 0.010522 | 0.010522 | 0.010873 | 0.009996 | 0.009785 | 0.008417 |
| 17 | 0.012126 | 0.015343 | 0.014725 | 0.016111 | 0.016457 | 0.017901 | 0.017323 | 0.017323 | 0.017901 | 0.016457 | 0.016111 | 0.013859 |
| 18 | 0.012531 | 0.015855 | 0.015216 | 0.016648 | 0.017006 | 0.018498 | 0.017901 | 0.017901 | 0.018498 | 0.017006 | 0.016648 | 0.014321 |
| 19 | 0.012173 | 0.015402 | 0.014781 | 0.016172 | 0.016520 | 0.017969 | 0.017390 | 0.017390 | 0.017969 | 0.016520 | 0.016172 | 0.013912 |
| 20 | 0.009026 | 0.011420 | 0.010960 | 0.011991 | 0.012249 | 0.013324 | 0.012894 | 0.012894 | 0.013324 | 0.012249 | 0.011991 | 0.010315 |
| 21 | 0.006103 | 0.007722 | 0.007411 | 0.008108 | 0.008283 | 0.009009 | 0.008719 | 0.008719 | 0.009009 | 0.008283 | 0.008108 | 0.006975 |
| 22 | 0.005407 | 0.006842 | 0.006566 | 0.007184 | 0.007338 | 0.007982 | 0.007724 | 0.007724 | 0.007982 | 0.007338 | 0.007184 | 0.006180 |
| 23 | 0.002680 | 0.003391 | 0.003255 | 0.003561 | 0.003638 | 0.003957 | 0.003829 | 0.003829 | 0.003957 | 0.003638 | 0.003561 | 0.003063 |
| 24 | 0.002079 | 0.002631 | 0.002525 | 0.002763 | 0.002822 | 0.003069 | 0.002970 | 0.002970 | 0.003069 | 0.002822 | 0.002763 | 0.002376 |

| Monthly total | 6.5% | 7.4% | 7.8% | 8.3% | 8.8% | 9.2% | 9.2% | 9.2% | 9.2% | 8.8% | 8.3% | 7.4% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

## Hourly Load Percentage by hour of the day - for each day of the month

| Appliance Category | Water Heating | Appliance Type | Electric Storage (off peak) | Occu-pancy | All day |
|---|---|---|---|---|---|

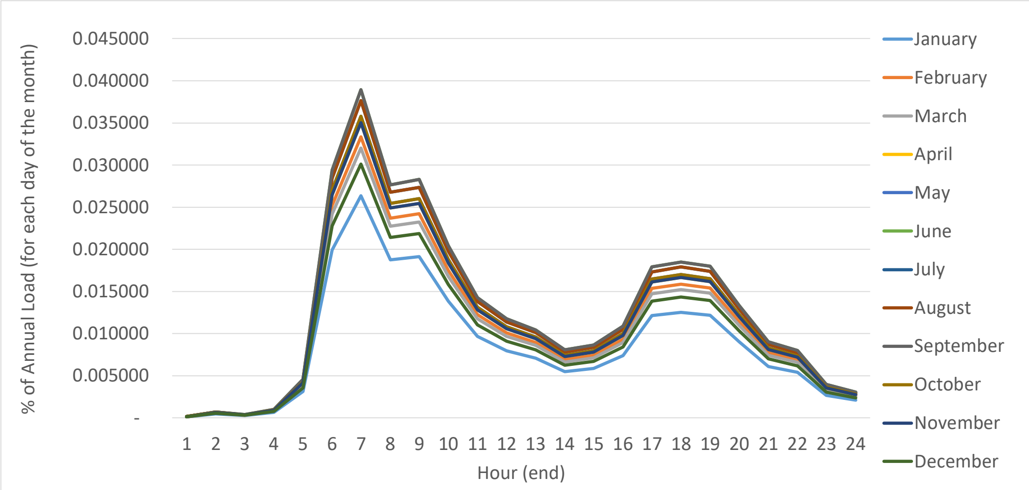



| Hour Ending | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.026015 | 0.032916 | 0.031589 | 0.034562 | 0.035305 | 0.038402 | 0.037164 | 0.037164 | 0.038402 | 0.035305 | 0.034562 | 0.029731 |
| 2 | 0.026015 | 0.032916 | 0.031589 | 0.034562 | 0.035305 | 0.038402 | 0.037164 | 0.037164 | 0.038402 | 0.035305 | 0.034562 | 0.029731 |
| 3 | 0.026015 | 0.032916 | 0.031589 | 0.034562 | 0.035305 | 0.038402 | 0.037164 | 0.037164 | 0.038402 | 0.035305 | 0.034562 | 0.029731 |
| 4 | 0.026015 | 0.032916 | 0.031589 | 0.034562 | 0.035305 | 0.038402 | 0.037164 | 0.037164 | 0.038402 | 0.035305 | 0.034562 | 0.029731 |
| 5 | 0.026015 | 0.032916 | 0.031589 | 0.034562 | 0.035305 | 0.038402 | 0.037164 | 0.037164 | 0.038402 | 0.035305 | 0.034562 | 0.029731 |
| 6 | 0.026015 | 0.032916 | 0.031589 | 0.034562 | 0.035305 | 0.038402 | 0.037164 | 0.037164 | 0.038402 | 0.035305 | 0.034562 | 0.029731 |
| 7 | 0.026015 | 0.032916 | 0.031589 | 0.034562 | 0.035305 | 0.038402 | 0.037164 | 0.037164 | 0.038402 | 0.035305 | 0.034562 | 0.029731 |
| 8 | - | - | - | - | - | - | - | - | - | - | - | - |
| 9 | - | - | - | - | - | - | - | - | - | - | - | - |
| 10 | - | - | - | - | - | - | - | - | - | - | - | - |
| 11 | - | - | - | - | - | - | - | - | - | - | - | - |
| 12 | - | - | - | - | - | - | - | - | - | - | - | - |
| 13 | - | - | - | - | - | - | - | - | - | - | - | - |
| 14 | - | - | - | - | - | - | - | - | - | - | - | - |
| 15 | - | - | - | - | - | - | - | - | - | - | - | - |
| 16 | - | - | - | - | - | - | - | - | - | - | - | - |
| 17 | - | - | - | - | - | - | - | - | - | - | - | - |
| 18 | - | - | - | - | - | - | - | - | - | - | - | - |
| 19 | - | - | - | - | - | - | - | - | - | - | - | - |
| 20 | - | - | - | - | - | - | - | - | - | - | - | - |
| 21 | - | - | - | - | - | - | - | - | - | - | - | - |
| 22 | - | - | - | - | - | - | - | - | - | - | - | - |
| 23 | - | - | - | - | - | - | - | - | - | - | - | - |
| 24 | 0.026015 | 0.032916 | 0.031589 | 0.034562 | 0.035305 | 0.038402 | 0.037164 | 0.037164 | 0.038402 | 0.035305 | 0.034562 | 0.029731 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monthly total | 6.5% | 7.4% | 7.8% | 8.3% | 8.8% | 9.2% | 9.2% | 9.2% | 9.2% | 8.8% | 8.3% | 7.4% |

## Hourly Load Percentage by hour of the day - for each day of the month

| Appliance Category | Water Heating | Appliance Type | Electric Instantaneous | Occu-pancy | All day |
|---|---|---|---|---|---|

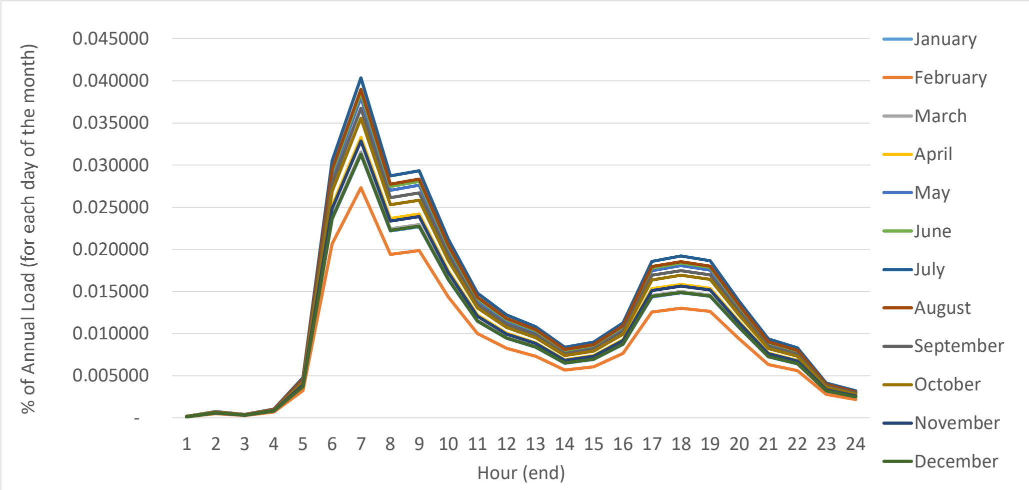



| Hour Ending | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.000107 | 0.000136 | 0.000130 | 0.000143 | 0.000146 | 0.000159 | 0.000153 | 0.000153 | 0.000159 | 0.000146 | 0.000143 | 0.000123 |
| 2 | 0.000477 | 0.000604 | 0.000579 | 0.000634 | 0.000648 | 0.000704 | 0.000682 | 0.000682 | 0.000704 | 0.000648 | 0.000634 | 0.000545 |
| 3 | 0.000254 | 0.000321 | 0.000308 | 0.000337 | 0.000345 | 0.000375 | 0.000363 | 0.000363 | 0.000375 | 0.000345 | 0.000337 | 0.000290 |
| 4 | 0.000669 | 0.000846 | 0.000812 | 0.000889 | 0.000908 | 0.000987 | 0.000956 | 0.000956 | 0.000987 | 0.000908 | 0.000889 | 0.000764 |
| 5 | 0.003108 | 0.003932 | 0.003774 | 0.004129 | 0.004218 | 0.004588 | 0.004440 | 0.004440 | 0.004588 | 0.004218 | 0.004129 | 0.003552 |
| 6 | 0.019922 | 0.025207 | 0.024191 | 0.026468 | 0.027037 | 0.029408 | 0.028460 | 0.028460 | 0.029408 | 0.027037 | 0.026468 | 0.022768 |
| 7 | 0.026357 | 0.033350 | 0.032005 | 0.035018 | 0.035771 | 0.038908 | 0.037653 | 0.037653 | 0.038908 | 0.035771 | 0.035018 | 0.030123 |
| 8 | 0.018737 | 0.023708 | 0.022752 | 0.024894 | 0.025429 | 0.027660 | 0.026767 | 0.026767 | 0.027660 | 0.025429 | 0.024894 | 0.021414 |
| 9 | 0.019148 | 0.024228 | 0.023251 | 0.025439 | 0.025986 | 0.028266 | 0.027354 | 0.027354 | 0.028266 | 0.025986 | 0.025439 | 0.021883 |
| 10 | 0.013829 | 0.017498 | 0.016792 | 0.018372 | 0.018768 | 0.020414 | 0.019755 | 0.019755 | 0.020414 | 0.018768 | 0.018372 | 0.015804 |
| 11 | 0.009664 | 0.012228 | 0.011734 | 0.012839 | 0.013115 | 0.014265 | 0.013805 | 0.013805 | 0.014265 | 0.013115 | 0.012839 | 0.011044 |
| 12 | 0.007964 | 0.010077 | 0.009670 | 0.010581 | 0.010808 | 0.011756 | 0.011377 | 0.011377 | 0.011756 | 0.010808 | 0.010581 | 0.009102 |
| 13 | 0.007065 | 0.008939 | 0.008579 | 0.009386 | 0.009588 | 0.010429 | 0.010093 | 0.010093 | 0.010429 | 0.009588 | 0.009386 | 0.008074 |
| 14 | 0.005469 | 0.006921 | 0.006641 | 0.007267 | 0.007423 | 0.008074 | 0.007814 | 0.007814 | 0.008074 | 0.007423 | 0.007267 | 0.006251 |
| 15 | 0.005856 | 0.007410 | 0.007111 | 0.007780 | 0.007947 | 0.008644 | 0.008366 | 0.008366 | 0.008644 | 0.007947 | 0.007780 | 0.006692 |
| 16 | 0.007365 | 0.009319 | 0.008944 | 0.009785 | 0.009996 | 0.010873 | 0.010522 | 0.010522 | 0.010873 | 0.009996 | 0.009785 | 0.008417 |
| 17 | 0.012126 | 0.015343 | 0.014725 | 0.016111 | 0.016457 | 0.017901 | 0.017323 | 0.017323 | 0.017901 | 0.016457 | 0.016111 | 0.013859 |
| 18 | 0.012531 | 0.015855 | 0.015216 | 0.016648 | 0.017006 | 0.018498 | 0.017901 | 0.017901 | 0.018498 | 0.017006 | 0.016648 | 0.014321 |
| 19 | 0.012173 | 0.015402 | 0.014781 | 0.016172 | 0.016520 | 0.017969 | 0.017390 | 0.017390 | 0.017969 | 0.016520 | 0.016172 | 0.013912 |
| 20 | 0.009026 | 0.011420 | 0.010960 | 0.011991 | 0.012249 | 0.013324 | 0.012894 | 0.012894 | 0.013324 | 0.012249 | 0.011991 | 0.010315 |
| 21 | 0.006103 | 0.007722 | 0.007411 | 0.008108 | 0.008283 | 0.009009 | 0.008719 | 0.008719 | 0.009009 | 0.008283 | 0.008108 | 0.006975 |
| 22 | 0.005407 | 0.006842 | 0.006566 | 0.007184 | 0.007338 | 0.007982 | 0.007724 | 0.007724 | 0.007982 | 0.007338 | 0.007184 | 0.006180 |
| 23 | 0.002680 | 0.003391 | 0.003255 | 0.003561 | 0.003638 | 0.003957 | 0.003829 | 0.003829 | 0.003957 | 0.003638 | 0.003561 | 0.003063 |
| 24 | 0.002079 | 0.002631 | 0.002525 | 0.002763 | 0.002822 | 0.003069 | 0.002970 | 0.002970 | 0.003069 | 0.002822 | 0.002763 | 0.002376 |

| Monthly total | 6.5% | 7.4% | 7.8% | 8.3% | 8.8% | 9.2% | 9.2% | 9.2% | 9.2% | 8.8% | 8.3% | 7.4% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

## Hourly Load Percentage by hour of the day - for each day of the month

| Appliance Category | Water Heating | Appliance Type | Heat Pump (Standard) | Occu-pancy | All day |
|---|---|---|---|---|---|

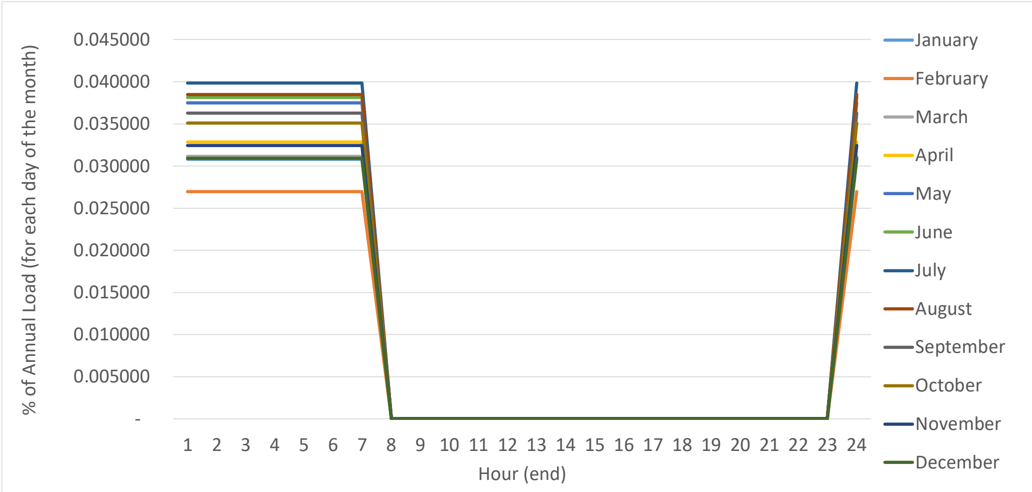



| Hour Ending | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.000127 | 0.000111 | 0.000129 | 0.000136 | 0.000155 | 0.000157 | 0.000165 | 0.000159 | 0.000150 | 0.000145 | 0.000134 | 0.000128 |
| 2 | 0.000565 | 0.000494 | 0.000571 | 0.000602 | 0.000688 | 0.000699 | 0.000731 | 0.000706 | 0.000665 | 0.000644 | 0.000594 | 0.000567 |
| 3 | 0.000301 | 0.000263 | 0.000304 | 0.000321 | 0.000366 | 0.000372 | 0.000389 | 0.000376 | 0.000354 | 0.000342 | 0.000316 | 0.000302 |
| 4 | 0.000792 | 0.000693 | 0.000801 | 0.000845 | 0.000964 | 0.000980 | 0.001024 | 0.000989 | 0.000932 | 0.000902 | 0.000833 | 0.000795 |
| 5 | 0.003679 | 0.003221 | 0.003721 | 0.003924 | 0.004478 | 0.004553 | 0.004759 | 0.004596 | 0.004332 | 0.004192 | 0.003872 | 0.003692 |
| 6 | 0.023584 | 0.020647 | 0.023852 | 0.025155 | 0.028707 | 0.029186 | 0.030508 | 0.029464 | 0.027772 | 0.026873 | 0.024822 | 0.023666 |
| 7 | 0.031202 | 0.027317 | 0.031558 | 0.033281 | 0.037980 | 0.038614 | 0.040363 | 0.038982 | 0.036744 | 0.035554 | 0.032840 | 0.031311 |
| 8 | 0.022181 | 0.019419 | 0.022434 | 0.023659 | 0.027000 | 0.027450 | 0.028694 | 0.027712 | 0.026121 | 0.025275 | 0.023346 | 0.022258 |
| 9 | 0.022667 | 0.019845 | 0.022926 | 0.024178 | 0.027592 | 0.028052 | 0.029323 | 0.028319 | 0.026693 | 0.025829 | 0.023857 | 0.022746 |
| 10 | 0.016371 | 0.014332 | 0.016557 | 0.017462 | 0.019927 | 0.020259 | 0.021177 | 0.020453 | 0.019278 | 0.018654 | 0.017230 | 0.016428 |
| 11 | 0.011440 | 0.010015 | 0.011570 | 0.012202 | 0.013925 | 0.014157 | 0.014799 | 0.014292 | 0.013472 | 0.013036 | 0.012041 | 0.011480 |
| 12 | 0.009428 | 0.008254 | 0.009535 | 0.010056 | 0.011476 | 0.011667 | 0.012196 | 0.011778 | 0.011102 | 0.010743 | 0.009923 | 0.009461 |
| 13 | 0.008364 | 0.007322 | 0.008459 | 0.008921 | 0.010181 | 0.010350 | 0.010819 | 0.010449 | 0.009849 | 0.009530 | 0.008803 | 0.008393 |
| 14 | 0.006475 | 0.005669 | 0.006549 | 0.006906 | 0.007881 | 0.008013 | 0.008376 | 0.008089 | 0.007625 | 0.007378 | 0.006815 | 0.006497 |
| 15 | 0.006932 | 0.006069 | 0.007011 | 0.007394 | 0.008438 | 0.008579 | 0.008968 | 0.008661 | 0.008164 | 0.007899 | 0.007296 | 0.006956 |
| 16 | 0.008719 | 0.007633 | 0.008818 | 0.009300 | 0.010613 | 0.010790 | 0.011279 | 0.010893 | 0.010268 | 0.009935 | 0.009177 | 0.008749 |
| 17 | 0.014355 | 0.012568 | 0.014519 | 0.015312 | 0.017474 | 0.017765 | 0.018570 | 0.017935 | 0.016905 | 0.016358 | 0.015109 | 0.014405 |
| 18 | 0.014834 | 0.012987 | 0.015003 | 0.015823 | 0.018057 | 0.018358 | 0.019190 | 0.018533 | 0.017469 | 0.016903 | 0.015613 | 0.014886 |
| 19 | 0.014410 | 0.012616 | 0.014575 | 0.015371 | 0.017541 | 0.017833 | 0.018641 | 0.018003 | 0.016970 | 0.016420 | 0.015167 | 0.014460 |
| 20 | 0.010685 | 0.009354 | 0.010806 | 0.011397 | 0.013006 | 0.013223 | 0.013822 | 0.013349 | 0.012582 | 0.012175 | 0.011246 | 0.010722 |
| 21 | 0.007225 | 0.006325 | 0.007307 | 0.007706 | 0.008794 | 0.008941 | 0.009346 | 0.009026 | 0.008508 | 0.008233 | 0.007604 | 0.007250 |
| 22 | 0.006401 | 0.005604 | 0.006474 | 0.006828 | 0.007792 | 0.007921 | 0.008280 | 0.007997 | 0.007538 | 0.007294 | 0.006737 | 0.006423 |
| 23 | 0.003173 | 0.002778 | 0.003209 | 0.003384 | 0.003862 | 0.003927 | 0.004105 | 0.003964 | 0.003737 | 0.003616 | 0.003340 | 0.003184 |
| 24 | 0.002461 | 0.002155 | 0.002490 | 0.002626 | 0.002996 | 0.003046 | 0.003184 | 0.003075 | 0.002899 | 0.002805 | 0.002591 | 0.002470 |

| Monthly total | 7.6% | 6.0% | 7.7% | 7.9% | 9.3% | 9.1% | 9.9% | 9.5% | 8.7% | 8.7% | 7.8% | 7.7% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

## Hourly Load Percentage by hour of the day - for each day of the month

| Appliance Category | Water Heating | Appliance Type | Heat Pump (off-peak) | Occu-pancy | All day |
|---|---|---|---|---|---|

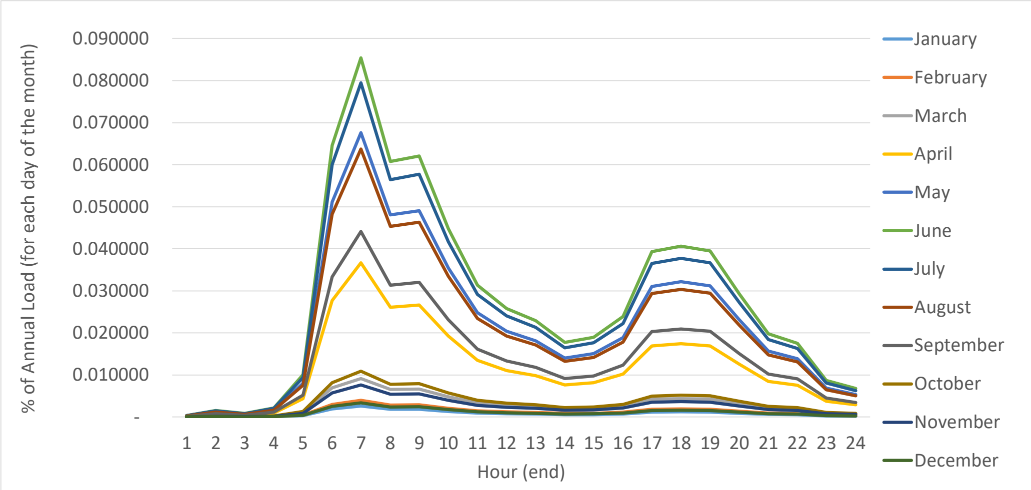



| Hour Ending | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.030796 | 0.026961 | 0.031147 | 0.032848 | 0.037487 | 0.038111 | 0.039838 | 0.038475 | 0.036266 | 0.035092 | 0.032413 | 0.030904 |
| 2 | 0.030796 | 0.026961 | 0.031147 | 0.032848 | 0.037487 | 0.038111 | 0.039838 | 0.038475 | 0.036266 | 0.035092 | 0.032413 | 0.030904 |
| 3 | 0.030796 | 0.026961 | 0.031147 | 0.032848 | 0.037487 | 0.038111 | 0.039838 | 0.038475 | 0.036266 | 0.035092 | 0.032413 | 0.030904 |
| 4 | 0.030796 | 0.026961 | 0.031147 | 0.032848 | 0.037487 | 0.038111 | 0.039838 | 0.038475 | 0.036266 | 0.035092 | 0.032413 | 0.030904 |
| 5 | 0.030796 | 0.026961 | 0.031147 | 0.032848 | 0.037487 | 0.038111 | 0.039838 | 0.038475 | 0.036266 | 0.035092 | 0.032413 | 0.030904 |
| 6 | 0.030796 | 0.026961 | 0.031147 | 0.032848 | 0.037487 | 0.038111 | 0.039838 | 0.038475 | 0.036266 | 0.035092 | 0.032413 | 0.030904 |
| 7 | 0.030796 | 0.026961 | 0.031147 | 0.032848 | 0.037487 | 0.038111 | 0.039838 | 0.038475 | 0.036266 | 0.035092 | 0.032413 | 0.030904 |
| 8 | - | - | - | - | - | - | - | - | - | - | - | - |
| 9 | - | - | - | - | - | - | - | - | - | - | - | - |
| 10 | - | - | - | - | - | - | - | - | - | - | - | - |
| 11 | - | - | - | - | - | - | - | - | - | - | - | - |
| 12 | - | - | - | - | - | - | - | - | - | - | - | - |
| 13 | - | - | - | - | - | - | - | - | - | - | - | - |
| 14 | - | - | - | - | - | - | - | - | - | - | - | - |
| 15 | - | - | - | - | - | - | - | - | - | - | - | - |
| 16 | - | - | - | - | - | - | - | - | - | - | - | - |
| 17 | - | - | - | - | - | - | - | - | - | - | - | - |
| 18 | - | - | - | - | - | - | - | - | - | - | - | - |
| 19 | - | - | - | - | - | - | - | - | - | - | - | - |
| 20 | - | - | - | - | - | - | - | - | - | - | - | - |
| 21 | - | - | - | - | - | - | - | - | - | - | - | - |
| 22 | - | - | - | - | - | - | - | - | - | - | - | - |
| 23 | - | - | - | - | - | - | - | - | - | - | - | - |
| 24 | 0.030796 | 0.026961 | 0.031147 | 0.032848 | 0.037487 | 0.038111 | 0.039838 | 0.038475 | 0.036266 | 0.035092 | 0.032413 | 0.030904 |

| Monthly total | 7.6% | 6.0% | 7.7% | 7.9% | 9.3% | 9.1% | 9.9% | 9.5% | 8.7% | 8.7% | 7.8% | 7.7% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

## Hourly Load Percentage by hour of the day - for each day of the month

| Appliance Category | Water Heating | Appliance Type | Solar electric (Standard) | Occu-pancy | All day |
|---|---|---|---|---|---|

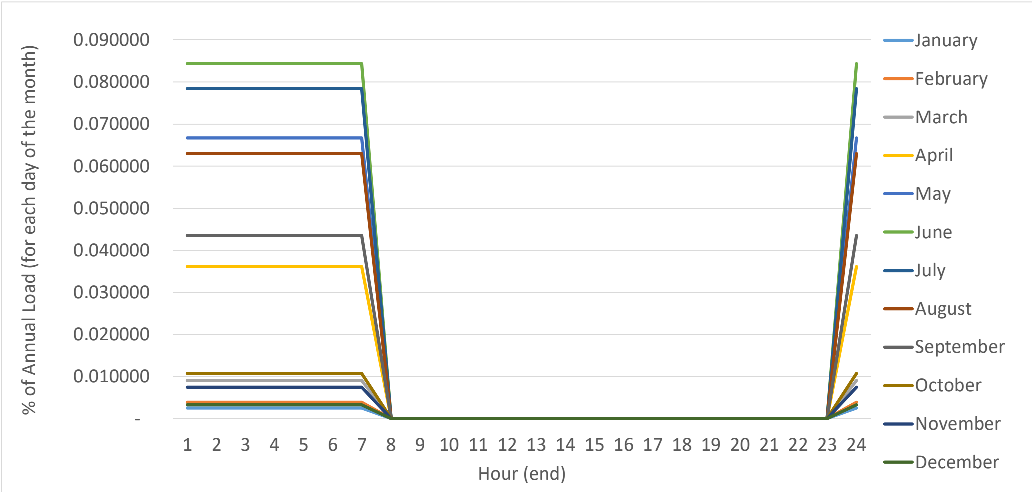



| Hour Ending | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.000010 | 0.000016 | 0.000037 | 0.000149 | 0.000275 | 0.000348 | 0.000324 | 0.000260 | 0.000180 | 0.000044 | 0.000031 | 0.000014 |
| 2 | 0.000047 | 0.000072 | 0.000166 | 0.000663 | 0.001223 | 0.001547 | 0.001438 | 0.001154 | 0.000798 | 0.000196 | 0.000138 | 0.000061 |
| 3 | 0.000025 | 0.000038 | 0.000088 | 0.000353 | 0.000651 | 0.000823 | 0.000765 | 0.000614 | 0.000425 | 0.000105 | 0.000073 | 0.000032 |
| 4 | 0.000065 | 0.000101 | 0.000233 | 0.000930 | 0.001715 | 0.002168 | 0.002016 | 0.001619 | 0.001119 | 0.000275 | 0.000193 | 0.000085 |
| 5 | 0.000304 | 0.000470 | 0.001083 | 0.004322 | 0.007969 | 0.010074 | 0.009366 | 0.007520 | 0.005198 | 0.001280 | 0.000896 | 0.000397 |
| 6 | 0.001947 | 0.003014 | 0.006943 | 0.027703 | 0.051082 | 0.064580 | 0.060036 | 0.048206 | 0.033319 | 0.008202 | 0.005742 | 0.002542 |
| 7 | 0.002576 | 0.003988 | 0.009186 | 0.036651 | 0.067583 | 0.085442 | 0.079430 | 0.063779 | 0.044082 | 0.010852 | 0.007597 | 0.003363 |
| 8 | 0.001831 | 0.002835 | 0.006530 | 0.026055 | 0.048044 | 0.060740 | 0.056466 | 0.045340 | 0.031338 | 0.007715 | 0.005401 | 0.002391 |
| 9 | 0.001871 | 0.002897 | 0.006673 | 0.026626 | 0.049097 | 0.062071 | 0.057704 | 0.046333 | 0.032024 | 0.007884 | 0.005519 | 0.002443 |
| 10 | 0.001352 | 0.002092 | 0.004820 | 0.019230 | 0.035459 | 0.044828 | 0.041674 | 0.033463 | 0.023128 | 0.005694 | 0.003986 | 0.001765 |
| 11 | 0.000944 | 0.001462 | 0.003368 | 0.013438 | 0.024779 | 0.031326 | 0.029122 | 0.023384 | 0.016162 | 0.003979 | 0.002785 | 0.001233 |
| 12 | 0.000778 | 0.001205 | 0.002776 | 0.011074 | 0.020420 | 0.025816 | 0.024000 | 0.019271 | 0.013319 | 0.003279 | 0.002295 | 0.001016 |
| 13 | 0.000690 | 0.001069 | 0.002462 | 0.009824 | 0.018115 | 0.022902 | 0.021291 | 0.017096 | 0.011816 | 0.002909 | 0.002036 | 0.000901 |
| 14 | 0.000535 | 0.000828 | 0.001906 | 0.007606 | 0.014024 | 0.017730 | 0.016483 | 0.013235 | 0.009148 | 0.002252 | 0.001577 | 0.000698 |
| 15 | 0.000572 | 0.000886 | 0.002041 | 0.008143 | 0.015015 | 0.018983 | 0.017647 | 0.014170 | 0.009794 | 0.002411 | 0.001688 | 0.000747 |
| 16 | 0.000720 | 0.001114 | 0.002567 | 0.010242 | 0.018885 | 0.023876 | 0.022196 | 0.017822 | 0.012318 | 0.003032 | 0.002123 | 0.000940 |
| 17 | 0.001185 | 0.001835 | 0.004226 | 0.016862 | 0.031093 | 0.039309 | 0.036544 | 0.029343 | 0.020281 | 0.004993 | 0.003495 | 0.001547 |
| 18 | 0.001225 | 0.001896 | 0.004367 | 0.017425 | 0.032131 | 0.040621 | 0.037763 | 0.030322 | 0.020958 | 0.005159 | 0.003612 | 0.001599 |
| 19 | 0.001190 | 0.001842 | 0.004242 | 0.016927 | 0.031213 | 0.039460 | 0.036684 | 0.029456 | 0.020359 | 0.005012 | 0.003509 | 0.001553 |
| 20 | 0.000882 | 0.001366 | 0.003146 | 0.012551 | 0.023143 | 0.029258 | 0.027200 | 0.021840 | 0.015095 | 0.003716 | 0.002602 | 0.001152 |
| 21 | 0.000596 | 0.000923 | 0.002127 | 0.008487 | 0.015649 | 0.019784 | 0.018392 | 0.014768 | 0.010207 | 0.002513 | 0.001759 | 0.000779 |
| 22 | 0.000528 | 0.000818 | 0.001884 | 0.007519 | 0.013864 | 0.017528 | 0.016295 | 0.013084 | 0.009043 | 0.002226 | 0.001559 | 0.000690 |
| 23 | 0.000262 | 0.000406 | 0.000934 | 0.003727 | 0.006873 | 0.008689 | 0.008077 | 0.006486 | 0.004483 | 0.001104 | 0.000773 | 0.000342 |
| 24 | 0.000203 | 0.000315 | 0.000725 | 0.002891 | 0.005332 | 0.006740 | 0.006266 | 0.005031 | 0.003478 | 0.000856 | 0.000599 | 0.000265 |

| Monthly total | 0.6% | 0.9% | 2.2% | 8.7% | 16.5% | 20.2% | 19.4% | 15.6% | 10.4% | 2.7% | 1.8% | 0.8% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

## Hourly Load Percentage by hour of the day - for each day of the month

| Appliance Category | Water Heating | Appliance Type | Solar electric (off-peak) | Occu-pancy | All day |
|---|---|---|---|---|---|

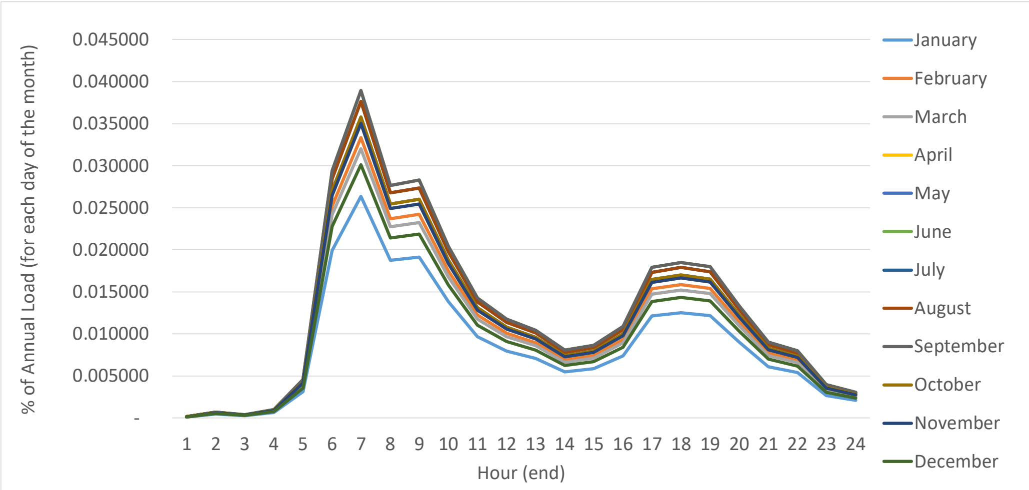



| Hour Ending | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.002542 | 0.003936 | 0.009067 | 0.036175 | 0.066705 | 0.084330 | 0.078397 | 0.062950 | 0.043509 | 0.010711 | 0.007498 | 0.003319 |
| 2 | 0.002542 | 0.003936 | 0.009067 | 0.036175 | 0.066705 | 0.084330 | 0.078397 | 0.062950 | 0.043509 | 0.010711 | 0.007498 | 0.003319 |
| 3 | 0.002542 | 0.003936 | 0.009067 | 0.036175 | 0.066705 | 0.084330 | 0.078397 | 0.062950 | 0.043509 | 0.010711 | 0.007498 | 0.003319 |
| 4 | 0.002542 | 0.003936 | 0.009067 | 0.036175 | 0.066705 | 0.084330 | 0.078397 | 0.062950 | 0.043509 | 0.010711 | 0.007498 | 0.003319 |
| 5 | 0.002542 | 0.003936 | 0.009067 | 0.036175 | 0.066705 | 0.084330 | 0.078397 | 0.062950 | 0.043509 | 0.010711 | 0.007498 | 0.003319 |
| 6 | 0.002542 | 0.003936 | 0.009067 | 0.036175 | 0.066705 | 0.084330 | 0.078397 | 0.062950 | 0.043509 | 0.010711 | 0.007498 | 0.003319 |
| 7 | 0.002542 | 0.003936 | 0.009067 | 0.036175 | 0.066705 | 0.084330 | 0.078397 | 0.062950 | 0.043509 | 0.010711 | 0.007498 | 0.003319 |
| 8 | - | - | - | - | - | - | - | - | - | - | - | - |
| 9 | - | - | - | - | - | - | - | - | - | - | - | - |
| 10 | - | - | - | - | - | - | - | - | - | - | - | - |
| 11 | - | - | - | - | - | - | - | - | - | - | - | - |
| 12 | - | - | - | - | - | - | - | - | - | - | - | - |
| 13 | - | - | - | - | - | - | - | - | - | - | - | - |
| 14 | - | - | - | - | - | - | - | - | - | - | - | - |
| 15 | - | - | - | - | - | - | - | - | - | - | - | - |
| 16 | - | - | - | - | - | - | - | - | - | - | - | - |
| 17 | - | - | - | - | - | - | - | - | - | - | - | - |
| 18 | - | - | - | - | - | - | - | - | - | - | - | - |
| 19 | - | - | - | - | - | - | - | - | - | - | - | - |
| 20 | - | - | - | - | - | - | - | - | - | - | - | - |
| 21 | - | - | - | - | - | - | - | - | - | - | - | - |
| 22 | - | - | - | - | - | - | - | - | - | - | - | - |
| 23 | - | - | - | - | - | - | - | - | - | - | - | - |
| 24 | 0.002542 | 0.003936 | 0.009067 | 0.036175 | 0.066705 | 0.084330 | 0.078397 | 0.062950 | 0.043509 | 0.010711 | 0.007498 | 0.003319 |

| Monthly total | 0.6% | 0.9% | 2.2% | 8.7% | 16.5% | 20.2% | 19.4% | 15.6% | 10.4% | 2.7% | 1.8% | 0.8% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

## Hourly Load Percentage by hour of the day - for each day of the month

| Appliance Category | Water Heating | Appliance Type | Gas storage | Occu-pancy | All day |
|---|---|---|---|---|---|

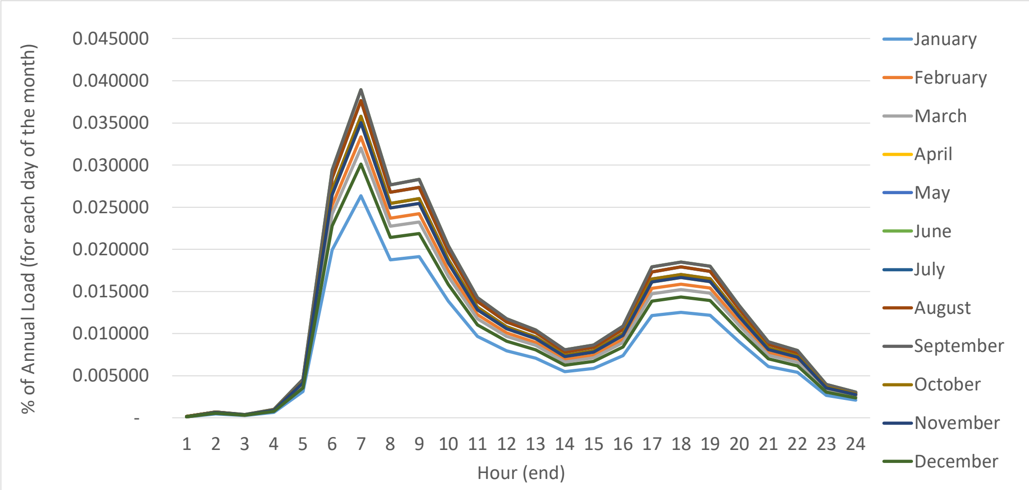



| Hour Ending | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 0.000107 | 0.000136 | 0.000130 | 0.000143 | 0.000146 | 0.000159 | 0.000153 | 0.000153 | 0.000159 | 0.000146 | 0.000143 | 0.000123 |
| **2** | 0.000477 | 0.000604 | 0.000579 | 0.000634 | 0.000648 | 0.000704 | 0.000682 | 0.000682 | 0.000704 | 0.000648 | 0.000634 | 0.000545 |
| **3** | 0.000254 | 0.000321 | 0.000308 | 0.000337 | 0.000345 | 0.000375 | 0.000363 | 0.000363 | 0.000375 | 0.000345 | 0.000337 | 0.000290 |
| **4** | 0.000669 | 0.000846 | 0.000812 | 0.000889 | 0.000908 | 0.000987 | 0.000956 | 0.000956 | 0.000987 | 0.000908 | 0.000889 | 0.000764 |
| **5** | 0.003108 | 0.003932 | 0.003774 | 0.004129 | 0.004218 | 0.004588 | 0.004440 | 0.004440 | 0.004588 | 0.004218 | 0.004129 | 0.003552 |
| **6** | 0.019922 | 0.025207 | 0.024191 | 0.026468 | 0.027037 | 0.029408 | 0.028460 | 0.028460 | 0.029408 | 0.027037 | 0.026468 | 0.022768 |
| **7** | 0.026357 | 0.033350 | 0.032005 | 0.035018 | 0.035771 | 0.038908 | 0.037653 | 0.037653 | 0.038908 | 0.035771 | 0.035018 | 0.030123 |
| **8** | 0.018737 | 0.023708 | 0.022752 | 0.024894 | 0.025429 | 0.027660 | 0.026767 | 0.026767 | 0.027660 | 0.025429 | 0.024894 | 0.021414 |
| **9** | 0.019148 | 0.024228 | 0.023251 | 0.025439 | 0.025986 | 0.028266 | 0.027354 | 0.027354 | 0.028266 | 0.025986 | 0.025439 | 0.021883 |
| **10** | 0.013829 | 0.017498 | 0.016792 | 0.018372 | 0.018768 | 0.020414 | 0.019755 | 0.019755 | 0.020414 | 0.018768 | 0.018372 | 0.015804 |
| **11** | 0.009664 | 0.012228 | 0.011734 | 0.012839 | 0.013115 | 0.014265 | 0.013805 | 0.013805 | 0.014265 | 0.013115 | 0.012839 | 0.011044 |
| **12** | 0.007964 | 0.010077 | 0.009670 | 0.010581 | 0.010808 | 0.011756 | 0.011377 | 0.011377 | 0.011756 | 0.010808 | 0.010581 | 0.009102 |
| **13** | 0.007065 | 0.008939 | 0.008579 | 0.009386 | 0.009588 | 0.010429 | 0.010093 | 0.010093 | 0.010429 | 0.009588 | 0.009386 | 0.008074 |
| **14** | 0.005469 | 0.006921 | 0.006641 | 0.007267 | 0.007423 | 0.008074 | 0.007814 | 0.007814 | 0.008074 | 0.007423 | 0.007267 | 0.006251 |
| **15** | 0.005856 | 0.007410 | 0.007111 | 0.007780 | 0.007947 | 0.008644 | 0.008366 | 0.008366 | 0.008644 | 0.007947 | 0.007780 | 0.006692 |
| **16** | 0.007365 | 0.009319 | 0.008944 | 0.009785 | 0.009996 | 0.010873 | 0.010522 | 0.010522 | 0.010873 | 0.009996 | 0.009785 | 0.008417 |
| **17** | 0.012126 | 0.015343 | 0.014725 | 0.016111 | 0.016457 | 0.017901 | 0.017323 | 0.017323 | 0.017901 | 0.016457 | 0.016111 | 0.013859 |
| **18** | 0.012531 | 0.015855 | 0.015216 | 0.016648 | 0.017006 | 0.018498 | 0.017901 | 0.017901 | 0.018498 | 0.017006 | 0.016648 | 0.014321 |
| **19** | 0.012173 | 0.015402 | 0.014781 | 0.016172 | 0.016520 | 0.017969 | 0.017390 | 0.017390 | 0.017969 | 0.016520 | 0.016172 | 0.013912 |
| **20** | 0.009026 | 0.011420 | 0.010960 | 0.011991 | 0.012249 | 0.013324 | 0.012894 | 0.012894 | 0.013324 | 0.012249 | 0.011991 | 0.010315 |
| **21** | 0.006103 | 0.007722 | 0.007411 | 0.008108 | 0.008283 | 0.009009 | 0.008719 | 0.008719 | 0.009009 | 0.008283 | 0.008108 | 0.006975 |
| **22** | 0.005407 | 0.006842 | 0.006566 | 0.007184 | 0.007338 | 0.007982 | 0.007724 | 0.007724 | 0.007982 | 0.007338 | 0.007184 | 0.006180 |
| **23** | 0.002680 | 0.003391 | 0.003255 | 0.003561 | 0.003638 | 0.003957 | 0.003829 | 0.003829 | 0.003957 | 0.003638 | 0.003561 | 0.003063 |
| **24** | 0.002079 | 0.002631 | 0.002525 | 0.002763 | 0.002822 | 0.003069 | 0.002970 | 0.002970 | 0.003069 | 0.002822 | 0.002763 | 0.002376 |

| Monthly total | 6.5% | 7.4% | 7.8% | 8.3% | 8.8% | 9.2% | 9.2% | 9.2% | 9.2% | 8.8% | 8.3% | 7.4% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

## Hourly Load Percentage by hour of the day - for each day of the month

| Appliance Category | Water Heating | Appliance Type | Gas Instantaneous | Occu-pancy | All day |
|---|---|---|---|---|---|

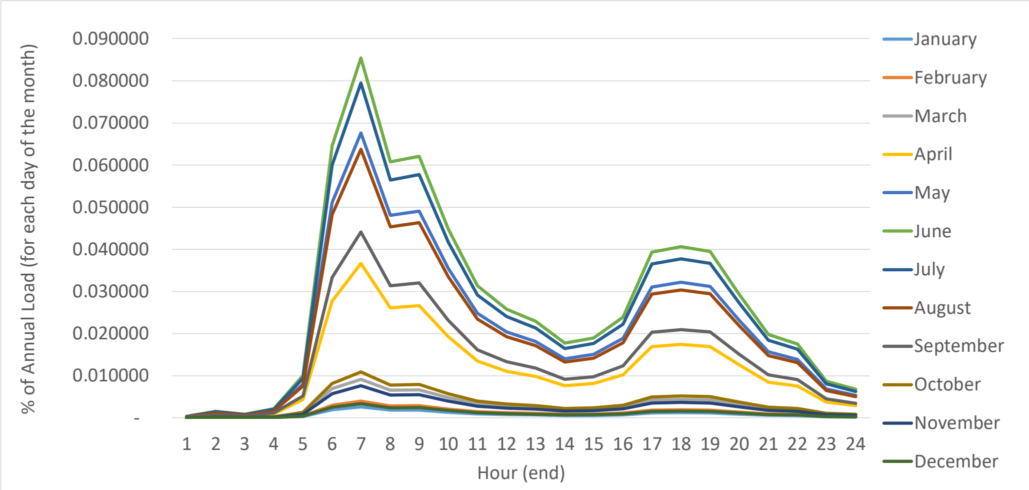



| Hour Ending | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.000107 | 0.000136 | 0.000130 | 0.000143 | 0.000146 | 0.000159 | 0.000153 | 0.000153 | 0.000159 | 0.000146 | 0.000143 | 0.000123 |
| 2 | 0.000477 | 0.000604 | 0.000579 | 0.000634 | 0.000648 | 0.000704 | 0.000682 | 0.000682 | 0.000704 | 0.000648 | 0.000634 | 0.000545 |
| 3 | 0.000254 | 0.000321 | 0.000308 | 0.000337 | 0.000345 | 0.000375 | 0.000363 | 0.000363 | 0.000375 | 0.000345 | 0.000337 | 0.000290 |
| 4 | 0.000669 | 0.000846 | 0.000812 | 0.000889 | 0.000908 | 0.000987 | 0.000956 | 0.000956 | 0.000987 | 0.000908 | 0.000889 | 0.000764 |
| 5 | 0.003108 | 0.003932 | 0.003774 | 0.004129 | 0.004218 | 0.004588 | 0.004440 | 0.004440 | 0.004588 | 0.004218 | 0.004129 | 0.003552 |
| 6 | 0.019922 | 0.025207 | 0.024191 | 0.026468 | 0.027037 | 0.029408 | 0.028460 | 0.028460 | 0.029408 | 0.027037 | 0.026468 | 0.022768 |
| 7 | 0.026357 | 0.033350 | 0.032005 | 0.035018 | 0.035771 | 0.038908 | 0.037653 | 0.037653 | 0.038908 | 0.035771 | 0.035018 | 0.030123 |
| 8 | 0.018737 | 0.023708 | 0.022752 | 0.024894 | 0.025429 | 0.027660 | 0.026767 | 0.026767 | 0.027660 | 0.025429 | 0.024894 | 0.021414 |
| 9 | 0.019148 | 0.024228 | 0.023251 | 0.025439 | 0.025986 | 0.028266 | 0.027354 | 0.027354 | 0.028266 | 0.025986 | 0.025439 | 0.021883 |
| 10 | 0.013829 | 0.017498 | 0.016792 | 0.018372 | 0.018768 | 0.020414 | 0.019755 | 0.019755 | 0.020414 | 0.018768 | 0.018372 | 0.015804 |
| 11 | 0.009664 | 0.012228 | 0.011734 | 0.012839 | 0.013115 | 0.014265 | 0.013805 | 0.013805 | 0.014265 | 0.013115 | 0.012839 | 0.011044 |
| 12 | 0.007964 | 0.010077 | 0.009670 | 0.010581 | 0.010808 | 0.011756 | 0.011377 | 0.011377 | 0.011756 | 0.010808 | 0.010581 | 0.009102 |
| 13 | 0.007065 | 0.008939 | 0.008579 | 0.009386 | 0.009588 | 0.010429 | 0.010093 | 0.010093 | 0.010429 | 0.009588 | 0.009386 | 0.008074 |
| 14 | 0.005469 | 0.006921 | 0.006641 | 0.007267 | 0.007423 | 0.008074 | 0.007814 | 0.007814 | 0.008074 | 0.007423 | 0.007267 | 0.006251 |
| 15 | 0.005856 | 0.007410 | 0.007111 | 0.007780 | 0.007947 | 0.008644 | 0.008366 | 0.008366 | 0.008644 | 0.007947 | 0.007780 | 0.006692 |
| 16 | 0.007365 | 0.009319 | 0.008944 | 0.009785 | 0.009996 | 0.010873 | 0.010522 | 0.010522 | 0.010873 | 0.009996 | 0.009785 | 0.008417 |
| 17 | 0.012126 | 0.015343 | 0.014725 | 0.016111 | 0.016457 | 0.017901 | 0.017323 | 0.017323 | 0.017901 | 0.016457 | 0.016111 | 0.013859 |
| 18 | 0.012531 | 0.015855 | 0.015216 | 0.016648 | 0.017006 | 0.018498 | 0.017901 | 0.017901 | 0.018498 | 0.017006 | 0.016648 | 0.014321 |
| 19 | 0.012173 | 0.015402 | 0.014781 | 0.016172 | 0.016520 | 0.017969 | 0.017390 | 0.017390 | 0.017969 | 0.016520 | 0.016172 | 0.013912 |
| 20 | 0.009026 | 0.011420 | 0.010960 | 0.011991 | 0.012249 | 0.013324 | 0.012894 | 0.012894 | 0.013324 | 0.012249 | 0.011991 | 0.010315 |
| 21 | 0.006103 | 0.007722 | 0.007411 | 0.008108 | 0.008283 | 0.009009 | 0.008719 | 0.008719 | 0.009009 | 0.008283 | 0.008108 | 0.006975 |
| 22 | 0.005407 | 0.006842 | 0.006566 | 0.007184 | 0.007338 | 0.007982 | 0.007724 | 0.007724 | 0.007982 | 0.007338 | 0.007184 | 0.006180 |
| 23 | 0.002680 | 0.003391 | 0.003255 | 0.003561 | 0.003638 | 0.003957 | 0.003829 | 0.003829 | 0.003957 | 0.003638 | 0.003561 | 0.003063 |
| 24 | 0.002079 | 0.002631 | 0.002525 | 0.002763 | 0.002822 | 0.003069 | 0.002970 | 0.002970 | 0.003069 | 0.002822 | 0.002763 | 0.002376 |

| Monthly total | 6.5% | 7.4% | 7.8% | 8.3% | 8.8% | 9.2% | 9.2% | 9.2% | 9.2% | 8.8% | 8.3% | 7.4% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

## Hourly Load Percentage by hour of the day - for each day of the month

| Appliance Category | Water Heating | Appliance Type | Solar Gas | Occu-pancy | All day |
|---|---|---|---|---|---|

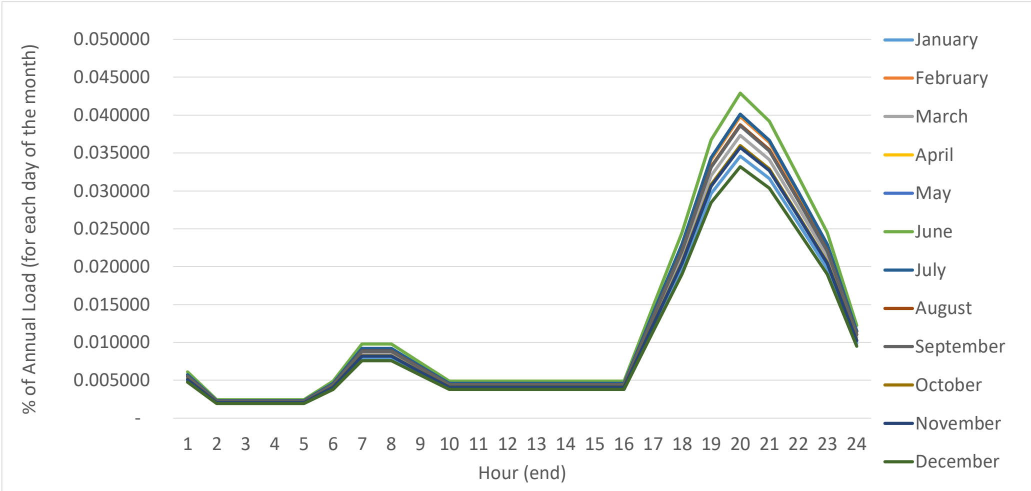



| Hour Ending | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.000010 | 0.000016 | 0.000037 | 0.000149 | 0.000275 | 0.000348 | 0.000324 | 0.000260 | 0.000180 | 0.000044 | 0.000031 | 0.000014 |
| 2 | 0.000047 | 0.000072 | 0.000166 | 0.000663 | 0.001223 | 0.001547 | 0.001438 | 0.001154 | 0.000798 | 0.000196 | 0.000138 | 0.000061 |
| 3 | 0.000025 | 0.000038 | 0.000088 | 0.000353 | 0.000651 | 0.000823 | 0.000765 | 0.000614 | 0.000425 | 0.000105 | 0.000073 | 0.000032 |
| 4 | 0.000065 | 0.000101 | 0.000233 | 0.000930 | 0.001715 | 0.002168 | 0.002016 | 0.001619 | 0.001119 | 0.000275 | 0.000193 | 0.000085 |
| 5 | 0.000304 | 0.000470 | 0.001083 | 0.004322 | 0.007969 | 0.010074 | 0.009366 | 0.007520 | 0.005198 | 0.001280 | 0.000896 | 0.000397 |
| 6 | 0.001947 | 0.003014 | 0.006943 | 0.027703 | 0.051082 | 0.064580 | 0.060036 | 0.048206 | 0.033319 | 0.008202 | 0.005742 | 0.002542 |
| 7 | 0.002576 | 0.003988 | 0.009186 | 0.036651 | 0.067583 | 0.085442 | 0.079430 | 0.063779 | 0.044082 | 0.010852 | 0.007597 | 0.003363 |
| 8 | 0.001831 | 0.002835 | 0.006530 | 0.026055 | 0.048044 | 0.060740 | 0.056466 | 0.045340 | 0.031338 | 0.007715 | 0.005401 | 0.002391 |
| 9 | 0.001871 | 0.002897 | 0.006673 | 0.026626 | 0.049097 | 0.062071 | 0.057704 | 0.046333 | 0.032024 | 0.007884 | 0.005519 | 0.002443 |
| 10 | 0.001352 | 0.002092 | 0.004820 | 0.019230 | 0.035459 | 0.044828 | 0.041674 | 0.033463 | 0.023128 | 0.005694 | 0.003986 | 0.001765 |
| 11 | 0.000944 | 0.001462 | 0.003368 | 0.013438 | 0.024779 | 0.031326 | 0.029122 | 0.023384 | 0.016162 | 0.003979 | 0.002785 | 0.001233 |
| 12 | 0.000778 | 0.001205 | 0.002776 | 0.011074 | 0.020420 | 0.025816 | 0.024000 | 0.019271 | 0.013319 | 0.003279 | 0.002295 | 0.001016 |
| 13 | 0.000690 | 0.001069 | 0.002462 | 0.009824 | 0.018115 | 0.022902 | 0.021291 | 0.017096 | 0.011816 | 0.002909 | 0.002036 | 0.000901 |
| 14 | 0.000535 | 0.000828 | 0.001906 | 0.007606 | 0.014024 | 0.017730 | 0.016483 | 0.013235 | 0.009148 | 0.002252 | 0.001577 | 0.000698 |
| 15 | 0.000572 | 0.000886 | 0.002041 | 0.008143 | 0.015015 | 0.018983 | 0.017647 | 0.014170 | 0.009794 | 0.002411 | 0.001688 | 0.000747 |
| 16 | 0.000720 | 0.001114 | 0.002567 | 0.010242 | 0.018885 | 0.023876 | 0.022196 | 0.017822 | 0.012318 | 0.003032 | 0.002123 | 0.000940 |
| 17 | 0.001185 | 0.001835 | 0.004226 | 0.016862 | 0.031093 | 0.039309 | 0.036544 | 0.029343 | 0.020281 | 0.004993 | 0.003495 | 0.001547 |
| 18 | 0.001225 | 0.001896 | 0.004367 | 0.017425 | 0.032131 | 0.040621 | 0.037763 | 0.030322 | 0.020958 | 0.005159 | 0.003612 | 0.001599 |
| 19 | 0.001190 | 0.001842 | 0.004242 | 0.016927 | 0.031213 | 0.039460 | 0.036684 | 0.029456 | 0.020359 | 0.005012 | 0.003509 | 0.001553 |
| 20 | 0.000882 | 0.001366 | 0.003146 | 0.012551 | 0.023143 | 0.029258 | 0.027200 | 0.021840 | 0.015095 | 0.003716 | 0.002602 | 0.001152 |
| 21 | 0.000596 | 0.000923 | 0.002127 | 0.008487 | 0.015649 | 0.019784 | 0.018392 | 0.014768 | 0.010207 | 0.002513 | 0.001759 | 0.000779 |
| 22 | 0.000528 | 0.000818 | 0.001884 | 0.007519 | 0.013864 | 0.017528 | 0.016295 | 0.013084 | 0.009043 | 0.002226 | 0.001559 | 0.000690 |
| 23 | 0.000262 | 0.000406 | 0.000934 | 0.003727 | 0.006873 | 0.008689 | 0.008077 | 0.006486 | 0.004483 | 0.001104 | 0.000773 | 0.000342 |
| 24 | 0.000203 | 0.000315 | 0.000725 | 0.002891 | 0.005332 | 0.006740 | 0.006266 | 0.005031 | 0.003478 | 0.000856 | 0.000599 | 0.000265 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monthly total | 0.6% | 0.9% | 2.2% | 8.7% | 16.5% | 20.2% | 19.4% | 15.6% | 10.4% | 2.7% | 1.8% | 0.8% |

## Hourly Load Percentage by hour of the day - for each day of the month

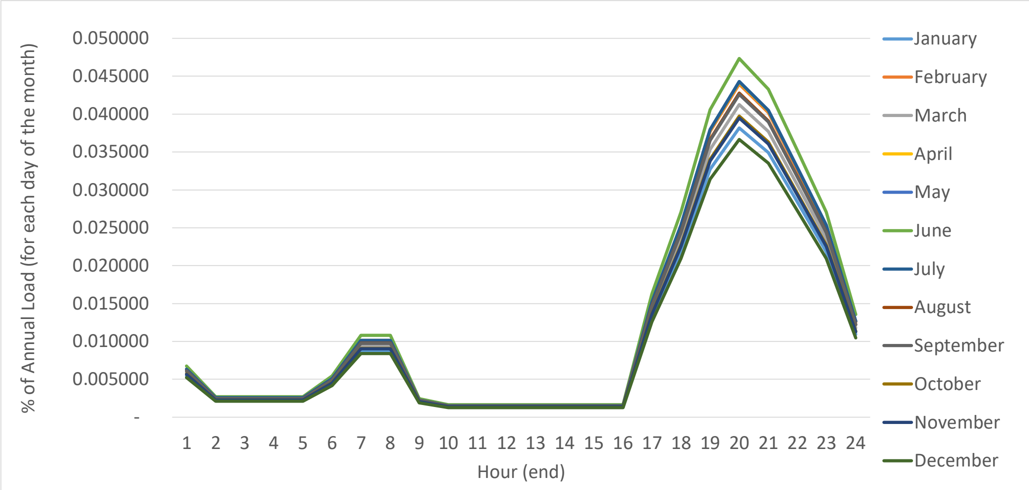
| Appliance Category | Lighting - All | Appliance Type | All | Occu-pancy | All day |
|---|---|---|---|---|---|




| Hour Ending | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.004939 | 0.005686 | 0.005334 | 0.005716 | 0.005729 | 0.006124 | 0.005729 | 0.005531 | 0.005511 | 0.005136 | 0.005103 | 0.004741 |
| 2 | 0.001975 | 0.002275 | 0.002133 | 0.002286 | 0.002292 | 0.002450 | 0.002292 | 0.002212 | 0.002205 | 0.002054 | 0.002041 | 0.001896 |
| 3 | 0.001975 | 0.002275 | 0.002133 | 0.002286 | 0.002292 | 0.002450 | 0.002292 | 0.002212 | 0.002205 | 0.002054 | 0.002041 | 0.001896 |
| 4 | 0.001975 | 0.002275 | 0.002133 | 0.002286 | 0.002292 | 0.002450 | 0.002292 | 0.002212 | 0.002205 | 0.002054 | 0.002041 | 0.001896 |
| 5 | 0.001975 | 0.002275 | 0.002133 | 0.002286 | 0.002292 | 0.002450 | 0.002292 | 0.002212 | 0.002205 | 0.002054 | 0.002041 | 0.001896 |
| 6 | 0.003951 | 0.004549 | 0.004267 | 0.004572 | 0.004583 | 0.004899 | 0.004583 | 0.004425 | 0.004409 | 0.004109 | 0.004083 | 0.003793 |
| 7 | 0.007902 | 0.009098 | 0.008534 | 0.009145 | 0.009166 | 0.009798 | 0.009166 | 0.008850 | 0.008818 | 0.008218 | 0.008165 | 0.007586 |
| 8 | 0.007902 | 0.009098 | 0.008534 | 0.009145 | 0.009166 | 0.009798 | 0.009166 | 0.008850 | 0.008818 | 0.008218 | 0.008165 | 0.007586 |
| 9 | 0.005926 | 0.006824 | 0.006400 | 0.006859 | 0.006875 | 0.007349 | 0.006875 | 0.006637 | 0.006614 | 0.006163 | 0.006124 | 0.005689 |
| 10 | 0.003951 | 0.004549 | 0.004267 | 0.004572 | 0.004583 | 0.004899 | 0.004583 | 0.004425 | 0.004409 | 0.004109 | 0.004083 | 0.003793 |
| 11 | 0.003951 | 0.004549 | 0.004267 | 0.004572 | 0.004583 | 0.004899 | 0.004583 | 0.004425 | 0.004409 | 0.004109 | 0.004083 | 0.003793 |
| 12 | 0.003951 | 0.004549 | 0.004267 | 0.004572 | 0.004583 | 0.004899 | 0.004583 | 0.004425 | 0.004409 | 0.004109 | 0.004083 | 0.003793 |
| 13 | 0.003951 | 0.004549 | 0.004267 | 0.004572 | 0.004583 | 0.004899 | 0.004583 | 0.004425 | 0.004409 | 0.004109 | 0.004083 | 0.003793 |
| 14 | 0.003951 | 0.004549 | 0.004267 | 0.004572 | 0.004583 | 0.004899 | 0.004583 | 0.004425 | 0.004409 | 0.004109 | 0.004083 | 0.003793 |
| 15 | 0.003951 | 0.004549 | 0.004267 | 0.004572 | 0.004583 | 0.004899 | 0.004583 | 0.004425 | 0.004409 | 0.004109 | 0.004083 | 0.003793 |
| 16 | 0.003951 | 0.004549 | 0.004267 | 0.004572 | 0.004583 | 0.004899 | 0.004583 | 0.004425 | 0.004409 | 0.004109 | 0.004083 | 0.003793 |
| 17 | 0.011853 | 0.013647 | 0.012801 | 0.013717 | 0.013749 | 0.014697 | 0.013749 | 0.013275 | 0.013228 | 0.012327 | 0.012248 | 0.011379 |
| 18 | 0.019754 | 0.022746 | 0.021335 | 0.022862 | 0.022915 | 0.024495 | 0.022915 | 0.022125 | 0.022046 | 0.020545 | 0.020413 | 0.018964 |
| 19 | 0.029632 | 0.034119 | 0.032002 | 0.034294 | 0.034373 | 0.036743 | 0.034373 | 0.033187 | 0.033069 | 0.030817 | 0.030619 | 0.028446 |
| 20 | 0.034570 | 0.039805 | 0.037336 | 0.040009 | 0.040101 | 0.042867 | 0.040101 | 0.038719 | 0.038580 | 0.035953 | 0.035722 | 0.033187 |
| 21 | 0.031607 | 0.036393 | 0.034136 | 0.036580 | 0.036664 | 0.039193 | 0.036664 | 0.035400 | 0.035273 | 0.032871 | 0.032661 | 0.030343 |
| 22 | 0.025681 | 0.029569 | 0.027735 | 0.029721 | 0.029790 | 0.031844 | 0.029790 | 0.028762 | 0.028660 | 0.026708 | 0.026537 | 0.024653 |
| 23 | 0.019754 | 0.022746 | 0.021335 | 0.022862 | 0.022915 | 0.024495 | 0.022915 | 0.022125 | 0.022046 | 0.020545 | 0.020413 | 0.018964 |
| 24 | 0.009877 | 0.011373 | 0.010667 | 0.011431 | 0.011458 | 0.012248 | 0.011458 | 0.011062 | 0.011023 | 0.010272 | 0.010206 | 0.009482 |
| Monthly total | 7.7% | 8.0% | 8.3% | 8.6% | 9.0% | 9.3% | 9.0% | 8.6% | 8.3% | 8.0% | 7.7% | 7.4% |

## Hourly Load Percentage by hour of the day - for each day of the month

| Appliance Category | Lighting - All | Appliance Type | All | Occu-pancy | Work day |
|---|---|---|---|---|---|

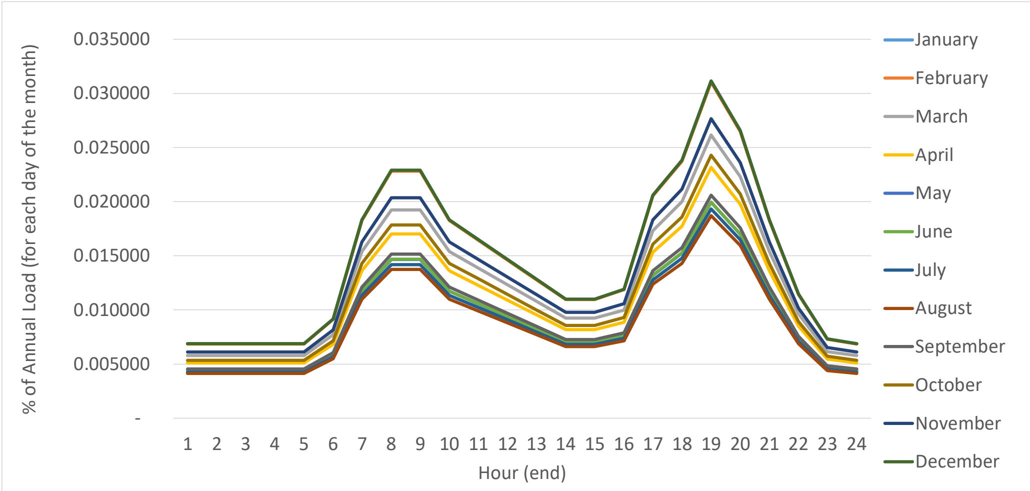



| Hour Ending | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.005454 | 0.006279 | 0.005890 | 0.006312 | 0.006326 | 0.006763 | 0.006326 | 0.006108 | 0.006086 | 0.005672 | 0.005635 | 0.005236 |
| 2 | 0.002181 | 0.002512 | 0.002356 | 0.002525 | 0.002530 | 0.002705 | 0.002530 | 0.002443 | 0.002435 | 0.002269 | 0.002254 | 0.002094 |
| 3 | 0.002181 | 0.002512 | 0.002356 | 0.002525 | 0.002530 | 0.002705 | 0.002530 | 0.002443 | 0.002435 | 0.002269 | 0.002254 | 0.002094 |
| 4 | 0.002181 | 0.002512 | 0.002356 | 0.002525 | 0.002530 | 0.002705 | 0.002530 | 0.002443 | 0.002435 | 0.002269 | 0.002254 | 0.002094 |
| 5 | 0.002181 | 0.002512 | 0.002356 | 0.002525 | 0.002530 | 0.002705 | 0.002530 | 0.002443 | 0.002435 | 0.002269 | 0.002254 | 0.002094 |
| 6 | 0.004363 | 0.005024 | 0.004712 | 0.005049 | 0.005061 | 0.005410 | 0.005061 | 0.004886 | 0.004869 | 0.004537 | 0.004508 | 0.004188 |
| 7 | 0.008726 | 0.010047 | 0.009424 | 0.010099 | 0.010122 | 0.010820 | 0.010122 | 0.009773 | 0.009738 | 0.009075 | 0.009017 | 0.008377 |
| 8 | 0.008726 | 0.010047 | 0.009424 | 0.010099 | 0.010122 | 0.010820 | 0.010122 | 0.009773 | 0.009738 | 0.009075 | 0.009017 | 0.008377 |
| 9 | 0.001963 | 0.002261 | 0.002120 | 0.002272 | 0.002277 | 0.002435 | 0.002277 | 0.002199 | 0.002191 | 0.002042 | 0.002029 | 0.001885 |
| 10 | 0.001309 | 0.001507 | 0.001414 | 0.001515 | 0.001518 | 0.001623 | 0.001518 | 0.001466 | 0.001461 | 0.001361 | 0.001353 | 0.001257 |
| 11 | 0.001309 | 0.001507 | 0.001414 | 0.001515 | 0.001518 | 0.001623 | 0.001518 | 0.001466 | 0.001461 | 0.001361 | 0.001353 | 0.001257 |
| 12 | 0.001309 | 0.001507 | 0.001414 | 0.001515 | 0.001518 | 0.001623 | 0.001518 | 0.001466 | 0.001461 | 0.001361 | 0.001353 | 0.001257 |
| 13 | 0.001309 | 0.001507 | 0.001414 | 0.001515 | 0.001518 | 0.001623 | 0.001518 | 0.001466 | 0.001461 | 0.001361 | 0.001353 | 0.001257 |
| 14 | 0.001309 | 0.001507 | 0.001414 | 0.001515 | 0.001518 | 0.001623 | 0.001518 | 0.001466 | 0.001461 | 0.001361 | 0.001353 | 0.001257 |
| 15 | 0.001309 | 0.001507 | 0.001414 | 0.001515 | 0.001518 | 0.001623 | 0.001518 | 0.001466 | 0.001461 | 0.001361 | 0.001353 | 0.001257 |
| 16 | 0.001309 | 0.001507 | 0.001414 | 0.001515 | 0.001518 | 0.001623 | 0.001518 | 0.001466 | 0.001461 | 0.001361 | 0.001353 | 0.001257 |
| 17 | 0.013089 | 0.015071 | 0.014136 | 0.015148 | 0.015183 | 0.016230 | 0.015183 | 0.014659 | 0.014607 | 0.013612 | 0.013525 | 0.012565 |
| 18 | 0.021815 | 0.025118 | 0.023560 | 0.025247 | 0.025305 | 0.027050 | 0.025305 | 0.024432 | 0.024345 | 0.022687 | 0.022542 | 0.020942 |
| 19 | 0.032722 | 0.037677 | 0.035340 | 0.037870 | 0.037957 | 0.040575 | 0.037957 | 0.036649 | 0.036518 | 0.034031 | 0.033813 | 0.031413 |
| 20 | 0.038176 | 0.043956 | 0.041230 | 0.044182 | 0.044284 | 0.047338 | 0.044284 | 0.042757 | 0.042604 | 0.039703 | 0.039448 | 0.036649 |
| 21 | 0.034903 | 0.040189 | 0.037696 | 0.040395 | 0.040488 | 0.043280 | 0.040488 | 0.039092 | 0.038952 | 0.036300 | 0.036067 | 0.033507 |
| 22 | 0.028359 | 0.032653 | 0.030628 | 0.032821 | 0.032896 | 0.035165 | 0.032896 | 0.031762 | 0.031649 | 0.029493 | 0.029304 | 0.027225 |
| 23 | 0.021815 | 0.025118 | 0.023560 | 0.025247 | 0.025305 | 0.027050 | 0.025305 | 0.024432 | 0.024345 | 0.022687 | 0.022542 | 0.020942 |
| 24 | 0.010907 | 0.012559 | 0.011780 | 0.012623 | 0.012652 | 0.013525 | 0.012652 | 0.012216 | 0.012173 | 0.011344 | 0.011271 | 0.010471 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monthly total | 7.7% | 8.0% | 8.3% | 8.6% | 9.0% | 9.3% | 9.0% | 8.6% | 8.3% | 8.0% | 7.7% | 7.4% |

## Hourly Load Percentage by hour of the day - for each day of the month

| Appliance Category | Pool pump | Appliance Type | 50 kL pool | Occu-pancy | All day |
|---|---|---|---|---|---|

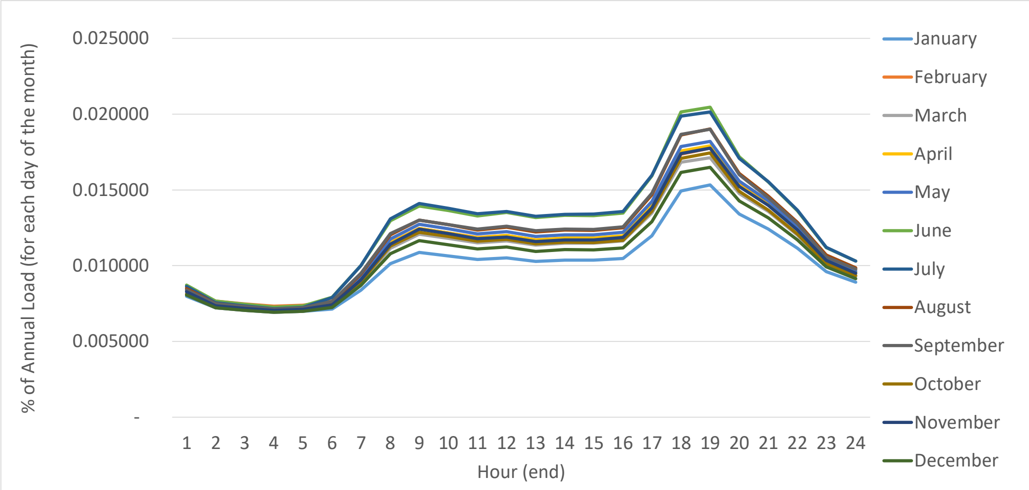



| Hour Ending | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.006869 | 0.006845 | 0.005770 | 0.005111 | 0.004396 | 0.004401 | 0.004259 | 0.004122 | 0.004543 | 0.005358 | 0.006104 | 0.006869 |
| 2 | 0.006869 | 0.006845 | 0.005770 | 0.005111 | 0.004396 | 0.004401 | 0.004259 | 0.004122 | 0.004543 | 0.005358 | 0.006104 | 0.006869 |
| 3 | 0.006869 | 0.006845 | 0.005770 | 0.005111 | 0.004396 | 0.004401 | 0.004259 | 0.004122 | 0.004543 | 0.005358 | 0.006104 | 0.006869 |
| 4 | 0.006869 | 0.006845 | 0.005770 | 0.005111 | 0.004396 | 0.004401 | 0.004259 | 0.004122 | 0.004543 | 0.005358 | 0.006104 | 0.006869 |
| 5 | 0.006869 | 0.006845 | 0.005770 | 0.005111 | 0.004396 | 0.004401 | 0.004259 | 0.004122 | 0.004543 | 0.005358 | 0.006104 | 0.006869 |
| 6 | 0.009159 | 0.009126 | 0.007693 | 0.006814 | 0.005862 | 0.005868 | 0.005679 | 0.005495 | 0.006057 | 0.007144 | 0.008139 | 0.009159 |
| 7 | 0.018318 | 0.018252 | 0.015387 | 0.013628 | 0.011723 | 0.011736 | 0.011357 | 0.010991 | 0.012114 | 0.014288 | 0.016278 | 0.018318 |
| 8 | 0.022897 | 0.022816 | 0.019234 | 0.017036 | 0.014654 | 0.014670 | 0.014196 | 0.013738 | 0.015143 | 0.017860 | 0.020348 | 0.022897 |
| 9 | 0.022897 | 0.022816 | 0.019234 | 0.017036 | 0.014654 | 0.014670 | 0.014196 | 0.013738 | 0.015143 | 0.017860 | 0.020348 | 0.022897 |
| 10 | 0.018318 | 0.018252 | 0.015387 | 0.013628 | 0.011723 | 0.011736 | 0.011357 | 0.010991 | 0.012114 | 0.014288 | 0.016278 | 0.018318 |
| 11 | 0.016486 | 0.016427 | 0.013848 | 0.012266 | 0.010551 | 0.010562 | 0.010221 | 0.009892 | 0.010903 | 0.012859 | 0.014651 | 0.016486 |
| 12 | 0.014654 | 0.014602 | 0.012310 | 0.010903 | 0.009379 | 0.009388 | 0.009086 | 0.008793 | 0.009691 | 0.011430 | 0.013023 | 0.014654 |
| 13 | 0.012822 | 0.012777 | 0.010771 | 0.009540 | 0.008206 | 0.008215 | 0.007950 | 0.007693 | 0.008480 | 0.010002 | 0.011395 | 0.012822 |
| 14 | 0.010991 | 0.010951 | 0.009232 | 0.008177 | 0.007034 | 0.007041 | 0.006814 | 0.006594 | 0.007269 | 0.008573 | 0.009767 | 0.010991 |
| 15 | 0.010991 | 0.010951 | 0.009232 | 0.008177 | 0.007034 | 0.007041 | 0.006814 | 0.006594 | 0.007269 | 0.008573 | 0.009767 | 0.010991 |
| 16 | 0.011907 | 0.011864 | 0.010002 | 0.008859 | 0.007620 | 0.007628 | 0.007382 | 0.007144 | 0.007874 | 0.009287 | 0.010581 | 0.011907 |
| 17 | 0.020608 | 0.020534 | 0.017310 | 0.015332 | 0.013189 | 0.013203 | 0.012777 | 0.012365 | 0.013628 | 0.016074 | 0.018313 | 0.020608 |
| 18 | 0.023813 | 0.023728 | 0.020003 | 0.017717 | 0.015240 | 0.015256 | 0.014764 | 0.014288 | 0.015748 | 0.018574 | 0.021162 | 0.023813 |
| 19 | 0.031140 | 0.031029 | 0.026158 | 0.023168 | 0.019930 | 0.019951 | 0.019307 | 0.018684 | 0.020594 | 0.024289 | 0.027673 | 0.031140 |
| 20 | 0.026561 | 0.026466 | 0.022311 | 0.019761 | 0.016999 | 0.017017 | 0.016468 | 0.015937 | 0.017566 | 0.020717 | 0.023604 | 0.026561 |
| 21 | 0.018318 | 0.018252 | 0.015387 | 0.013628 | 0.011723 | 0.011736 | 0.011357 | 0.010991 | 0.012114 | 0.014288 | 0.016278 | 0.018318 |
| 22 | 0.011449 | 0.011408 | 0.009617 | 0.008518 | 0.007327 | 0.007335 | 0.007098 | 0.006869 | 0.007571 | 0.008930 | 0.010174 | 0.011449 |
| 23 | 0.007327 | 0.007301 | 0.006155 | 0.005451 | 0.004689 | 0.004694 | 0.004543 | 0.004396 | 0.004846 | 0.005715 | 0.006511 | 0.007327 |
| 24 | 0.006869 | 0.006845 | 0.005770 | 0.005111 | 0.004396 | 0.004401 | 0.004259 | 0.004122 | 0.004543 | 0.005358 | 0.006104 | 0.006869 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monthly total | 10.8% | 9.8% | 9.1% | 7.8% | 6.9% | 6.7% | 6.7% | 6.5% | 6.9% | 8.5% | 9.3% | 10.8% |

## Hourly Load Percentage by hour of the day - for each day of the month

| Appliance Category | All Plug Loads | Appliance Type | All plug loads | Occu-pancy | All day |
|---|---|---|---|---|---|



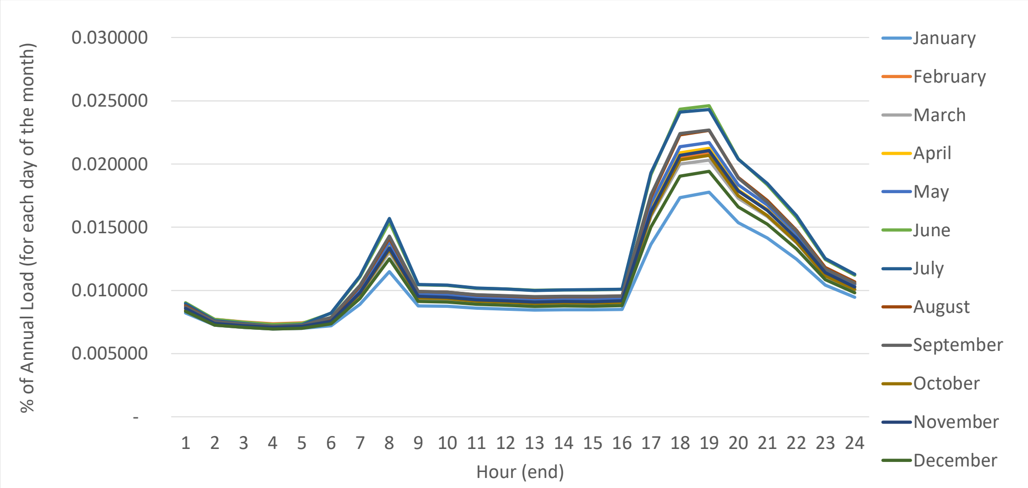

| Hour Ending | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.007978 | 0.008571 | 0.008076 | 0.008305 | 0.008301 | 0.008715 | 0.008631 | 0.008473 | 0.008405 | 0.008129 | 0.008267 | 0.008046 |
| 2 | 0.007206 | 0.007649 | 0.007206 | 0.007390 | 0.007340 | 0.007668 | 0.007565 | 0.007475 | 0.007483 | 0.007251 | 0.007344 | 0.007206 |
| 3 | 0.007037 | 0.007463 | 0.007037 | 0.007208 | 0.007150 | 0.007440 | 0.007337 | 0.007262 | 0.007286 | 0.007075 | 0.007170 | 0.007037 |
| 4 | 0.006910 | 0.007322 | 0.006910 | 0.007069 | 0.007000 | 0.007255 | 0.007150 | 0.007090 | 0.007131 | 0.006940 | 0.007038 | 0.006910 |
| 5 | 0.006974 | 0.007392 | 0.006974 | 0.007139 | 0.007075 | 0.007347 | 0.007243 | 0.007176 | 0.007208 | 0.007007 | 0.007104 | 0.006974 |
| 6 | 0.007127 | 0.007662 | 0.007307 | 0.007468 | 0.007464 | 0.007905 | 0.007876 | 0.007576 | 0.007639 | 0.007326 | 0.007402 | 0.007226 |
| 7 | 0.008380 | 0.009251 | 0.008884 | 0.009135 | 0.009227 | 0.010001 | 0.010002 | 0.009440 | 0.009485 | 0.008953 | 0.009050 | 0.008691 |
| 8 | 0.010132 | 0.011515 | 0.011153 | 0.011505 | 0.011752 | 0.012949 | 0.013076 | 0.012035 | 0.012103 | 0.011293 | 0.011417 | 0.010787 |
| 9 | 0.010875 | 0.012452 | 0.012060 | 0.012444 | 0.012731 | 0.013930 | 0.014084 | 0.012993 | 0.012999 | 0.012195 | 0.012403 | 0.011648 |
| 10 | 0.010635 | 0.012162 | 0.011787 | 0.012157 | 0.012436 | 0.013630 | 0.013781 | 0.012698 | 0.012715 | 0.011913 | 0.012104 | 0.011380 |
| 11 | 0.010405 | 0.011858 | 0.011491 | 0.011842 | 0.012093 | 0.013277 | 0.013413 | 0.012351 | 0.012404 | 0.011602 | 0.011768 | 0.011098 |
| 12 | 0.010514 | 0.011987 | 0.011626 | 0.011995 | 0.012228 | 0.013504 | 0.013578 | 0.012533 | 0.012612 | 0.011738 | 0.011894 | 0.011214 |
| 13 | 0.010272 | 0.011690 | 0.011351 | 0.011696 | 0.011915 | 0.013183 | 0.013254 | 0.012212 | 0.012306 | 0.011433 | 0.011577 | 0.010937 |
| 14 | 0.010356 | 0.011805 | 0.011469 | 0.011815 | 0.012042 | 0.013310 | 0.013388 | 0.012333 | 0.012413 | 0.011542 | 0.011702 | 0.011042 |
| 15 | 0.010349 | 0.011802 | 0.011471 | 0.011808 | 0.012043 | 0.013290 | 0.013389 | 0.012318 | 0.012382 | 0.011529 | 0.011700 | 0.011038 |
| 16 | 0.010467 | 0.011948 | 0.011612 | 0.011961 | 0.012199 | 0.013474 | 0.013560 | 0.012489 | 0.012550 | 0.011677 | 0.011853 | 0.011172 |
| 17 | 0.011958 | 0.013825 | 0.013479 | 0.013942 | 0.014231 | 0.015924 | 0.015942 | 0.014658 | 0.014771 | 0.013596 | 0.013797 | 0.012901 |
| 18 | 0.014921 | 0.017351 | 0.016809 | 0.017550 | 0.017864 | 0.020126 | 0.019850 | 0.018623 | 0.018667 | 0.017090 | 0.017392 | 0.016135 |
| 19 | 0.015324 | 0.017751 | 0.017124 | 0.017902 | 0.018206 | 0.020456 | 0.020138 | 0.019008 | 0.018990 | 0.017429 | 0.017750 | 0.016492 |
| 20 | 0.013396 | 0.015340 | 0.014745 | 0.015313 | 0.015576 | 0.017182 | 0.017087 | 0.016084 | 0.016001 | 0.014908 | 0.015220 | 0.014264 |
| 21 | 0.012405 | 0.014128 | 0.013564 | 0.014018 | 0.014262 | 0.015512 | 0.015535 | 0.014596 | 0.014481 | 0.013643 | 0.013971 | 0.013146 |
| 22 | 0.011143 | 0.012549 | 0.012017 | 0.012390 | 0.012579 | 0.013614 | 0.013657 | 0.012849 | 0.012766 | 0.012075 | 0.012332 | 0.011695 |
| 23 | 0.009601 | 0.010602 | 0.010079 | 0.010373 | 0.010486 | 0.011186 | 0.011207 | 0.010692 | 0.010581 | 0.010124 | 0.010329 | 0.009906 |
| 24 | 0.008907 | 0.009769 | 0.009284 | 0.009555 | 0.009651 | 0.010301 | 0.010308 | 0.009863 | 0.009760 | 0.009337 | 0.009501 | 0.009147 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monthly total | 7.5% | 7.7% | 8.2% | 8.2% | 8.6% | 9.0% | 9.3% | 8.8% | 8.5% | 8.2% | 8.1% | 7.9% |

Also includes electrical cooking loads

Hourly Load Percentage by hour of the day - for each day of the month

| Appliance Category | All Plug Loads | Appliance Type | All plug loads | Occu-pancy | Work day |
|---|---|---|---|---|---|




| Hour Ending | January | February | March | April | May | June | July | August | September | October | November | December |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.008231 | 0.008880 | 0.008372 | 0.008610 | 0.008616 | 0.009037 | 0.008959 | 0.008785 | 0.008700 | 0.008421 | 0.008582 | 0.008328 |
| 2 | 0.007253 | 0.007701 | 0.007253 | 0.007439 | 0.007388 | 0.007717 | 0.007612 | 0.007522 | 0.007532 | 0.007298 | 0.007392 | 0.007253 |
| 3 | 0.007073 | 0.007502 | 0.007073 | 0.007245 | 0.007185 | 0.007477 | 0.007372 | 0.007297 | 0.007322 | 0.007110 | 0.007206 | 0.007073 |
| 4 | 0.006946 | 0.007361 | 0.006946 | 0.007106 | 0.007035 | 0.007291 | 0.007185 | 0.007125 | 0.007168 | 0.006976 | 0.007075 | 0.006946 |
| 5 | 0.007009 | 0.007432 | 0.007009 | 0.007175 | 0.007110 | 0.007384 | 0.007278 | 0.007211 | 0.007245 | 0.007043 | 0.007141 | 0.007009 |
| 6 | 0.007212 | 0.007810 | 0.007490 | 0.007648 | 0.007672 | 0.008196 | 0.008207 | 0.007784 | 0.007869 | 0.007500 | 0.007566 | 0.007365 |
| 7 | 0.008902 | 0.009976 | 0.009652 | 0.009928 | 0.010086 | 0.011059 | 0.011126 | 0.010319 | 0.010400 | 0.009734 | 0.009828 | 0.009366 |
| 8 | 0.011499 | 0.013344 | 0.013026 | 0.013454 | 0.013841 | 0.015423 | 0.015683 | 0.014163 | 0.014305 | 0.013234 | 0.013364 | 0.012489 |
| 9 | 0.008782 | 0.009718 | 0.009301 | 0.009579 | 0.009696 | 0.010447 | 0.010471 | 0.009910 | 0.009904 | 0.009399 | 0.009525 | 0.009121 |
| 10 | 0.008744 | 0.009670 | 0.009254 | 0.009531 | 0.009644 | 0.010395 | 0.010417 | 0.009859 | 0.009858 | 0.009353 | 0.009474 | 0.009077 |
| 11 | 0.008590 | 0.009478 | 0.009072 | 0.009336 | 0.009437 | 0.010178 | 0.010194 | 0.009646 | 0.009662 | 0.009160 | 0.009270 | 0.008899 |
| 12 | 0.008519 | 0.009394 | 0.009001 | 0.009262 | 0.009352 | 0.010116 | 0.010113 | 0.009571 | 0.009599 | 0.009077 | 0.009181 | 0.008820 |
| 13 | 0.008446 | 0.009305 | 0.008920 | 0.009171 | 0.009255 | 0.010013 | 0.010007 | 0.009468 | 0.009503 | 0.008983 | 0.009086 | 0.008737 |
| 14 | 0.008471 | 0.009339 | 0.008954 | 0.009206 | 0.009292 | 0.010046 | 0.010043 | 0.009501 | 0.009534 | 0.009016 | 0.009123 | 0.008768 |
| 15 | 0.008462 | 0.009335 | 0.008957 | 0.009203 | 0.009294 | 0.010046 | 0.010052 | 0.009498 | 0.009519 | 0.009005 | 0.009120 | 0.008763 |
| 16 | 0.008497 | 0.009378 | 0.008998 | 0.009248 | 0.009340 | 0.010101 | 0.010103 | 0.009549 | 0.009568 | 0.009049 | 0.009164 | 0.008802 |
| 17 | 0.013637 | 0.016098 | 0.015856 | 0.016398 | 0.016858 | 0.019132 | 0.019280 | 0.017363 | 0.017556 | 0.015983 | 0.016204 | 0.015005 |
| 18 | 0.017339 | 0.020501 | 0.020011 | 0.020903 | 0.021380 | 0.024344 | 0.024104 | 0.022297 | 0.022413 | 0.020345 | 0.020700 | 0.019045 |
| 19 | 0.017782 | 0.020918 | 0.020315 | 0.021250 | 0.021701 | 0.024605 | 0.024299 | 0.022659 | 0.022698 | 0.020679 | 0.021064 | 0.019415 |
| 20 | 0.015360 | 0.017873 | 0.017294 | 0.017963 | 0.018358 | 0.020408 | 0.020380 | 0.018938 | 0.018872 | 0.017475 | 0.017862 | 0.016598 |
| 21 | 0.014164 | 0.016401 | 0.015851 | 0.016379 | 0.016751 | 0.018341 | 0.018462 | 0.017113 | 0.016987 | 0.015923 | 0.016339 | 0.015238 |
| 22 | 0.012478 | 0.014280 | 0.013764 | 0.014188 | 0.014480 | 0.015778 | 0.015914 | 0.014761 | 0.014679 | 0.013813 | 0.014133 | 0.013289 |
| 23 | 0.010407 | 0.011639 | 0.011117 | 0.011437 | 0.011612 | 0.012430 | 0.012514 | 0.011811 | 0.011684 | 0.011151 | 0.011407 | 0.010860 |
| 24 | 0.009472 | 0.010509 | 0.010032 | 0.010322 | 0.010470 | 0.011215 | 0.011274 | 0.010677 | 0.010563 | 0.010080 | 0.010278 | 0.009829 |

| Monthly total | 7.5% | 7.7% | 8.2% | 8.2% | 8.6% | 9.0% | 9.3% | 8.8% | 8.5% | 8.2% | 8.1% | 7.9% |
|---|---|---|---|---|---|---|---|---|---|---|---|---|

Also includes electrical cooking loads

## *10.3 Appendix 3 – Water Heaters – Basis for Energy Estimates*

(This appendix is an updated extract from the SV Cost Calculator Documentation)

### 10.3.1 Overall Parameters Assumed for Hot Water Modelling

To model energy consumption of water heaters, a large number of assumptions have to be made. In general terms, most assumptions are in accordance with AS/NZS4234: 2008 *Heated Water Systems – Calculation of energy consumption*, which is the standard used to simulate energy consumption for most systems modelled. The main parameters assumed for all water heater types are set out in this section.

Daily load profile assumed is given in Table 46. This draw off profile is usually described as "flat". Draw off profile has little impact on energy consumption for most water heater types. The exceptions are larger electric storage on off peak (where the impact of draw off pattern is generally small, with morning hot water load reducing heat losses slightly) and solar thermal systems on off peak controlled load tariff (where impacts are more significant, with morning hot water load having substantially better performance than evening hot water load). For modelling purposes the flat load profile has been used.

**Table 46: Daily share of hot water draw off by time of day**

| Hour | Hot water load |
|---|---|
| 7:00 | 0.150 |
| 8:00 | 0.150 |
| 11:00 | 0.100 |
| 13:00 | 0.100 |
| 15:00 | 0.125 |
| 16:00 | 0.125 |
| 17:00 | 0.125 |
| 18:00 | 0.125 |

Table notes: Hot water load sums to 1.000. Source: Table A4 AS/NZS4234.

The seasonal load profile assumed is set out in Table 47. The fall in energy demand for hot water in summer is driven by an increase in cold water temperature in warmer months as well as a reduction in hot water volumes.

**Table 47: Seasonal load factors for hot water demand**

| Month | Seasonal factor |
|---|---|
| Jan | 0.7 |
| Feb | 0.8 |
| Mar | 0.85 |
| Apr | 0.9 |
| May | 0.95 |
| Jun | 1 |
| Jul | 1 |
| Aug | 1 |
| Sep | 1 |
| Oct | 0.95 |
| Nov | 0.9 |
| Dec | 0.8 |

Table notes: Hot water draw-off is defined as MJ/day demand in winter months. Source: Table A5 AS/NZS4234.

Actual hot water use is generally poorly documented in Australia. There are just a handful of studies that monitor hot water consumption in the home (directly or indirectly). Despite the lack of dedicated end use metering data for water heaters, there is a large body of controlled load data for electric storage water heaters, as these systems have been very prevalent for a long time in Australia. However, access to this data is becoming increasingly difficult over time. Some limited utility data for controlled loads in SA and NSW has been compared. This represents data from around 500,000 residential customers.

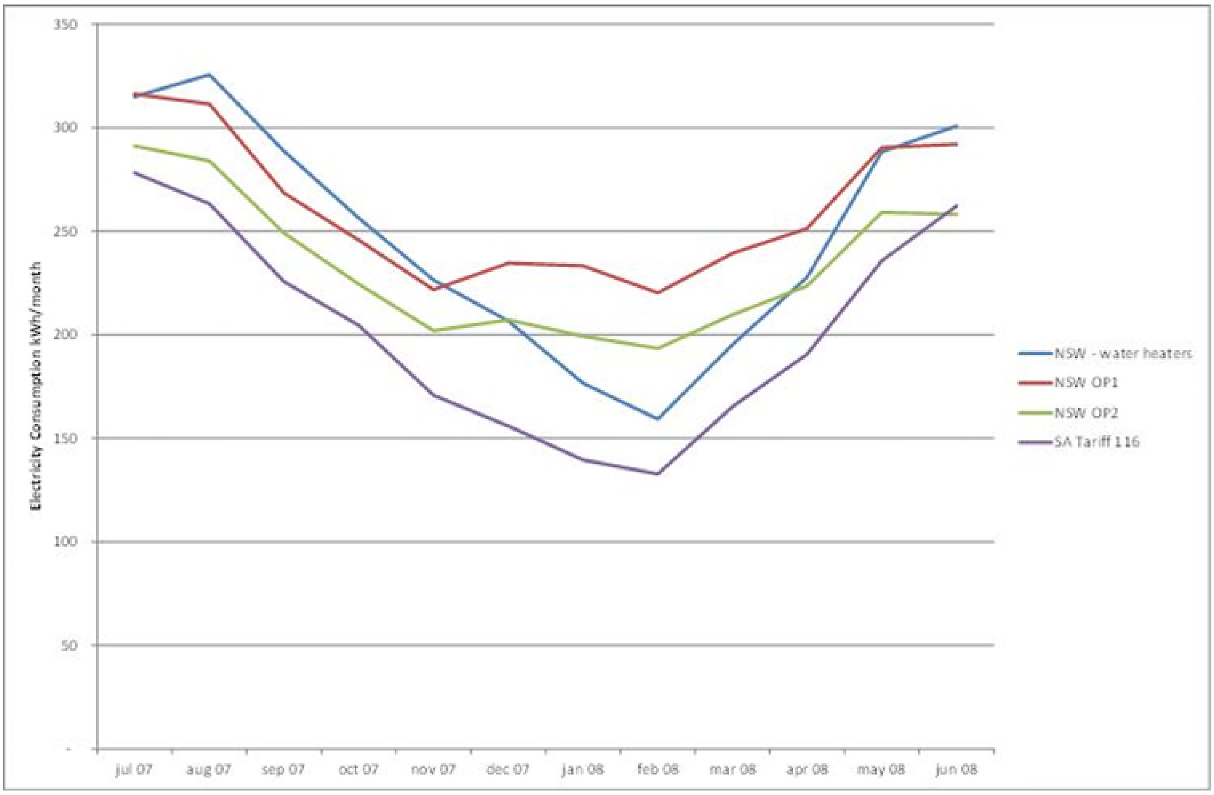



**Figure 17: Comparison of controlled load data from various utility sources**

Source: AUSGRID 2012 and utility sources.

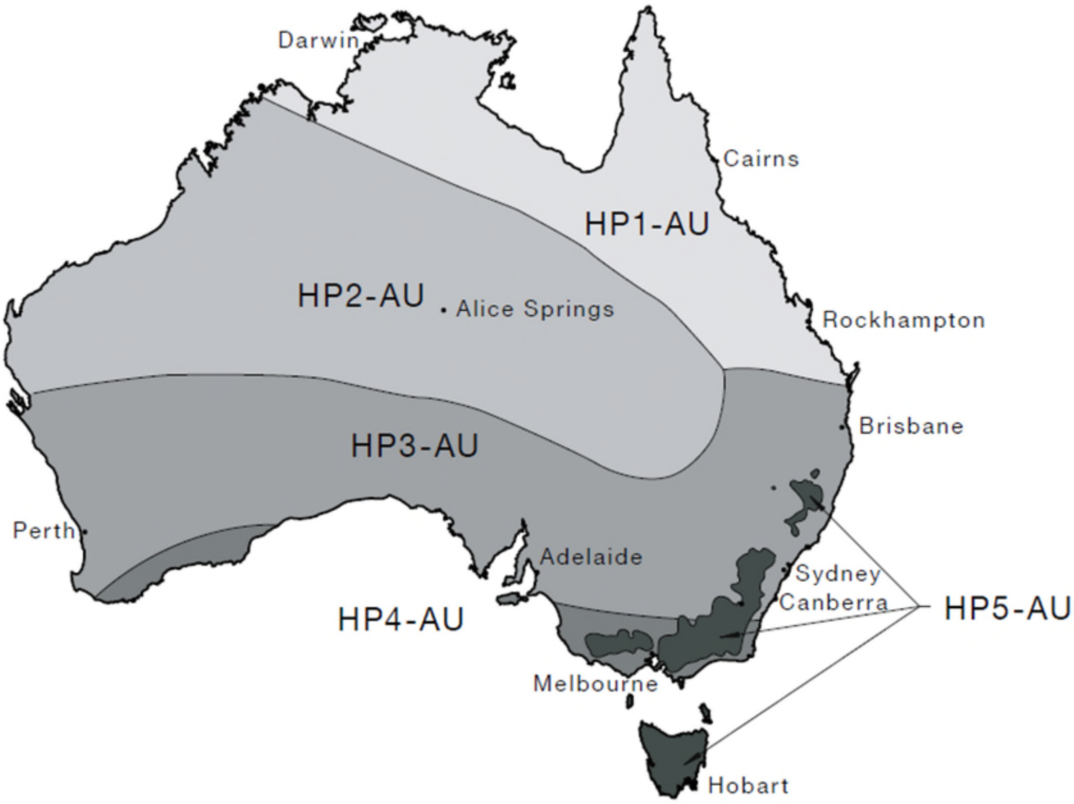
Data from the University of South Australia (Whaley et al. 2014) suggests that the seasonal profile in real homes (based on 12 houses in Adelaide) (summer = 0.51 winter) is slightly more pronounced that the assumed profile in AS/NZS4234 (summer = 0.7 winter). The utility data in Figure 17 suggests a seasonal hot water pattern of about 0.6 in summer when compared to the winter peak, once the data is corrected for heat losses. So the seasonal pattern in AS/NZS4234 is a reasonable approximation, but may be slightly understated, which may result in a very small overestimate of energy consumption. For the purposes of modelling, AS4234 values have been used.

AS/NZS4234 defines hourly hot water load as:

Hourly hot water load = Winter peak load × seasonal factor x hourly share

For water heater modelling, AS/NZS4234 defines four climate zones for most water heater types and five climate zones for heat pump water heaters. The five climate zones for heat pumps are depicted in Figure 18. Heat pump zones and other zones are the same except for areas excised by HP5-AU (some of Zone 3 and Zone 4), which includes the southern part of the Great Dividing Range and Tasmania.

**Figure 18: AS/NZS4234 Amendment 3: heat pump climate zones**




Reference climates for each zone are:

- Zone 1 = HP1-AU = reference climate Rockhampton
- Zone 2 = HP2-AU = reference climate Alice Springs
- Zone 3 = HP3-AU = reference climate Sydney
- Zone 4 = HP4-AU = reference climate Melbourne
- HP5-AU = reference climate Canberra

Another critical parameter is the cold water temperature and how this varies throughout the year. Cold water inlet temperatures are defined as an average temperature by month by climate zone as set out in Table 48.

**Table 48: Monthly cold water inlet temperatures by climate (°C)**

| Month | Zone 1 | Zone 2 | Zone 3 | Zone 4 | Zone HP5-AU |
|---|---|---|---|---|---|
| Jan | 28 | 29 | 23 | 20 | 18 |
| Feb | 28 | 27 | 23 | 20 | 18 |
| Mar | 27 | 24 | 21 | 18 | 19 |
| Apr | 25 | 20 | 18 | 15 | 15 |
| May | 23 | 14 | 15 | 11 | 13 |
| Jun | 20 | 11 | 12 | 9 | 9 |
| Jul | 20 | 9 | 11 | 8 | 5 |
| Aug | 21 | 12 | 12 | 10 | 5 |

| | | | | | |
|---|---|---|---|---|---|
| Sep | 24 | 18 | 15 | 12 | 7 |
| Oct | 26 | 23 | 19 | 15 | 8 |
| Nov | 28 | 26 | 21 | 17 | 12 |
| Dec | 28 | 28 | 22 | 19 | 16 |
| Average** | 22.2 | 17.6 | 15.6 | 12.8 | 10.5 |
| Average | 24.8 | 20.1 | 17.7 | 14.5 | 12.1 |

Notes: Cold water temperature is in degrees Celsius. Source: Table A6 AS/NZS4234. ** is a weighted average temperature based on temperature times monthly weighting in Table 47.

The University of South Australia research data (Whaley et al. 2014) suggests that cold water supply temperatures in Adelaide are around 2°C warmer than the assumed supply temperature in AS/NZS4234 for Zone 3 (which is applicable to Adelaide). Limited monitoring in Melbourne by Sustainability Victoria (Sustainability Victoria 2016) also suggests that the AS/NZS4234 assumed supply temperature specified in AS/NZS4234 for Zone 4 is perhaps a little colder than would be expected in normal homes in Melbourne (also by around 2K). However, for modelling purposes, the cold water temperatures in AS/NZS4234 have been used. Note that the assumed cold water temperature has only a small impact on modelling as hot water demand is defined as energy delivered in the hot water. It does, however, have some impact on the calculated volume of hot water delivered (in litres).

For instantaneous systems, AS/NZS4234 specifies the number of separate hot water events per day. This is important as the start-up heat capacity is applied for each separate hot water event. This reflects the energy wasted in the water heater to heat up components and water from cold before useful hot water is delivered. This parameter applies to instantaneous gas and electric systems, but not storage systems.

AS/NZS4234 defines five hot water demand levels, ranging from Very Small (12 to 17 MJ/day, depending on climate) to Large (45 to 63 MJ/day, depending on climate). The modelling conducted for this analysis did not use the pre-defined hot water demand levels in the standard. Instead, a series of fixed hot water loads were applied to all systems in all climates. These were:

- 0 MJ/day winter peak load
- 20 MJ/day winter peak load
- 40 MJ/day winter peak load
- 60 MJ/day winter peak load.

For this modelling, all other parameters defined in the standard were applied. This approach allowed the annual energy input of each type of water heater to be estimated for any daily winter peak load in any climate. This provided a more flexible and realistic approach to estimating hot water energy consumption for different system types under real world usage conditions. Under the standard, solar water heaters are required to reach 60% solar contribution in Zone 3 (Clause 3.4). This limitation was not applied to the modelling.

### *10.3.2 Star Rating Equation Parameters for Gas Water Heaters*

Gas water heaters have a star rating under the AGA system, which nominally runs from 1 to 6 stars (AS4552 2005).

Base energy consumption for a 1 star water heater is 28,900 MJ/year. An additional star is achieved for each 7% reduction in base energy consumption (i.e. for each 2023 MJ/year reduction in energy). Unlike electrical appliance star ratings, the energy step sizes for gas water heaters remain equal through the progression. The energy delivered under the test method is 200 litres of water at 60°C (temperature rise of 45K from a cold water temperature of 15°C), which is 37.7MJ per day or 13,761 MJ per annum.

In 2013 national regulations were introduced requiring a minimum 4 star rating (AS/NZS4552.2 2010), effectively setting a maximum energy consumption of less than or equal to 22,831 MJ/year under the gas labelling scheme.

The key parameters that determine the overall efficiency of gas water heaters are:

- Maintenance rate (storage water heaters only)
- Burner efficiency (both types)
- Start-up heat capacity (instantaneous types).

The calculations in the standard assume that the maintenance rate does not apply when the burner is operating on a storage system, so the gas input rate has a small influence on total energy consumption (as this affects burner on time). For instantaneous systems, the standby electrical power and operating electrical power are included in the total label energy, but for this modelling, electricity and gas are separately estimated.

AS4552 assumes 19 starts per day for an instantaneous gas water heater for the determination of annual energy consumption for the specified hot water energy of 37.7 MJ/day. This equates to approximately 0.5 starts per MJ of hot water delivered. Field work in Victoria estimated that the number of “significant hot water events” (volume over around 5 litres) was around 0.85 starts per MJ of hot water (this ignores many of the smaller hot water events, some of which may trigger an instantaneous water heater to start), so the standard is likely to be quite conservative in terms of annual energy consumption for instantaneous systems.

In order to achieve a specific star rating, it is possible to alter the two main relevant performance parameters. This means that two different water heaters that achieve the same star rating could have slightly different energy consumption at hot water loads other than 37.7MJ/day. Assumed parameters used for modelling are set out in the following table and these are representative for mainstream products on the market today (mid 2020).

**Table 49: Assumed Values for Modelling of Gas Water Heaters**

| Type | Efficiency | Maintenance Rate MJ/day | Burner Efficiency % | Start-up heat cap MJ/start |
|---|---|---|---|---|
| Gas storage | 4 star (SRI 4.0-4.9) | 17.0 | 80.5% | N/A |
| Gas storage | 5.5 star (SRI ≥5.0) | 12.0 | 88.0% | N/A |
| Gas instantaneous | 5 star (SRI 5.0-5.9) | N/A | 77.5% | 0.45 |
| Gas instantaneous | 6 star (SRI 6.0-6.5) | N/A | 82.5% | 0.25 |
| Gas instantaneous | 7 star (SRI ≥6.5) | N/A | 92.5% | 0.35 |

Most instantaneous gas water heater models with a rating of around 6 stars are operating well below the condensing range with a thermal efficiency in the range 80% to 85% (although a few models are above 90%). All models in the 7 star range (above an SRI of 6.5 stars) are operating in the condensing range (over 89%). Products with high efficiency burners tend to have higher start-up heat capacity due to larger and heavier heat exchangers. For models operating below 89% thermal efficiency, there appears to be a weak correlation between increasing thermal efficiency and decreasing start-up heat capacity (most likely due to quality of the heat changer). For products operating above 89% thermal efficiency, there is a weak correlation between increasing thermal efficiency and increasing start-up heat capacity, reflecting the need for heavier heat exchangers to achieve very high efficiency levels in the condensing range.

Most instantaneous water heaters now have an electrical connection and the total annual energy used for controls and fans is typically 350 to 500 MJ/year (around 100 to 140 kWh/year) for older systems. Newer systems have much lower standby power, with some models as low as 1.5W (average around 4W). On mode power is typically around 40W to 60W. This means that electricity consumption is around 200 MJ/year with no use (assumed standby of 6W) climbing to about 278 MJ/year for a hot water delivery of 300 litres per day.

AS/NZS4234 sets out a function of starts per MJ of hot water delivered for different loads. This is approximately a straight line represented by 3.4 + 1.44 starts per kWh of hot water delivered. This has been used as the default function for the hot water model. However, end use metering data suggest more starts per kWh of hot water delivered, in the range of 3 to 5 starts per kWh of hot water delivered. This is an area where more research is warranted. For modelling in the project, the assumptions in the standard have been used.

### *10.3.3 Electric Water Heaters*

Electric storage water heaters do not have a star rating system. However, these have been subject to MEPS on the maximum permitted heat loss since October 1999 (AS1056.1 1991; AS/NZS4692.2 2005). While there are some small variations across models, it can be assumed that all models just comply with regulated MEPS levels.

Heat loss values of water heaters before and after MEPS 1999 are shown in the table below as per AS1056.1. Heat loss values from 1985 to 1999 were not regulated, but many products on the market would have met the specified levels. In 2005, the MEPS levels for small water heaters were strengthened.

**Table 50: Heat Loss Values for Electric Storage Water Heaters to AS1056.1**

| Hot Water Delivery Capacity L | Heat loss 1985-99 kWh/day | Heat loss post 1999 kWh/day | Heat loss post 2005 kWh/day |
|---:|---:|---:|---:|
| 25 | 1.7 | 1.40 | 0.98 |
| 50 | 1.95 | 1.70 | 1.19 |
| 80 | 2.1 | 1.47 | 1.47 |
| 125 | 2.5 | 1.75 | 1.75 |
| 160 | 2.8 | 1.96 | 1.96 |
| 250 | 3.4 | 2.38 | 2.38 |
| 315 | 3.8 | 2.66 | 2.66 |
| 400 | 4.1 | 2.87 | 2.87 |

For modelling purposes, these heat loss levels have been converted to MJ/day. A representative off peak system is taken as 315 litres while a small continuous tariff system is taken as 80 litres. Test conditions under AS1056.1 specify a 55K temperature difference between hot water and the surrounding air and the measured data is corrected back to this temperature difference. This is likely to overstate slightly the normal heat loss during use due to slightly lower typical storage temperatures (closer to 60°C). However, additional losses during typical installations will come from fittings and pipes connected to the water heater, as well as temperature/pressure relief (T/PR) valve losses (from expansion). These losses have not been modelled as they are mostly site specific. For all electric storage water heaters, it is assumed that these operate on mains pressure with a single element and a hot side T/PR valve, adding 0.2 kWh/day to the values in Table 50.

Heat loss values are impacted by the hot water storage temperature and the ambient temperature around the storage water heater. For modelling purposes, it is assumed that the tanks storage temperature is 60°C and that the ambient temperature is adjusted by climate zone. For modelling purposes, it is assumed that all tanks are installed outdoors and the average annual outdoor temperature has been calculated from the RMY climate file used for each of the five AS/NZS4234 water heater climate zones. Heat losses measured in the standard are adjusted by a factor of (60°C – $T_{ambient}$) over 55K for the selected climate zone.

**Table 51: Key parameters for modelling electric storage water heaters**

| Climate | Climate | City | Cold water (°C) | Hot-cold dT (K) | AS/NZS 4234 zone | Annual average temp °C | Hot water-air diff (K) |
|---|---|---|---|---|---|---|---|
| 1 | Darwin | Darwin | 28 | 32 | 1 | 27.280 | 32.7 |
| 3 | Longreach | Brisbane | 21 | 39 | 2 | 23.529 | 36.5 |
| 10 | Brisbane | Brisbane | 21 | 39 | 3 | 20.145 | 39.9 |
| 13 | Perth | Perth | 20.7 | 39.3 | 3 | 18.423 | 41.6 |
| 16 | Adelaide | Adelaide | 17.9 | 42.1 | 3 | 17.008 | 43.0 |
| 21 | Melbourne | Melbourne | 16.2 | 43.8 | 4 | 15.789 | 44.2 |
| 24 | Canberra | Canberra | 15 | 45 | 3 | 13.269 | 46.7 |
| 26 | Hobart | Hobart | 12.9 | 47.1 | 4 | 12.727 | 47.3 |
| 27 | Mildura | Adelaide | 17.9 | 42.1 | 3 | 17.063 | 42.9 |
| 28 | Richmond | Sydney | 18.3 | 41.7 | 3 | 17.013 | 43.0 |
| 32 | Cairns | Brisbane | 21 | 39 | 3 | 24.444 | 35.6 |
| 56 | Mascot | Sydney | 18.3 | 41.7 | 3 | 18.300 | 41.7 |
| 60 | Tullamarine | Melbourne | 16.2 | 43.8 | 4 | 14.289 | 45.7 |
| 69 | Thredbo | Hobart | 12.9 | 47.1 | 4 | 8.573 | 51.4 |

Table notes: All temperatures are annual average values. Assumed hot water temperature is 60°C.

A future refinement could be to estimate the indoor average air temperature in unconditioned spaces on the basis that many smaller tanks on continuous tariff are likely to be installed indoors. One possible approach to estimate average indoor temperatures is given in Harrington et. al. (2015).

One factor that will affect heat loss values for storage water heaters is a reduction in heat losses for off peak controlled load systems that are energised for a limited number of hours per day. The reduction in heat loss occurs as the tank fills with cold water during the day as hot water is used, thus reducing overall average heat losses over 24 hours. The impact is somewhat dependent on hot water draw-off profile (flat, morning or evening peak hot water demand) as well as the total hot water demand. A methodology for calculating the impact on heat losses of off peak systems is set out in AS/NZS1056.4 (1997). For modelling under this project it is assumed that off peak heat losses for larger tanks are reduced by 5% for zero hot water demand and by 32% for a hot water demand of 300 litres per day (nominally 56.5 MJ/day), with linear interpolation between. As noted previously, this is influenced to some extent by draw-off profile, but modelling for this project has assumed a single, flat draw-off profile.

For modelling purposes, it is assumed that the conversion efficiency of elements in electric resistance storage water heaters is 98% while for instantaneous electric water heaters, the assumed conversion efficiency is 95% plus a start-up heat capacity of 0.2 MJ/start.

### *10.3.4 Solar and Heat Pump Systems*

For these types of systems, it is necessary to simulate energy consumption values using the approach set out in AS/NZS4234. The standard sets out a methodology for determination of system performance using a series of outdoor tests to measure a number of specific parameters for each water heater. A simulation tool using TRNSYS software then generates the estimated energy consumption for given ambient conditions and hot water demand. Under the standard, there are four possible climate zones for solar thermal systems and five possible climate zones for heat pump systems. This is the system used by the Clean Energy Regulator (CER) to calculate the allocation of Renewable Energy Certificates (RECS) under the Renewable Energy Target (RET) (Clean Energy Regulator 2020).

The Small Scale Renewable Energy Scheme under the RET allocates tradeable certificates called RECS. One REC is equivalent to 1 MWh of savings relative to a nominated reference water heater type over a nominal 10 year lifetime. Both solar and heat pump systems are included. The way the system works is that the total energy consumption for each solar water heater is assessed against the standard hot water loads defined in AS/NZS4234. Hot water loads range from Very Small to Large, as noted previously.

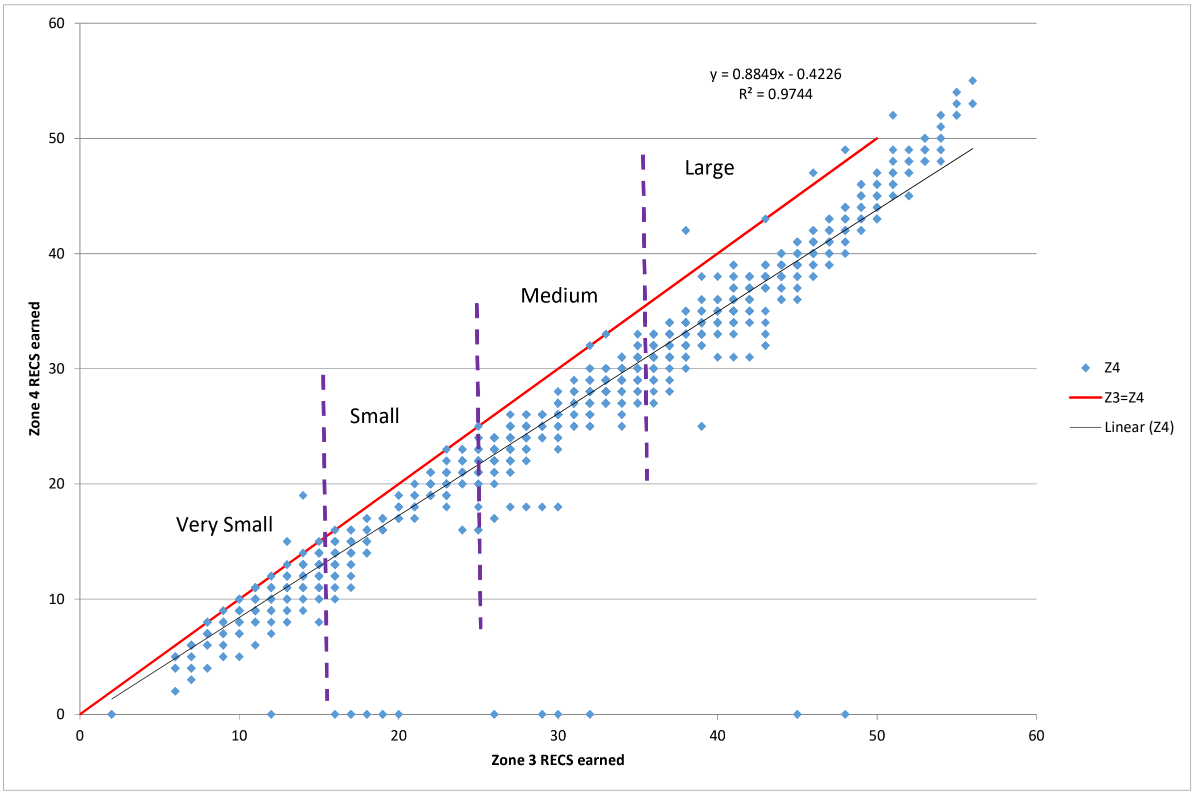
A water heater is awarded RECS for the largest system size it can successfully supply all year round under simulation conditions for a typical mean year of weather. This of course assumes that a large system will be installed in a house with a large hot water demand, which may not be the case. This is illustrated in Figure 19 where all solar water heaters approved by the Clean Energy Regulator as at July 2015 are plotted.

This shows that for solar thermal systems the performance in Zone 4 (Victoria) is about 11% lower than Zone 3 (NSW). The figure also shows very approximately the crossover points for each system size, although this can vary somewhat by system. Unfortunately, the CER listing does not identify the system rated size under AS/NZS4234. A more useful approach would be to show for each model the RECS earned for each of the standard hot water delivery values (or the annual input energy for each defined hot water demand, including 0 MJ/day). In order to qualify for RECS, a solar water heater must achieve a solar contribution of not less than 60% saving relative to a reference heater under Zone 3 at the claimed maximum capacity. The CER listing does not show the tank size, but this can sometimes be gleaned from the model number (Clean Energy Regulator 2019).

The problem with solar thermal water heaters is that the performance is somewhat non-linear with hot water load. As the hot water demand decreases, the share of solar savings increases as less and less boosting is required (but the total savings decrease). As hot water demand increases, the amount of boosting increases and the share of savings fall (but the total savings still increase). So the only practical way to simulate their performance is to simulate a range of hot water loads under AS/NZS4234 in order to fully characterise the system. This has been done for selected systems under all climates under AS/NZS4234. For solar thermal systems, a third order polynomial of hot water demand versus input energy has been fitted to the typical performance curve for selected systems.

At this stage of the project, only a standard system and a higher performance system has been modelled for solar thermal and heat pump water heaters in each climate. A better long term approach would be to alter the way that data is collected by the CER so that a performance map of annual energy input was shown for each hot water demand level (Very Small to Large, plus 0 MJ/day), so that these parameters could be used directly in a whole-of-home model. The current approach does not necessarily fully reward (or penalise) individual product performance in an energy simulation. In theory, the RECs earned in each climate could be used to crudely differentiate products today, but even that is fairly problematic as information on the rated system size is not shown on the CER listings.

**Figure 19: Solar Water Heaters Approved By the CER Showing RECS Under Zone 3 Versus Zone 4**




For heat pump systems, most models are rated as medium sized under SRES, although they are quite capable of supplying relatively large hot water demands for most of the time. Unlike solar thermal systems, the COP of a heat pump water heater does not change very much with increasing (or decreasing) hot water load. Most heat pump systems earn the same RECS or more RECS in Zone 4 when compared to Zone 3. Some 15 of the 266 models listed as of August 2020 do not have a rating for Zone 4 and 29 models do not have a rating in Zone 5 (HP5-AU). The average RECS earned by medium sized systems is shown below. The following table summarises the performance of heat pump systems on the CER register at the end of August 2020.

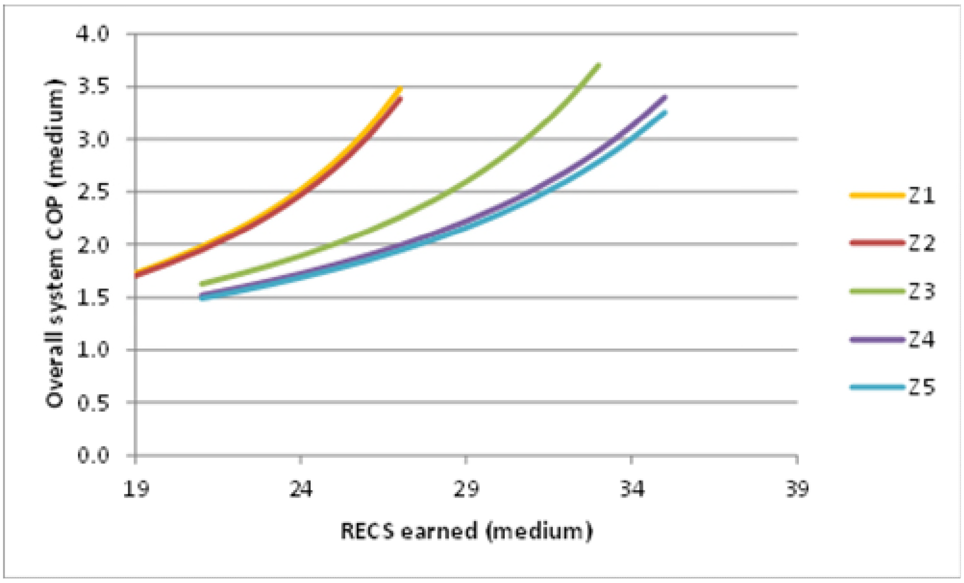
**Table 52: Summary of heat pump performance as listed by the CER, August 2020**

| Parameter | Zone 1 | Zone 2 | Zone 3 | Zone 4 | Zone HP5-AU |
|---|---|---|---|---|---|
| Average RECS medium | 23.8 | 22.8 | 28.0 | 29.7 | 28.7 |
| Best RECS medium | 30 | 32 | 33 | 36 | 36 |
| Count medium | 246 | 232 | 246 | 230 | 220 |
| Count All | 266 | 256 | 266 | 251 | 237 |
| Share medium | 92% | 91% | 92% | 92% | 93% |

Source: See http://www.cleanenergyregulator.gov.au/RET/Scheme-participants-and-industry/Agents-and-installers/Small-scale-systems-eligible-for-certificates/Register-of-solar-water-heaters

Using data from modelling under AS/NZS4234, it is possible to calculate the overall system COP from the RECs earned as shown in Figure 20. However, this is only valid for a specific hot water load (as used to calculate RECS). The input energy for a heat pump water heater can be considered as being made up of two components: heat losses from the tank and the heating of cold water to meet hot water demand. The heat loss is fairly independent of hot water load, so the heat pump energy is best characterised as a fixed component plus a linear variable load component. The most accurate way to do this is to estimate the likely raw total tank heat loss in Wh/day and then assume that the marginal COP applied to both the heat loss and the hot water load together.

**Figure 20: RECs earned under SRES and overall system COP, AS/NZS4234**




Most heat pump systems are in the size range 250 to 300 litres and a typical heat loss is estimated to be around 70 W, a value comparable to an electric storage water heater (1.68 kWh/day).

The next step is to assume that the overall COP of a heat pump system is given by the following equation:

Overall COP = $\frac{Energy_{hotwater}}{Energy_{input}}$

However, the energy input can be represented as two separate factors as follows:
Energy$_{input}$ = $\frac{Energy_{hotwater}}{COP_{marginal}} + \frac{Heatloss}{COP_{marginal}}$

It is then possible to estimate the marginal COP for a given heat pump system if the overall COP is known and the heat loss for the tank can be estimated. This approach assumes that the marginal COP is constant with load, which is a reasonable approximation for most systems. Using this approach it is then possible to calculate the marginal COP across all loads by rearranging the previous equations.

$$COP_{marginal} = \left[\frac{Energy_{hotwater} + Heatloss}{Energy_{hotwater}}\right] \times COP_{overall}$$

This equation is only valid for a non-zero hot water energy demand.

For a typical heat pump water heater that earns 28 RECs, the overall COP in Zone 4 is 2.09 and the marginal COP is 2.5. For the best performing heat pump water heater that earns 35 RECs, the overall COP in Zone 4 is 3.35 and the marginal COP is 3.96. These values have been used to model energy input for heat pump water heaters (standard and best efficiency), assuming a fixed raw tank heat loss of 6.5 MJ/day.

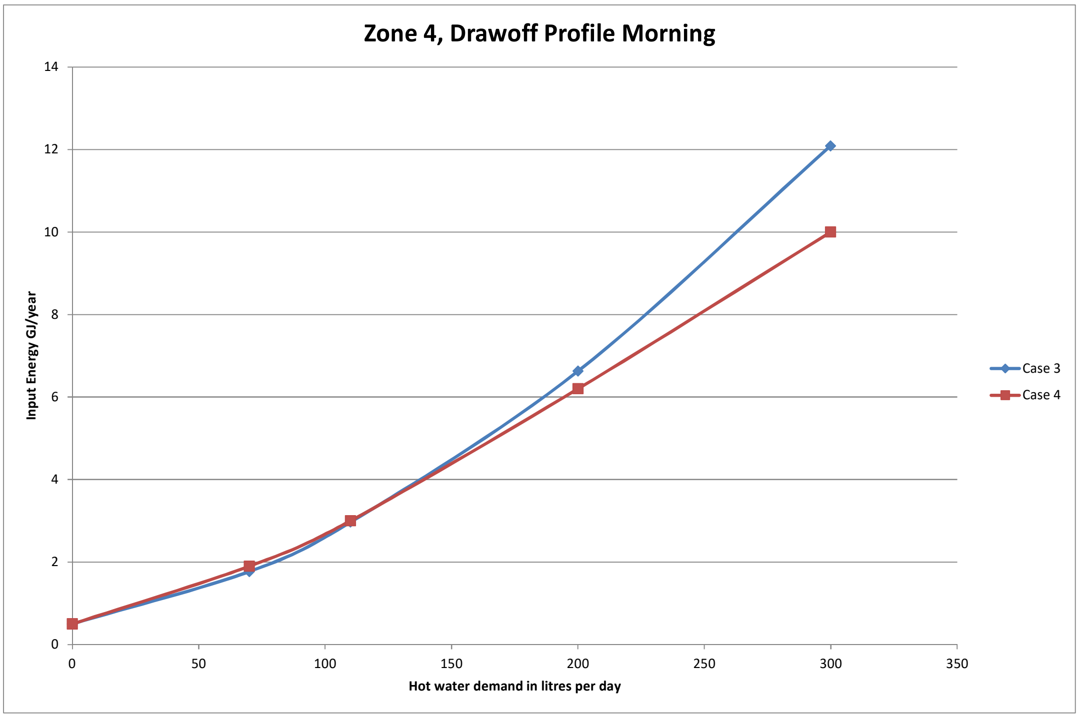
The impact of operating on off peak tariffs for solar and heat pump systems presents some interesting issues. Detailed modelled data of 10 different systems on peak and off peak tariffs was undertaken by George Wilkenfeld & Associates with Thermal Design in 2009 for DEWHA in a report title *Performance of Solar and Heat Pump Water Heaters* (George Wilkenfeld and Associates 2009). Review of data for solar thermal systems and heat pump systems has enabled some off peak factors to be derived for typical water heaters.

For solar thermal systems, an off peak system must have a volume of water that is heated each evening that is larger than the hot water demand in order to ensure adequate hot water supply under a range of usage levels. This means that there is likely to be less solar contribution. However, the impact is moderate. The impact is quite dependent on the usage profile, with morning peak hot water load having the least impact and evening peak hot water load having the most impact.

In contrast, the operation of heat pump systems on off peak tariffs will improve overall efficiency slightly. This is due to reduced heat loss (during the day when the system is not recharging the hot water in the tank during the day), longer compressor runs and lower average water temperatures on the condenser. The operation during cooler air temperatures at night has no significant impact on performance. The impact of off peak operation is quite independent of usage profile.

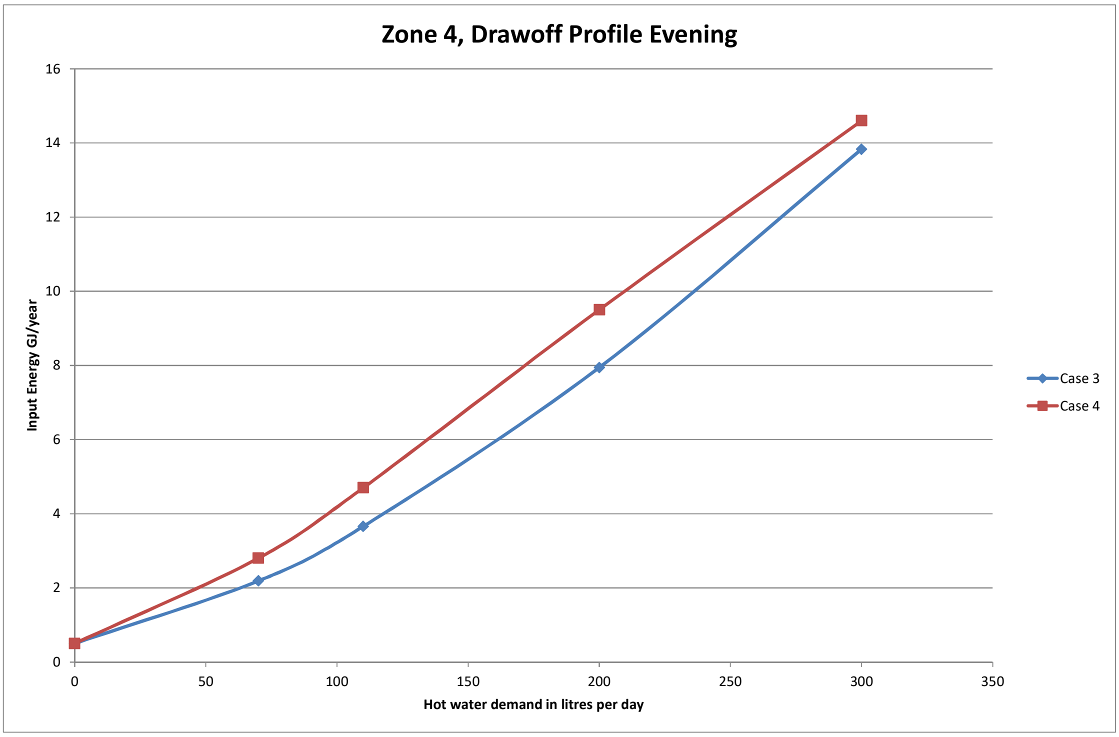
With all systems that operate on off peak tariffs, there is a risk that hot water demands may not be met on days when there is a large hot water demand and/or where there is unfavourable weather. With the heat pump and solar thermal systems modelled, the largest hot water demand could not be fully satisfied – this is why some of the data is contradictory at the largest hot water delivery capacity. The impact of off peak for solar thermal systems is illustrated in Figure 21 and Figure 22.

**Figure 21: Input Energy for Solar Thermal Systems Using Peak (Case 3) and Off Peak Tariffs (Case 4), Zone 4, Morning Peak**




Note: Case 4 on off peak was unable to meet all hot water demand for 200 and 300 litres/day.

**Figure 22: Input Energy for Solar Thermal Systems Using Peak (Case 3) and Off Peak Tariffs (Case 4), Zone 4, Evening Peak**




Note: Case 4 on off peak was unable to meet all hot water demand for 300 litres/day.

On the basis of this analysis, the following adjustment factors have been developed to estimate the energy consumption on off peak tariffs for solar thermal systems and heat pumps. Given the large impact of the timing of peak hot water demand on solar thermal systems, the distributed profile has been selected for this project as an average or typical value for solar thermal systems.

**Table 53: Adjustment Factors to Convert Total Energy Consumption from Peak to Off Peak Tariff**

| Type | Hot water load → Profile (peak) ↓ | 70 litres/d | 110 litres/d | 200 litres/d | 300 litres/d |
|---|---|---|---|---|---|
| Solar Thermal | Morning | 1.07 | 1.01 | 0.95 | 0.89 |
| Solar Thermal | Evening | 1.28 | 1.28 | 1.20 | 1.10 |
| Solar Thermal | Distributed | 1.12 | 1.10 | 1.06 | 1.02 |
| Heat Pump | All profiles | 1.00 | 0.99 | 0.95 | 0.87 |

The distributed profile off peak factor (y) for solar thermal can be represented as a straight line as follows:

$y = -0.0023x + 1.1486$
Where x is the average daily hot water demand in MJ/day.

The off peak factor (y) for heat pump systems can be represented as a quadratic as follows:

$y = - 0.0000493380452x^2 + 0.000511209397x + 1.00155955$

Where x is the average daily hot water demand in MJ/day. A cap of hot water delivery for heat pump systems of 280 litres for off peak systems and 350 litres for peak systems has been included.

### *10.3.5 Usage Considerations*

The main driver for water heat energy consumption is hot water demand. Hot water demand is highly variable by house and depends on many factors such as demographics and lifestyle. Rather than estimate a specific hot water demand, the modelling system has been configured to estimate input energy and hot water demand for all 19 water heater types for any selected house configuration.

### *10.3.6 Typical Efficiency Parameters by Type of Product*

The following tables set out the range of possible efficiency values for various types of water heating equipment.

**Table 54: Assumed Parameters for Conventional Water Heating Equipment**

| Equipment | Heat loss MJ/d | Typical COP | Start-up heat cap MJ/start | Notes |
|---|---|---|---|---|
| Electric storage 80 L | 5.3528 | 0.98 | | Pre MEPS 1999 |
| Electric storage 80 L | 3.8866 | 0.98 | | Post MEPS 1999 |
| Electric storage 300 L | 9.3092 | 0.98 | | Pre MEPS 1999 |
| Electric storage 300 L | 6.6561 | 0.98 | | Post MEPS 1999 |
| Electric instant | | 0.95 | 0.2 | Unusual |
| Gas storage 4 star | 17.0 | 80.5% | | |
| Gas storage >5 star | 12.0 | 88.0% | | |

| Equipment | Heat loss MJ/d | Typical COP | Start-up heat cap MJ/start | Notes |
|---|---|---|---|---|
| Gas instant 5 star | | 77.5% | 0.45 | Electricity scaled 0.2 to 0.33 GJ/y |
| Gas instant 6 star | | 82.5% | 0.25 | Electricity scaled 0.2 to 0.33 GJ/y |
| Gas instant 7 star | | 92.5% | 0.35 | Electricity scaled 0.2 to 0.33 GJ/y |

**Table 55: Characteristics of Medium Solar Systems Modelled**

| Equipment | Tank size litres | RECS in Zone 1 | RECS in Zone 2 | RECS in Zone 3 | RECS in Zone 4 | Solar Savings Zone 3 |
|---|---|---|---|---|---|---|
| Heat pump standard | 250 | 26 | 26 | 30 | 32 | 71% |
| Heat pump high eff | 250 | 27 | 27 | 32 | 35 | 76% |
| Solar thermal standard | 300 | 29 | 32 | 30 | 25 | 70% |
| Solar thermal high eff | 300 | 33 | 34 | 34 | 29 | 80% |
| Gas solar standard | 300 | 33 | 35 | 36 | 32 | 80% |
| Gas solar high eff | 300 | 35 | 35 | 38 | 35 | 84% |

Notes: Solar savings are calculated for a medium hot water delivery and are relative to the appropriate reference water heater as defined in AS/NZS4234. Note that solar savings are only valid at the specified hot water delivery. Solar gas systems are assumed to be close coupled thermosiphon with separate in line gas boosting. Standard systems are better than the August 2020 average, high efficiency systems are not quite as good as the best systems in August 2020.

The following tables set out the performance parameters for each of the major heat pump and solar thermal water heater types modelled by climate zone under AS/NZS4234. These are in the form of a third order polynomial as follows:

Annual MJ input = $b3 \times D^3 + b2 \times D^2 + b1 \times D + c$

Where b3, b2 b1 and c are coefficients defined in the following tables and D is the average annual hot water demand in MJ/day. The annual average value can be derived from the winter peak MJ/day times 0.904521 (sum of the monthly values in Table 47 weighted by days in the month). Note that the annual energy consumption calculation assumes all of the basic parameters in AS/NZS4234 apply as set out in Section 10.3.1, except for the hot water demand, which can be varied between 0 MJ/day to around 60 MJ/day.

**Table 56: Solar heat pump standard performance – model coefficients**

| Zone | b3 | b2 | b1 | c |
|---:|---:|---:|---:|---:|
| 1 | 0 | 0.174874 | 93.78964 | 690.9 |
| 2 | 0 | 0.188336 | 94.86797 | 747 |
| 3 | 0 | 0.138871 | 99.74422 | 821 |
| 4 | 0.002607 | -0.05811 | 106.2475 | 907.4 |

Note: Heat pump systems for Zones 1 to 3 are a quadratic (second order). Zone HP5-AU has not been modelled at this stage.

**Table 57: Solar heat pump high performance – model coefficients**

| Zone | b3 | b2 | b1 | c |
|---:|---:|---:|---:|---:|
| 1 | 0 | 0.17613 | 82.59551 | 491.9 |
| 2 | 0 | 0.19202 | 83.18115 | 498.9 |
| 3 | 0 | 0.142684 | 87.23387 | 505.0 |
| 4 | -0.00648 | 0.744336 | 74.55171 | 635.0 |

Note: Heat pump systems for Zones 1 to 3 are a quadratic (second order). Zone HP5-AU has not been modelled at this stage.

As an example, a winter peak hot water demand of 38 MJ/day in Zone 3 (medium hot water demand under AS/NZS4234) is equivalent to an annual average hot water demand of 34.4 MJ/day over the whole year. The annual energy consumption for a high efficiency heat pump to supply this hot water load (from Table 57 is $0.14268\times34.4^2 + 87.23387\times34.4 + 505 =$ 3,671.95 MJ/year (1,019.99 kWh/year)). A medium size electric reference water heater consumes 15,260 MJ/year, giving savings of 11,588 MJ/year or 3,218.9 kWh/year, which equates to 32 RECs over 10 years.

Note: For solar and gas solar systems, the performance curves were derived from modelling undertaken to AS/NZS4234 across a range of hot water demands.

**Table 58: Solar thermal electric boost standard performance – model coefficients**

| Zone | b3 | b2 | b1 | c |
|---:|---:|---:|---:|---:|
| 1 | -0.00021 | 3.280064 | -14.153 | 0 |
| 2 | 0.022872 | 0.931618 | -4.4814 | 0 |
| 3 | -0.020844 | 4.36594 | 7.0634 | 52 |
| 4 | -0.011760 | 2.75228 | 104.13 | 433.6 |

**Table 59: Solar thermal electric boost high performance – model coefficients**

| Zone | b3 | b2 | b1 | c |
|---:|---:|---:|---:|---:|
| 1 | 0.04026 | 0.0238 | -0.858 | 0.0 |
| 2 | 0.03743 | -0.9317 | 13.042 | 0.0 |
| 3 | -0.00170 | 2.9951 | -14.050 | 10.5 |
| 4 | -0.01484 | 3.3436 | 51.267 | 142.5 |

**Table 60: Solar thermal gas boost standard performance – model coefficients**

| Zone | b3 | b2 | b1 | c |
|---:|---:|---:|---:|---:|
| 1 | 0.03778 | 0.5677 | -3.163 | 0.0 |
| 2 | 0.03322 | -0.5147 | 7.101 | 0.0 |
| 3 | 0.00742 | 2.5476 | 4.850 | 0.0 |
| 4 | 0.00097 | 2.3215 | 97.955 | 0.0 |

Note: Model covers gas consumption only. Electrical consumption modelled separately.

**Table 61: Solar thermal gas boost high performance – model coefficients**

| Zone | b3 | b2 | b1 | c |
|---:|---:|---:|---:|---:|
| 1 | 0.05944 | -1.6477 | 15.601 | 0.0 |
| 2 | 0.03460 | -1.2474 | 15.152 | 0.0 |
| 3 | 0.02001 | 1.4104 | -6.376 | 0.0 |
| 4 | -0.00408 | 3.0339 | 38.949 | 0.0 |

Note: Model covers gas consumption only. Electrical consumption modelled separately.

### *10.3.7 Scaling for Usage*

The overall approach for the calculation of water heating energy is to first estimate the hot water demand in litres per day and then to calculate the required annual energy input by fuel for the particular type of water heater. These values are derived from equations using the parameters set out above.

No allowances have been made for distribution losses in the home. These are typically of the order of 10% of total hot water demand, but this varies by demand, household and hot water layout in the home (length of pipe runs, position of taps and water heater).

## 10.4 Appendix 4 – PV and Inverters – Basis for Cost Estimates

# A0357 Technical note

| | | | |
|---|---|---|---|
| **Author** | Ishpreet Singh Chawla, Joshua Jordan and Susan Dedman | **Project Number** | A0357 |
| **Date** | *14/05/2020* | **Revision** | 2 |
| **Subject** | Residential PV Costs | | |

## Current Residential PV Costs

Table 62 shows up-to-date residential PV system costs by city. The costs indicated here are inclusive of both the federal STC discount and GST, but not any other state-specific incentives or rebates.

**Table 62 – Residential PV System costs by city and DC capacity installed with STC discounts included[25]**

| | 1.5kW | 3kW | 4kW | 5kW | 6kW | 7kW | 10kW |
|---|---|---|---|---|---|---|---|
| **Adelaide, SA** | $ 3,510 | $ 4,230 | $ 4,510 | $ 4,880 | $ 5,460 | $ 6,540 | $ 10,000 |
| **Brisbane, QLD** | $ 3,000 | $ 3,810 | $ 4,540 | $ 5,080 | $ 5,570 | $ 6,760 | $ 10,160 |
| **Canberra, ACT** | $ 2,730 | $ 3,360 | $ 4,380 | $ 4,620 | $ 4,890 | $ 6,480 | $ 8,280 |
| **Darwin, NT** | $ 5,930 | $ 6,710 | $ 7,510 | $ 8,750 | $ 8,690 | $ 9,480 | $ 10,830 |
| **Hobart, TAS** | $ 3,240 | $ 4,150 | $ 5,100 | $ 6,090 | $ 7,170 | $ 8,420 | $ 11,000 |
| **Melbourne, VIC** | $ 3,380 | $ 4,080 | $ 4,710 | $ 4,920 | $ 5,190 | $ 6,910 | $ 10,400 |
| **Sydney, NSW** | $ 2,730 | $ 3,410 | $ 3,960 | $ 4,230 | $ 4,420 | $ 6,000 | $ 8,340 |
| **Perth, WA** | $ 2,490 | $ 2,790 | $ 3,320 | $ 3,420 | $ 3,880 | $ 5,260 | $ 9,720 |
| **Average** | $ 3,376 | $ 4,068 | $ 4,754 | $ 5,249 | $ 5,659 | $ 6,981 | $ 9,841 |

It should be noted that the system size is the DC capacity installed (rather than the AC, or inverter, capacity), and the costs shown are average costs. Site-specific characteristics like location/remoteness, mounting, roof type, the length of cable runs from rooftop to the inverter etc. will impact site-specific cost.

Figure 23 depicts the average *specific cost* (i.e. cost per unit of capacity) for rooftop PV in the major cities of Australia. The economies-of-scale effect is apparent and occurs primarily because inverter cost per unit of capacity decreases with increasing capacity, and because there are installation costs that are largely fixed (i.e. transport time, reticulation/inverter installation time) and greater capacity means greater amortisation of these costs. The slight increase in specific cost when moving from a 6 $kW_{DC}$ to a 7 $kW_{DC}$ system may be attributed to the fact that DNSPs don't allow single phase inverters bigger than 5 $kW_{AC}$, and hence systems 7 $kW_{DC}$ and above will tend to use three-phase inverters, which generally have a higher specific cost than single-phase inverters.

[25] https://www.solarchoice.net.au/blog/solar-power-system-prices

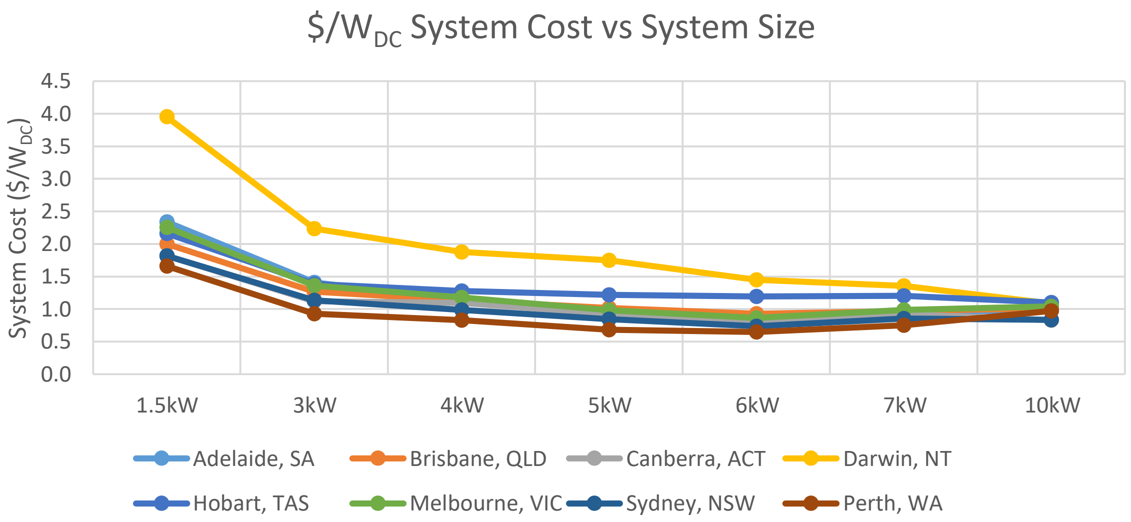



**Figure 23 – Average $/W$_{DC}$ costs of rooftop PV systems by city**

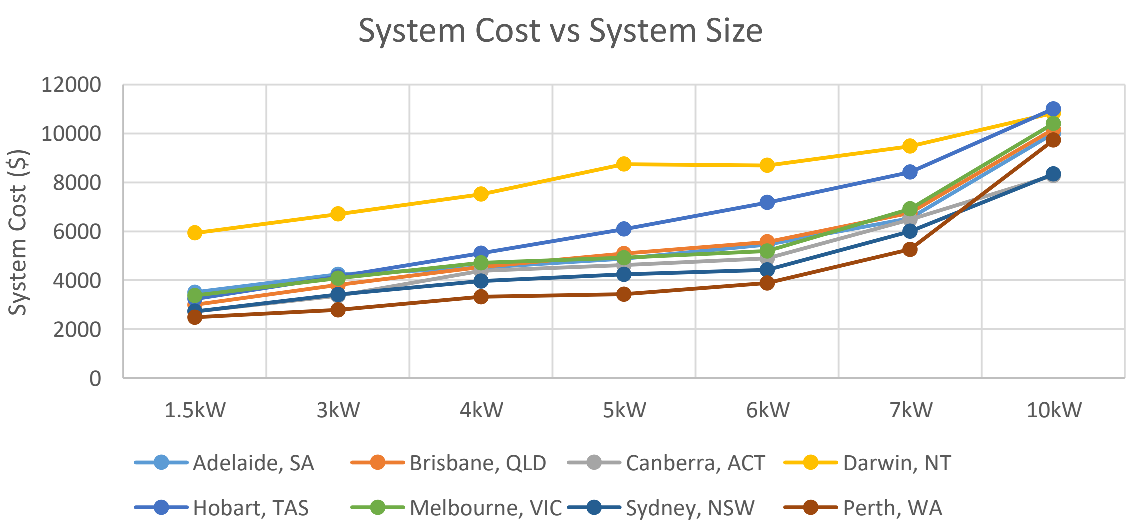



**Figure 24 – Average installed cost of rooftop PV systems by city**

**Figure 23 – Average $/W$_{DC}$ costs of rooftop PV systems by city**

Figure 23 and Figure 24 show similar trends in each city/state, except for Darwin where costs are considerably higher. This can be attributed to the additional structural costs required to resist corrosion and cyclonic winds, and the additional certification costs given the cyclonic winds.

## System Cost (excluding STCs)

The STC amount for each of the location was calculated by using their Zone ratings, the STC amount of $36.50 (March 2020) and a deeming period of 11 years for 2020 and subtracted from Table 62.
The costs obtained are mentioned below in Table 63.

**Table 63 – Residential PV System costs by city and DC capacity installed without STCs**

| | 1.5kW | 3kW | 4kW | 5kW | 6kW | 7kW | 10kW |
|---|---|---|---|---|---|---|---|
| **Adelaide, SA** | 4,342 | 5,895 | 6,729 | 7,654 | 8,789 | 10,424 | 15,549 |
| **Brisbane, QLD** | 3,832 | 5,475 | 6,759 | 7,854 | 8,899 | 10,644 | 15,709 |
| **Canberra, ACT** | 3,562 | 5,025 | 6,599 | 7,394 | 8,219 | 10,364 | 13,829 |
| **Darwin, NT** | 6,907 | 8,664 | 10,115 | 12,006 | 12,597 | 14,039 | 17,342 |
| **Hobart, TAS** | 3,954 | 5,577 | 7,003 | 8,469 | 10,025 | 11,750 | 15,758 |
| **Melbourne, VIC** | 4,094 | 5,507 | 6,613 | 7,299 | 8,045 | 10,240 | 15,158 |
| **Sydney, NSW** | 3,562 | 5,075 | 6,179 | 7,004 | 7,749 | 9,884 | 13,889 |
| **Perth, WA** | 3,322 | 4,455 | 5,539 | 6,194 | 7,209 | 9,144 | 15,269 |

### Inverter Costs

The prices of a range of residential inverter models were obtained from 2020 supplier pricelists. An AC/DC ratio of 1.3 was assumed when calculating the DC system size connected to the inverter. This data was used to get a fit for the inverter costs with the system sizes and is shown below in Figure 25. The inverter cost can be approximated to the formula:

$$Inverter\ Cost\ (\$\ including\ GST) = 0.18 * \ (System\ size\ in\ W_{DC}) + 536.20$$

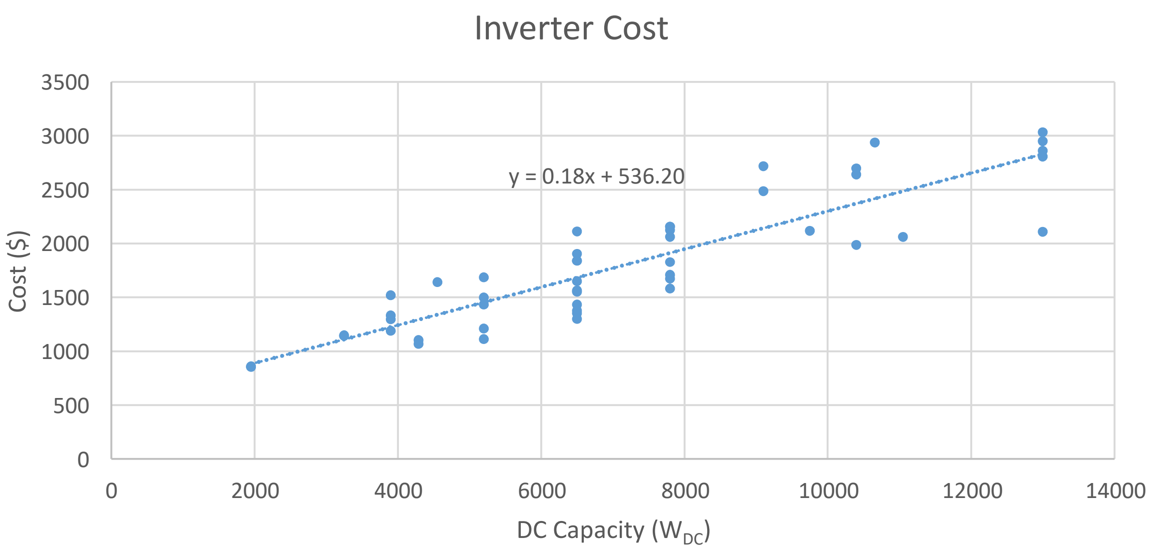



**Figure 25 - Inverter prices for systems of various DC capacities ($W_{DC}$)**

## Future Residential PV Costs

The key factors that determine rooftop solar system costs in Australia are equipment costs, installation costs, network connection fees/costs, and the STC rebate.
The value of the STC rebate depends on three factors:

DC capacity: the number of STC's that can be created is directly proportional to the PV panel capacity installed

Zoning: Australia is divided into four zones, designed to reflect expected solar generation in each zone.[26] Each Australian postcode falls into one of the four zones.

STC Price: STC prices fluctuate in the open market based on the balance of supply and demand. The STC spot price was $36.50[27] at the time this report was written.

Deeming period: STC's can be created each year, or "deemed" out to 2030. The deeming option enables the purchaser to effectively reduce their PV system's capital cost and is by far the most common approach. The maximum deeming period in 2020 is 11 years, and it will decrease every year until it reaches zero after 2030.

The formula for estimating the number of STC's that can be claimed for a <100kW$_{DC}$ installation is as follows:

*No. of STCs, = PV System Size (kW) X Postcode Zone Rating X Deeming period (years)*

The falling deeming period will place upward pressure on PV system pricing. STCs accounted for nearly 37% of the total cost of the PV system in 2019, and this percentage is expected to drop to 26% by 2023 as the maximum deeming period falls (Figure 26).[28]

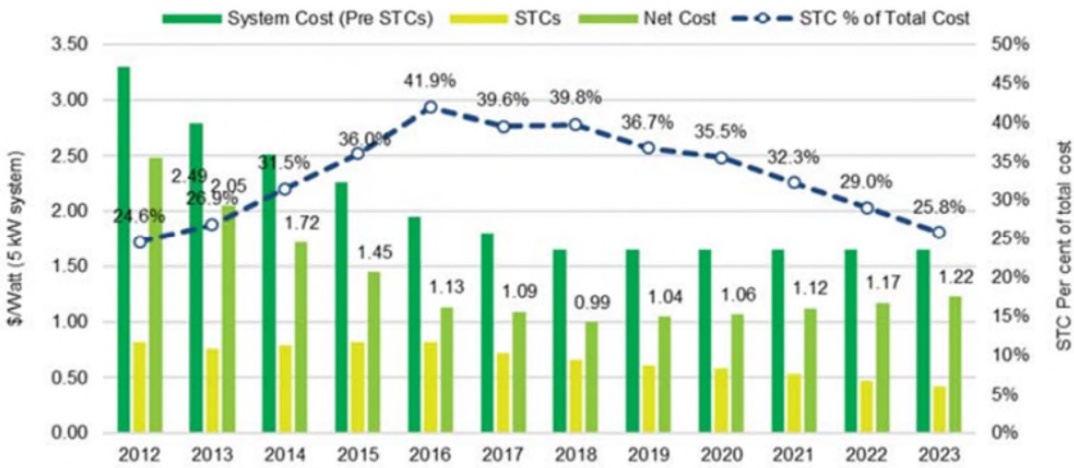



**Figure 26 - Forecasted PV system costs according to the Small-Scale PV modelling report (CER, October 2019)**

Declining system costs to date have been due to falling equipment and installation costs. Whilst we expect equipment costs to continue to decline gradually, we expect the reduction in the STC rebate to largely offset these reductions. Therefore, we expect largely stable installed costs in the medium-term for rooftop PV in Australia. (Note that Figure 26 from CER's report assumes a flat pre-STC system cost to continue from 2018. While in agreement with our forecast of modest cost reductions in module prices and continued gains in module efficiency, the CER also forecasts some degree of increased marketing costs to contribute to system pricing.)

Note that there is some risk that additional costs/barriers will be imposed by network and market operators to reduce the technical challenges associated with managing high proportions of distributed generation. It is unclear what form these costs/barriers would take, and hence they have been excluded in the forecast above.

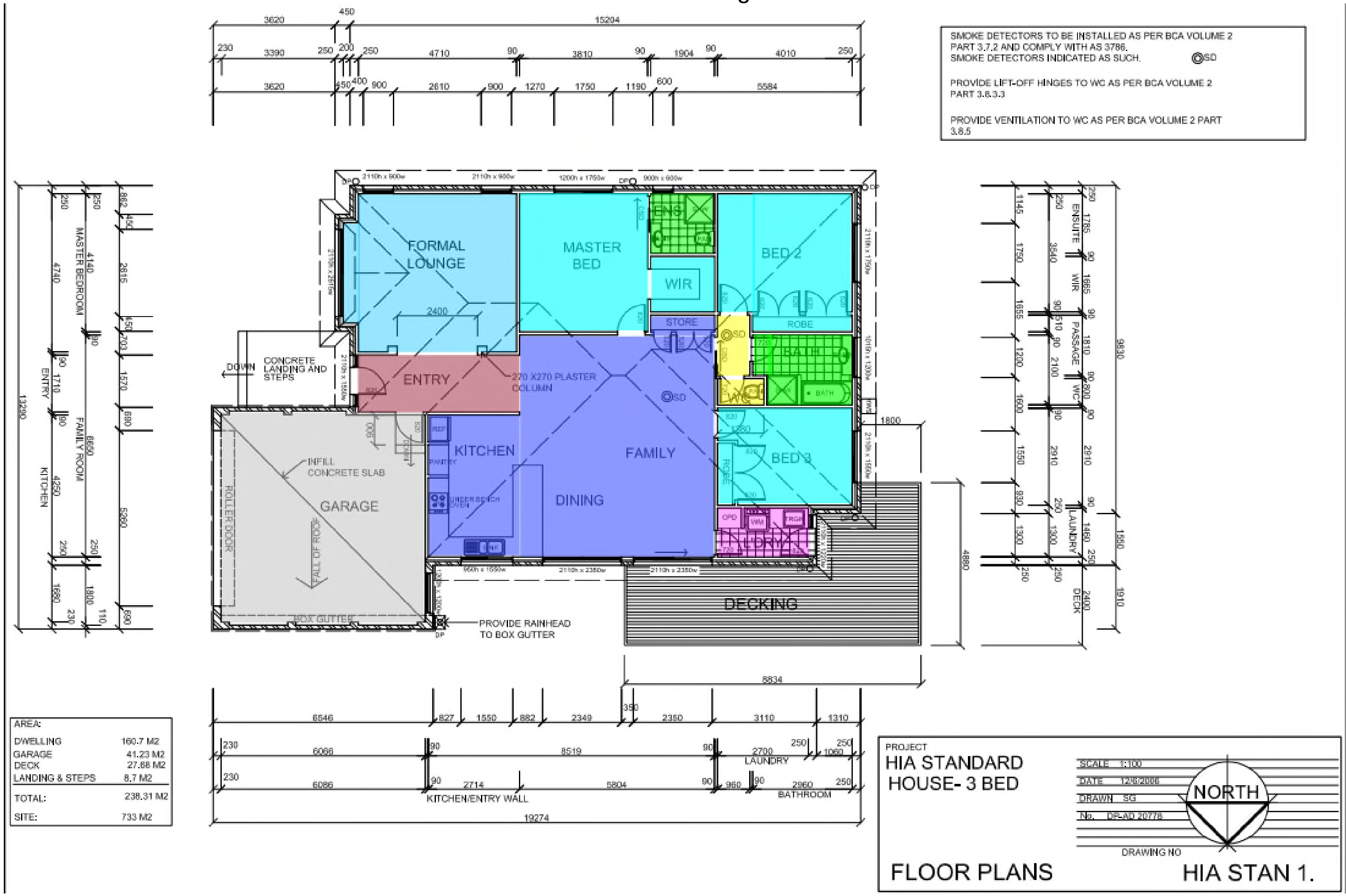
[26] https://www.energymatters.com.au/wp-content/uploads/2014/11/rec-zone-calculations.pdf

[27] https://www.green-bank.com.au/stc/trading-with-us/

[28] http://www.cleanenergyregulator.gov.au/DocumentAssets/Documents/Small-scale%20solar%20PV%20modelling%20report%20by%20GEM%20%E2%80%93%20October%202019.pdf

## 10.5 Appendix 5 – Simulated House Plans

Detached Dwelling Plan

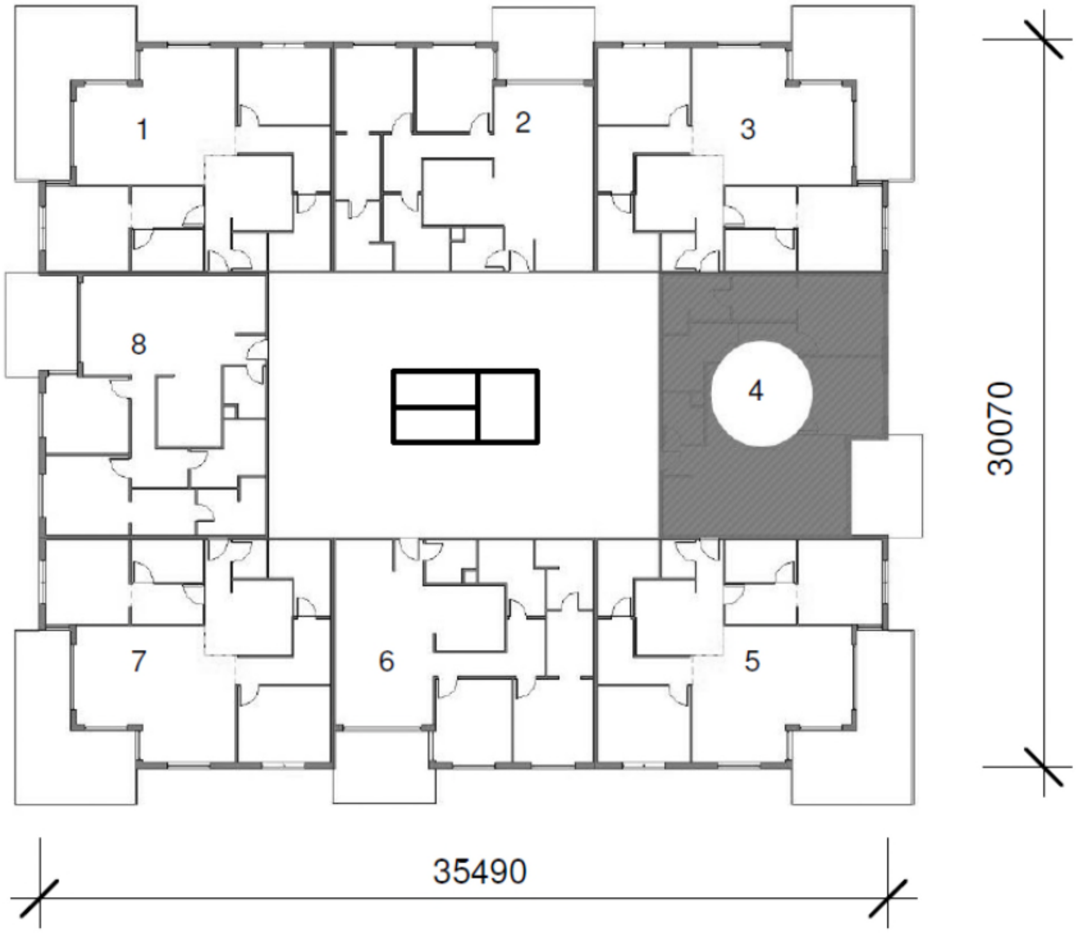



*Source: This dwelling plan and specifications for this indicative house design have been kindly provided to ABCB by the Housing Industry Association (HIA) to assist with the consultation process on the draft NCC 2022 changes.*

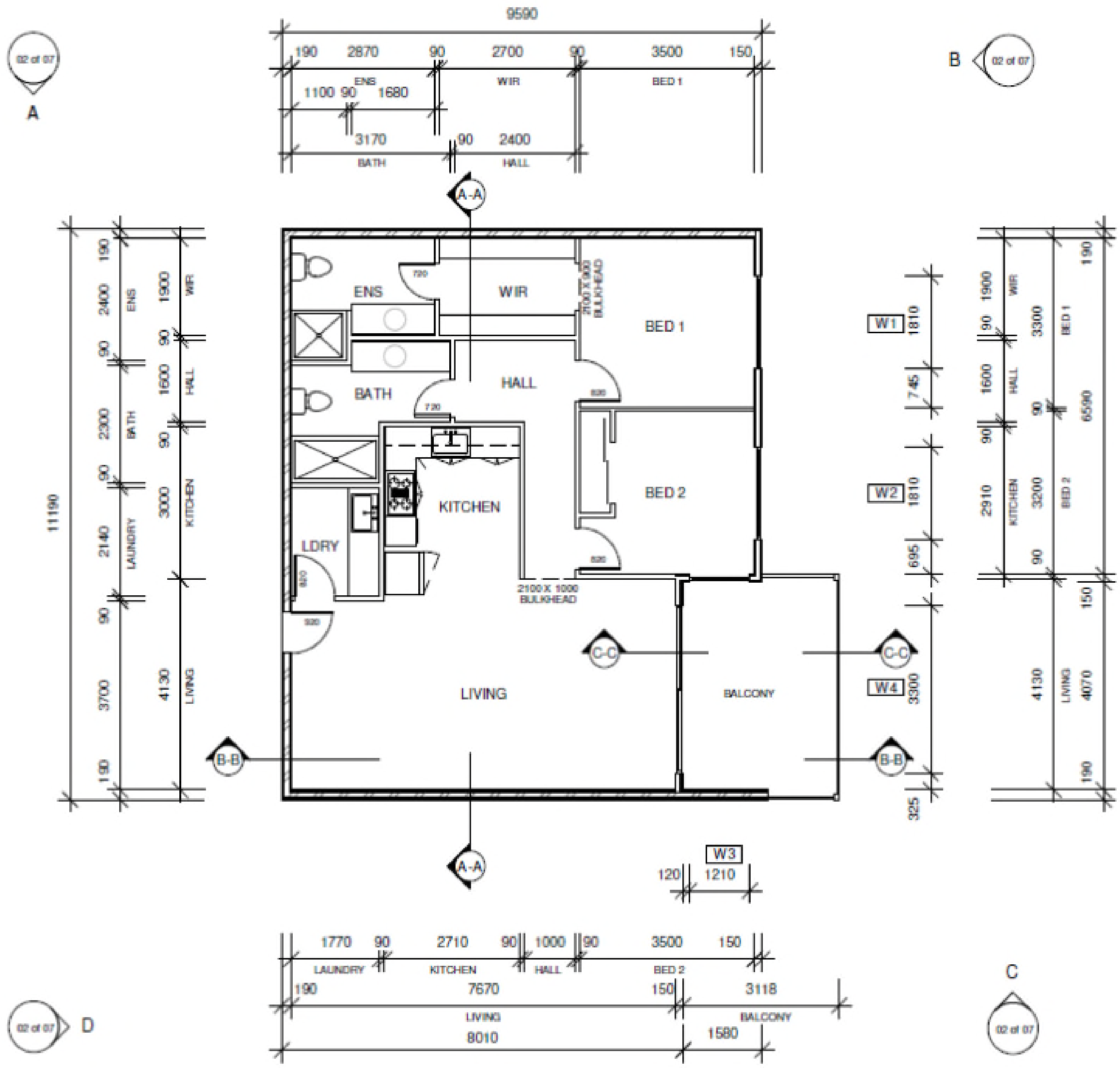
## Apartments

Perspective

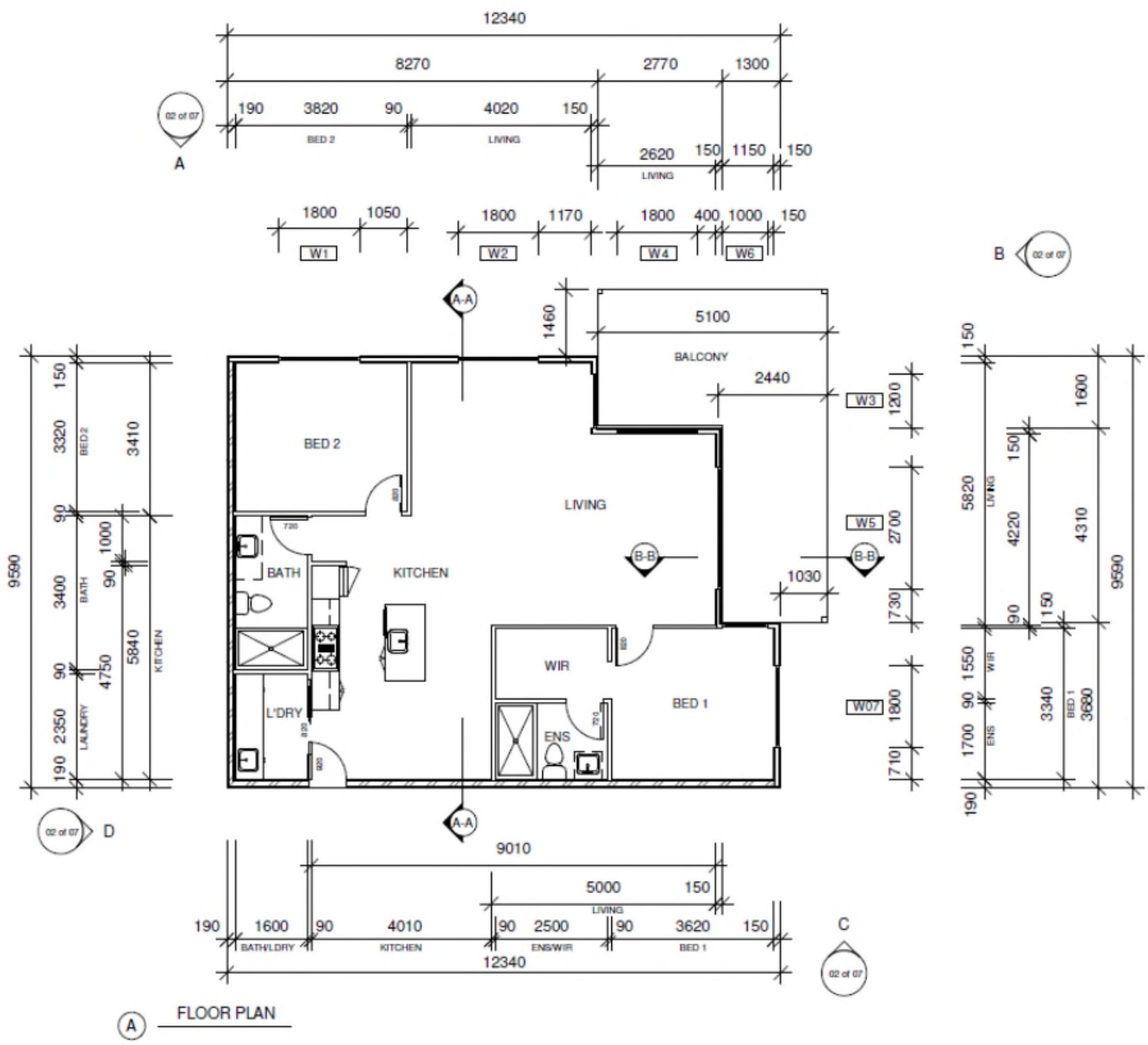
Floor plate



Middle Unit Plan



Corner Unit Plan



## 10.6 Appendix 6 – Equipment Propensities and New Housing Stock Data

This appendix makes estimates of the share of water heater types and space heating types in new Class 1 and Class 2 dwellings in each state and territory to allow RIS modelling of the impacts. Public data sources for new homes are relatively scarce, so the best available data sources have been used as documented. All sources used have been documented in this report. This appendix should be treated as an internal report and is not intended for publication in its current form. Various reports prepared by BIS Oxford Economics have been cited. These are commercial reports only available by subscription – access has been given to these reports for this project only by selected state agencies.

### *10.6.1 Types of houses built in Australia*

In the National Construction Code Volume One, a wide range of building types are defined (Australian Building Codes Board 2019a). For this project, the focus is on the most common buildings found in the residential sector, namely:

**A6.1 Class 1 buildings**

A Class 1 building includes one or more of the following sub-classifications:

(1)Class 1a is one or more buildings, which together form a single dwelling including the following:

(a) A detached house.

(b) One of a group of two or more attached dwellings, each being a building, separated by a fire-resisting wall, including a row house, terrace house, town house or villa unit.

Class 1a(a) used to be called Class 1a(i) and Class 1a(b) used to be called Class 1a(ii). These are colloquially called detached houses and attached houses (or semi-detached houses)

The other type of building in the residential sector is Class 2 as follows:

**A6.2 Class 2 buildings**

(1) A Class 2 building is a building containing two or more sole-occupancy units.

(2) Each sole-occupancy unit in a Class 2 building is a separate dwelling.

Class 2 dwellings are colloquially called flats or apartments.

The class of building (Class 1 or 2 as above) is important as this has an impact on the type of water heater and space conditioning that is likely to be present. In particular, many states restrict the type of water heater permitted in new Class 1 dwellings, while there are generally few restrictions on Class 2 swellings (except in NSW, which must comply with BASIX whole-of-home assessment). Also, in practical terms, most Class 2 dwelling have limited access to outdoor spaces or rooftops, so solar and heat pump systems are usually difficult to install.

### *10.6.2 Plumbing Code of Australia*

ABCB National Construction Code Volume Three: Plumbing Code of Australia (2019) sets out requirements for water heaters in Part B2 Heated Water Services (Australian Building Codes Board

2019b). The code sets out a range of requirements for water heaters in various situations. The default deemed to satisfy requirements in Clause B2.2 permit in Class 1 or Class 10[29] building:

- a solar water heater complying with B2.2(1)(b) (minimum RECS); or
- a heat pump water heater complying with B2.2(1)(b) (minimum RECS); or
- a gas water heater complying with B2.2(1)(c) (min 5 stars); or
- an electric resistance water heater only in the circumstances described in B2.2(1)(d) (small house sizes only); or
- a wood fired thermosiphon water heater or direct fired water heater each complying with AS/NZS 3500.4.

There are no restrictions on water heater type in Class 2 buildings in any state except for NSW, where all new dwellings have to be approved under BASIX.

There are appendices in the plumbing code for many of the states that modify these as follows:

- NSW does not apply these requirements as whole house systems are required to comply with BASIX (Class 1 and Class 2)
- Victoria only permits solar water heaters (not heat pumps or any other sort of water heaters) to be installed in new Class 1 dwellings, but there is a local requirement that permits a water tank compliance pathway in lieu of a solar water heater (in which case there is no restriction on water heater type)
- Queensland has no requirements for water heaters in new homes
- South Australia applies a slightly modified version of the default rules for solar, heat pump, gas and wood but does not permit an electric system to be installed where reticulated gas is available, but allows electric storage systems up to 250 litres where there is no reticulated gas.
- Western Australia does not appear to modify the default rules
- Tasmania permit electric water heaters without any restriction
- Northern Territory has no requirements for water heaters in new homes
- Australian Capital Territory does not appear to modify the default rules.

These rules, where applied, have a strong impact on the type of water heater that is installed in Class 1 dwellings. As noted above, Class 2 buildings are influenced primarily on whether mains gas is available on site regarding the type of water heater installed.

### 10.6.3 Household numbers and projections

For this project the assumed baseline of household projections at a state level is given in ABS3236 for both households and population (Australian Bureau of Statistics 2019). The latest edition from 2016 to 2041 was released in 2019. The impact of COVID-19 during 2020 will be significant, especially in terms of net migration, so the projections of household numbers may be lower. However, there are no other updated long projections available at this stage.

### 10.6.4 Share of Class 1 and Class 2 new dwellings

The main focus of this report is the share of water heating and space conditioning equipment being installed in new homes around Australia to allow RIS type assessment of a whole-of-home rating

[29] Class 10 buildings include sheds and garages and can also include swimming pools.

system to be undertaken. There are several data sources for the share of new homes being built in Australia as follows:

- ABS8731.0 Building Approvals, Australia gives a breakdown of Class 1a(a), Class 1a(b) and Class 2 dwellings on a monthly bases from around 1990 for each state and territory.
- ABS 8752.0 Building Activity, Australia gives a quarterly breakdown of building commencements by state and territory from around 1984, split into houses (Class 1a(a)) and total (which also includes Class 1a(b) and Class 2 dwellings).
- ABS 8752.0 Building Activity, Australia also gives a quarterly breakdown of building completions by state and territory from around 1984, split into houses (Class 1a(a)) and total (which also includes Class 1a(b) and Class 2 dwellings).

For ABS 8752.0 the latest available data is for the September 2020 quarter, data for the December 2020 quarter was released on 14 April 2021.

The number of approvals and commencements in each state over time closely match. The number of completions also matches closely over time, but with a slight time lag of 1 to 2 years. To illustrate this, annual data for NSW is shown in **Figure 27**.

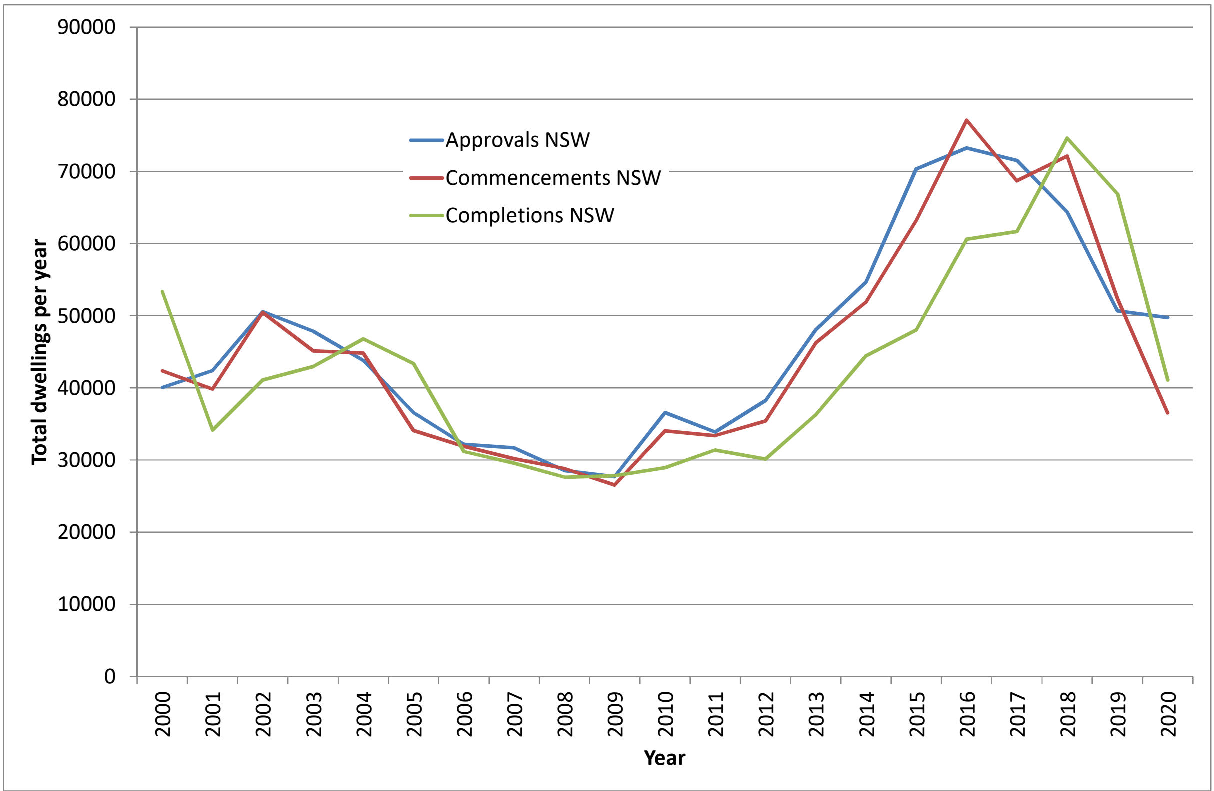



**Figure 27: Total dwelling approvals, commencements and completions in NSW from 2000 to 2019**

For this project, the share of Class 2 dwellings is the most important parameter. This is only available at the approvals stage as a long term series, so the share of each type of dwelling for approvals has been used to apportion the share of Class 1a(b) and Class 2 dwelling completions but with a 1 year time lag to reflect the temporal difference between approvals and completions.

This data allows the share of Class 2 dwellings as a share of all dwellings to be plotted over time as shown in **Figure 28**. As can be seen, the share of Class 2 is somewhat volatile from year to year. There was a surge in Class 2 share in all states after 2010 as urban areas moved to higher density building and consolidation with some urban infill. Most states, except WA and ACT, saw a decline in Class 2 share after around 2017. It is unclear whether this trend will continue in the medium term, but it appears that share of new Class 2 dwellings will decline slightly from 2020 in most jurisdictions.

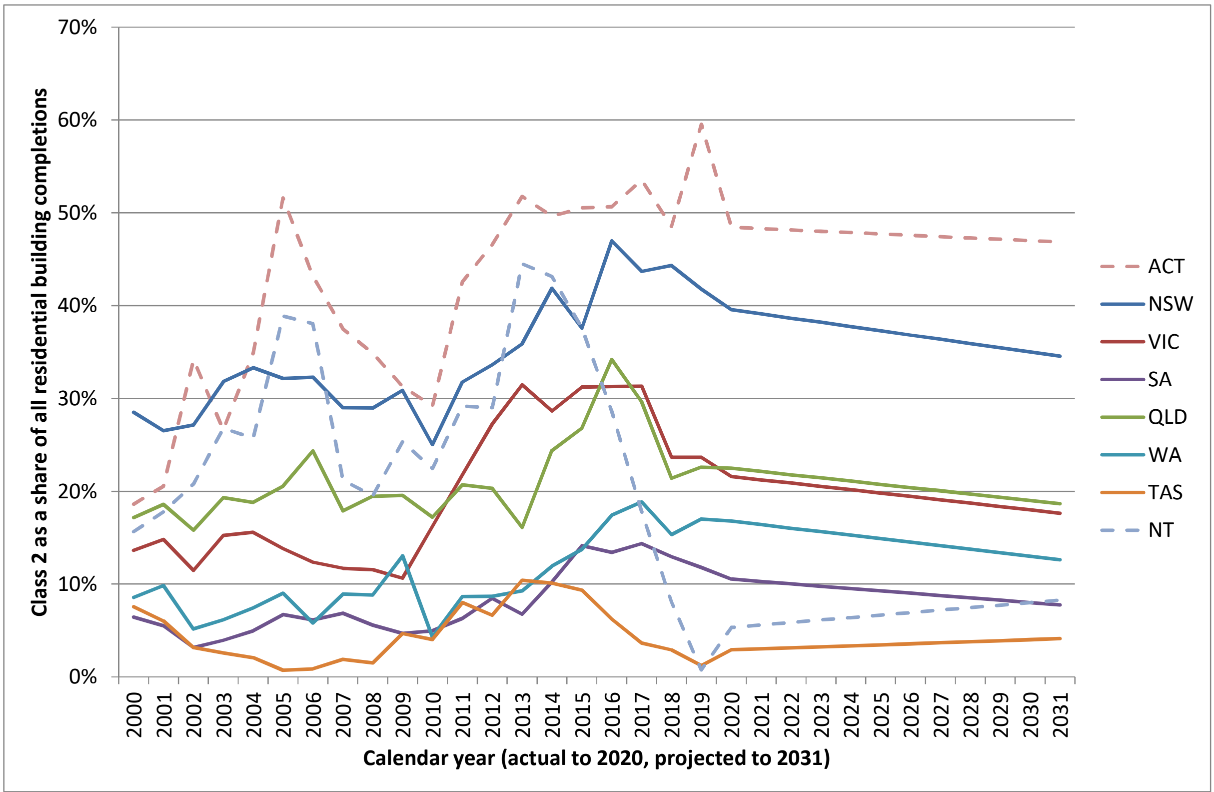



**Figure 28: Share of Class 2 dwelling completions by state by year to 2020 with trend to 2031**

Figure notes: NT seemed to experience a boom from 2010 and then a bust by 2018. Based on the long term activity in this territory, a rate of 15% Class 2 in 2022 is likely to be more representative.

### *10.6.5 Stock of Class 2 dwellings*

In order to understand how to split historical ownership trends into Class 1 and Class 2 dwellings where data is available, an estimate of the share of Class 2 dwellings in the stock by state and territory is required. The most comprehensive recent source is the 2016 census, which records this data at a state level. Quickstats on the ABS website https://www.abs.gov.au/websitedbs/D3310114.nsf/Home/2016%20search%20by%20geography

Share of Class 2 dwellings in the total stock of residential dwellings from the 2001 to 2016 census is shown in **Table 64** and **Figure 29**. NSW, NT and ACT are all showing a strong increase in the stock share of Class 2 dwellings, while the stock share of Class 2 dwellings in the remaining states appear to be falling. **Table 64** also shows the share of new Class 2 dwellings being built over the period 2015 to 2020. Given the recent rate of building for Class 2 dwellings, the stock share of Class 2 would be expected to increase in all states and territories except Tasmania and NT, where the recent rates are similar to the existing stock share. Note that it takes many years for a change in the rate of new building share to clearly appear in the stock.

**Table 64: Stock share of Class 2 dwellings from census 2001 to 2016, plus rate of new to 2020 and 2022**

| State | Census 2001 | Census 2006 | Census 2011 | Census 2016 | Estimated Class 2 stock in 2021 | New Class 2 share 2015-2020 | New Class 2 share Est 2022 |
|---|---|---|---|---|---|---|---|
| NSW | 17.9% | 19.0% | 18.8% | 19.9% | 22.5% | 42.3% | 38.2% |
| VIC | 11.9% | 13.4% | 12.9% | 11.6% | 13.6% | 27.1% | 20.5% |
| QLD | 12.1% | 13.0% | 11.7% | 11.3% | 13.0% | 26.2% | 21.4% |
| SA | 8.8% | 9.2% | 8.9% | 6.6% | 7.0% | 12.9% | 9.8% |
| WA | 7.1% | 8.1% | 7.9% | 5.7% | 6.8% | 16.5% | 15.6% |
| TAS | 6.9% | 8.6% | 7.5% | 5.7% | 5.6% | 4.4% | 15.0% |
| NT | 14.5% | 15.3% | 16.6% | 17.5% | 17.5% | 16.4% | 6.1% |
| ACT | 9.6% | 11.3% | 12.4% | 15.0% | 19.9% | 51.9% | 48.0% |

Source: Data 2001 to 2016 from ABS Census. Share of new Class 2 dwellings based on approvals and completions. Estimated stock calculated by the author. Estimated share of new Class 2 dwellings in 2022 estimated by the author based on projected trends from 2010 to 2020 as per Figure 28, except for NT where a longer term value of 15% has been estimated.

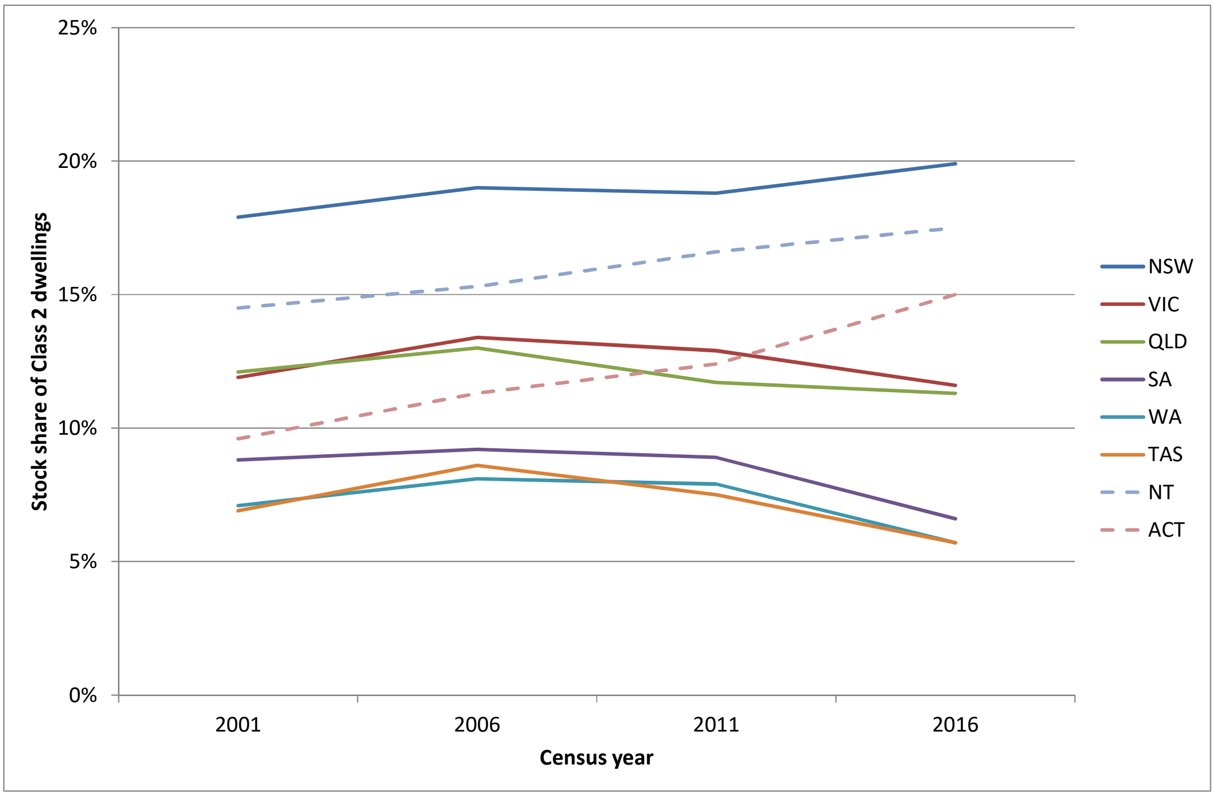



**Figure 29: Stock share of Class 2 dwellings from census 2001 to 2016**

### 10.6.6 Ownership trends for key equipment types

The key data of interest for this part of the study (i.e. this appendix) is the share of equipment type for water heating, space heating and space cooling in new dwellings in Australia. Unfortunately, there is very little data of this type collected at a state or national level. The exceptions are NSW, where BASIX regulations allow the detailed collection of this type of data in all new houses approved. There is also some data for Victoria, but this is somewhat limited. The approach used is to establish ownership trends for the equipment types of interest for the installed stock based on the available data sets, and then to use this data to infer what is likely to be happening in new homes.

The most important data set that documents the stock of installed equipment in all residential homes is *ABS4602 Environmental Issues: Energy Use and Conservation*. This series has data from 1994 to 2014, with earlier data available from other surveys in the 1980s (Australian Bureau of Statistics 2014). Unfortunately, ABS ceased collecting this data in 2014. A wide range of other data sources have been used to piece together key data for this report. More recent data for some jurisdictions is available in BIS Oxford reports on water heating and space conditioning.

#### Gas connections

A key piece of information is the number of dwellings that have a mains gas connection, as this has a strong influence on the type of water heater that is likely to be installed and to a lesser extent, the type of space heater. ABS4602 collected data on the number of houses with mains gas in each state and territory over the years from 1994 to 2014, with the following caveats:

- Houses with mains gas connections were reported in 1994, 2005, 2008, 2011 and 2014
- Houses with mains gas water heating were reported in 1994, 2005, 2008, 2011 and 2014
- Houses with mains gas heating were reported in 1994, 2005, 2008 only.
- Data on gas was reported for these end uses in 1999 and 2002 but these did not separate mains gas and LPG
- Data on gas space heating was reported in 2011 and 2014 but again, these did not separate mains gas and LPG.

The omission of data from 1999 and 2002 has no significant impact on the analysis for this project. However, the lack of separate reporting for LPG and mains gas for space heating in 2011 and 2014 is quite problematic. For mains gas dominated states like Victoria, the share of LPG is very low and this can almost be ignored. However, for states like Queensland, which have a low penetration of mains gas, LPG can account for as much as 70% of the total gas use in the state (which is still very low). So analysis was undertaken to estimate that stock of mains gas space heaters in each state based on the known share of mains gas and LPG from previous surveys.

Information on the number of residential gas connections after 2014 was obtained from the following sources:

- Australian Energy Regulator *Annual Retail Market Reports* which cover, NSW, Queensland, ACT and South Australia
- Victorian Essential Services Commission various *Victorian Energy Market Reports* for Victoria
- Tasmanian Economic Regulator *Energy in Tasmania Report 2019-20* for Tasmania

- Economic Regulation Authority of WA *Final decision on proposed revisions to the Mid-West and South-West Gas Distribution Systems* in 2019.

No specific data was found for NT, but mains gas connection rates are very low and are assumed to be steady. The overall gas connection data can be represented in several ways. Firstly, as the total number of residential gas connections by state and territory as shown in **Figure 30**. And secondly, as the share of all residential households that have a mains gas connection as shown in **Figure 31**. **Figure 31** shows that the share of gas households is fairly steady in NT, Tasmania, Queensland and South Australia, while there is significant growth in the share of connections in NSW and to a lesser extent Western Australia, while there is a slight decline in household gas share in Victoria and stronger long term decline in the ACT.

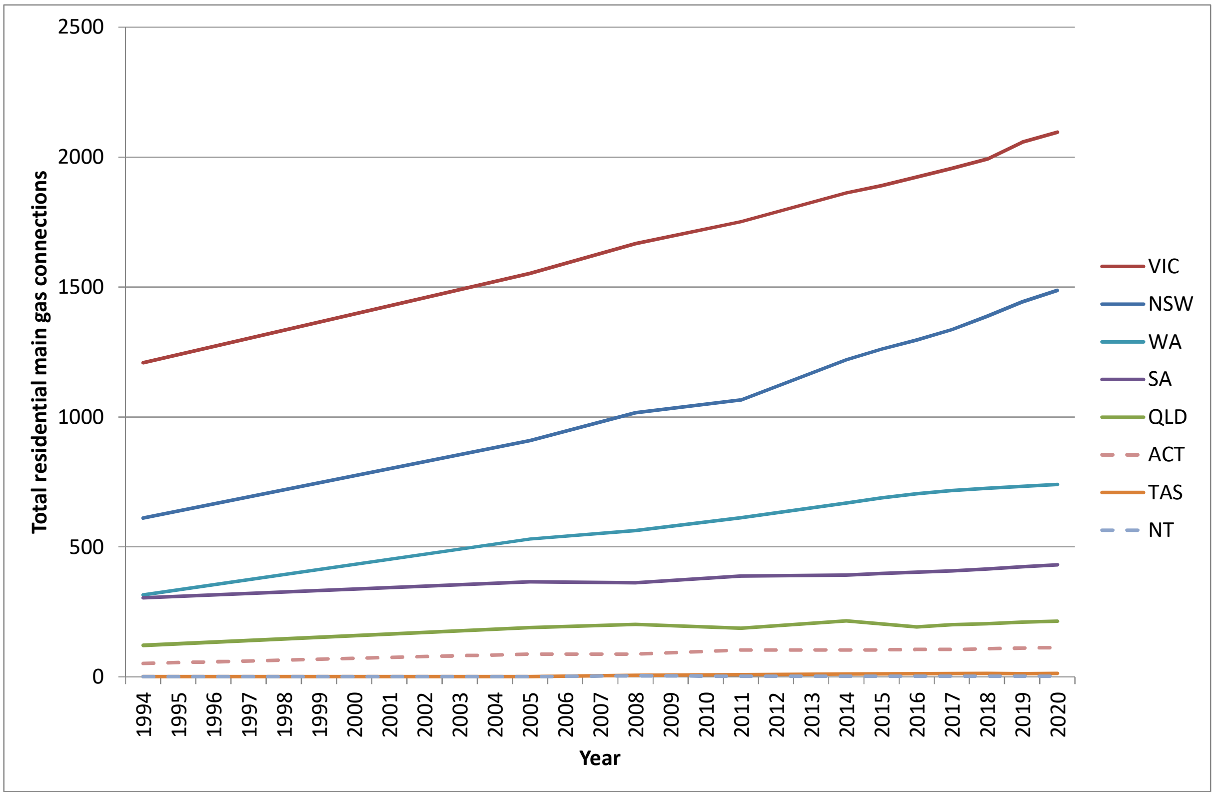



**Figure 30: Total residential mains gas connections by state and territory**

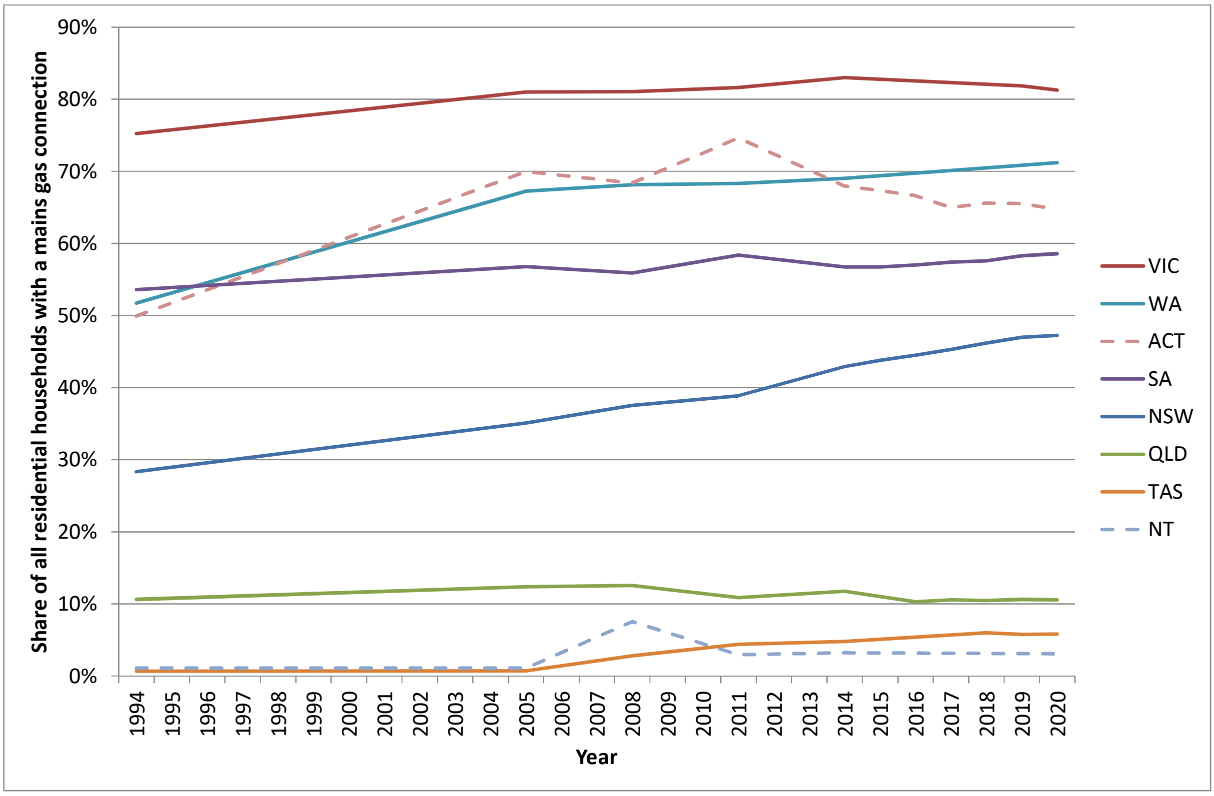



**Figure 31: Share of residential households that have a mains gas connection**

By examining the trends in total gas connections over recent years, it is possible to make an estimate of the percentage of new dwelling built in the past 5 years that have a mains gas connection. This has been done on the basis that most new gas connections will be to greenfield development sites rather than piping gas mains into existing suburbs without gas. There may be some exceptions to this, especially in Sydney. And there may also be cases where existing households with a mains gas connection disconnect over time. But these are thought to be relatively few at this stage, although moving away from a gas connection may be a future trend as there is a longer term impetus to reduce fossil fuel use. On this basis, an approximate estimate of the share of new homes that are connected to mains gas are set out in **Table 65**. This data is being used to estimate the share of fuel type for water heaters, and to a lesser extent, space heating in later sections. Where the apparent connection rate to new homes is above the existing total share of households with mains gas, then the share would be expected to increase over time (and vice versa).

**Table 65: Estimate share of new houses with a gas connection by state**

| State | 2020 existing total gas connections | New houses with mains gas | Expected trend in gas connections |
|---|---|---|---|
| New South Wales | 47% | 87% | Increasing |
| Victoria | 81% | 70% | Decreasing |
| Queensland | 11% | 0% | Decreasing |
| South Australia | 59% | 87% | Increasing |
| Western Australia | 71% | 100% | Increasing |
| Tasmania | 6% | 18% | Increasing |
| Northern Territory | 3% | 2% | Stable (est) |
| Australian Capital Territory | 65% | 42% | Decreasing |

Table notes: The apparent high rates in NSW, SA and WA may include some infill to existing homes. For subsequent analysis, a new house gas connection rate of 85% is used for NSW and SA and 90% for WA. NT is an estimate only.

## Trends in water heater types

The most comprehensive long term data set for water heater ownership by type in the residential sector is from the series of Australian Bureau of Statistics surveys from 1994 to 2014 ABS4602.0 *Environmental Issues: Energy Use and Conservation* (Australian Bureau of Statistics 2014). This provides detailed stock data for each state and territory, and in some cases, at capital city and balance of state sub-regions. EES has undertaken detailed analysis of this data for many years and has also obtained detailed private cross tabs to provide a more detailed picture of water heater data at a state level as illustrated below. This is the best and most reliable long term data set for water heater stock by type in all states.

Unfortunately, the Australian Bureau of Statistics ceased collecting household ownership data in 2014 and has not conducted any related surveys on appliance ownership since that year. The only other source of data on household water heaters in recent years is by BIS Oxford Economics titled *The Hot Water Systems Market in Australia* (BIS Oxford Economics 2018a, 2020a). This provides detailed data on the installed share of water heaters across 5 states (NSW, Victoria, Queensland, South Australia and Western Australia) as well as data on fuels used and sales. Various editions of the report give data on type of system installed for years 2014, 2016, 2018 and 2020. Each survey is based on a national sample size of around 4,000 to 5,000 households. Water heater system types documented are electric storage, gas instantaneous, gas storage, solar thermal electric boost, solar thermal gas boost, heat pump and electric instantaneous. While this survey is a little bit on the small side in terms of sample size, it is the only data available in recent years across all water heater types. The other consideration is that water heater surveys (conducted by phone or online) are notoriously difficult as many people don’t have any idea what sort of hot water system that have installed.

Detailed analysis of the BIS data revealed some discrepancies with ABS data in 2014 at a state level. There were also some discrepancies from survey to survey, which appeared to show more volatility for some parameters than is likely to be possible in terms of real stock changes. This varied by state and fuel. It is unclear what has generated these differences. So for this report, the data from

ABS4602 was used up to 2014 and the BIS data was used to establish trends in the ABS data for each of the main water heater types over time.

### Gas water heaters

While solid ownership data is now rare in the residential sector for all states, data on gas connections can provide a useful approach to estimate the share of gas water heaters as a starting point. There are several parameters that are very stable with respect to gas water heaters over time. Firstly, the number of households with a mains gas connection that have a mains gas water heater is fairly steady for all state and territories as shown in **Figure 32**. Given that the number of mains gas connections to 2020 can be established from public data sources, this provides a reasonable basis for estimating the number of mains gas water heaters installed in each state. Note that the number of main gas connections in Tasmania and NT are very small so the data appears volatile. Tasmania has also seen an increase in main gas connections from almost nothing in 2005.


**Figure 32: Share of households with mains gas that use a mains gas water heater**

The other parameter that is very stable over time with respect to gas water heaters is the share of mains gas water heaters of all gas water heaters (mains gas + LPG). It is expected that houses that have a main gas supply will always use mains gas for water heating if a gas water heater is selected as the operating costs are much lower. In general terms, houses that use LPG for water heating will be at sites where no mains gas is available, so mains gas and LPG can be considered as mutually exclusive for each end use. Of course there are houses with a mains gas connection that do not use mains gas for water heating as illustrated in **Figure 32** – it is assumed that other types of water heaters such as electric and solar systems will be used in these cases. The mains gas water heaters as a share of all gas water heaters by state is shown in **Figure 33**. For states with well-developed gas networks, more than 90% of gas water heaters are operated on mains gas (less than 10% on LPG). Tasmania, Queensland and NT have extremely limited mains gas networks (refer **Figure 31**), so around half of the gas water heaters are operated on main gas with the balance on LPG. Gas water heater ownership is very low in these states.

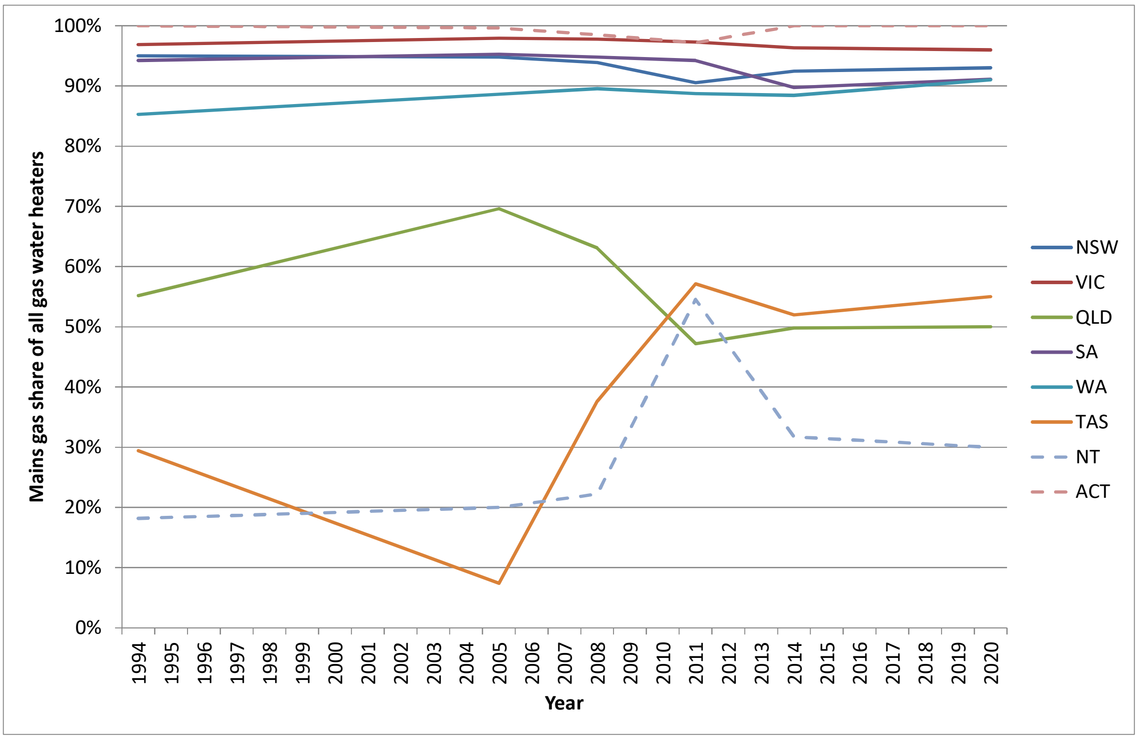



**Figure 33: Mains gas water heaters as a share of all gas water heaters by state**

Combining this data allows an estimate of gas water heater ownership to be made at a state level in 2020 as shown in **Figure 34**. This is an estimate of the installed stock of gas water heaters (existing and new houses over time). Most states are steady, with NSW, ACT and South Australia showing some overall growth in share of gas water heaters over time.

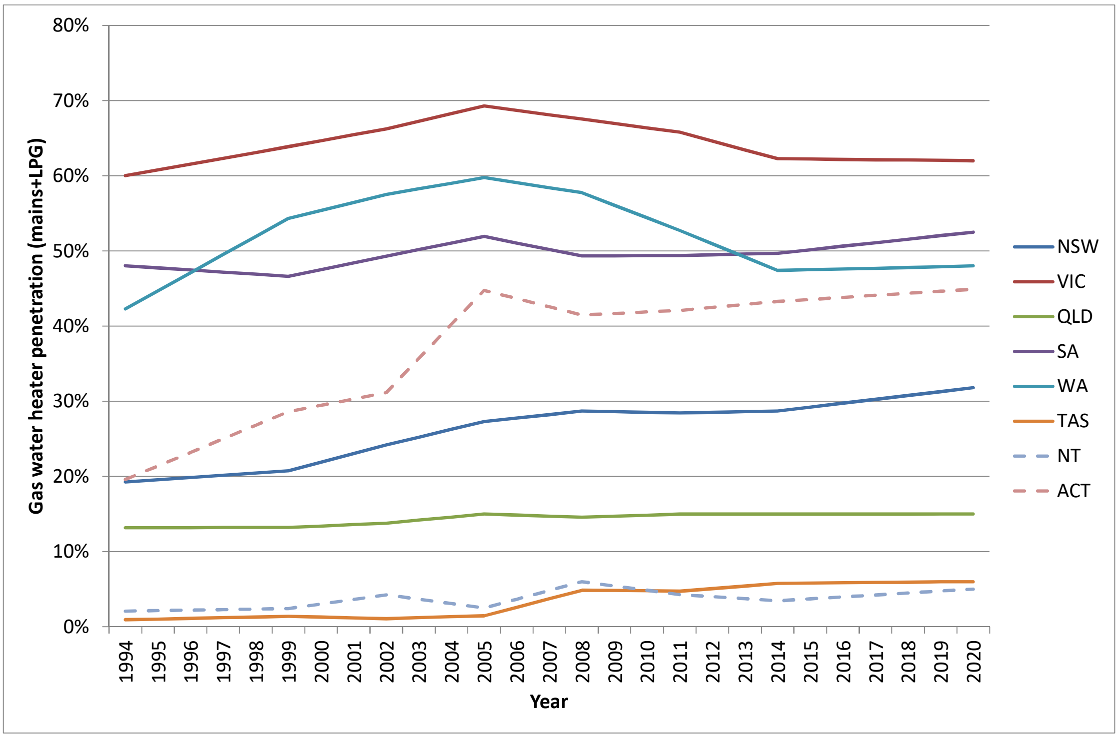



**Figure 34: Gas water heater penetration by state**

For this project, there is a strong interest in the likely share of water heater type in Class 1 and Class 2 dwellings. There is very little data on this aspect available. However, EES commissioned ABS to undertake some internal cross tabs on the 2005 edition of ABS4602 to establish some key parameters relating to dwelling type. The results are summarised in **Table 66**.

**Table 66: Share of dwelling types with mains gas water heaters, 2005**

| Share | NSW | VIC | QLD | SA | WA | TAS | NT | ACT | AU |
|---|---|---|---|---|---|---|---|---|---|
| **Detached 1a(a)** | 24.3% | 69.0% | 8.7% | 48.6% | 56.4% | | | | 38.4% |
| **Attached 1a(b)** | 36.7% | 75.6% | 5.6% | 54.5% | 59.8% | | | | 45.5% |
| **Class 2** | 29.5% | 60.9% | 37.4% | 69.6% | 50.0% | 2.5% | 2.1% | 16.5% | 38.2% |
| **Other** | 8.9% | 37.3% | 21.7% | 36.4% | 41.9% | | | | 20.3% |
| **Total Gas WH** | 26.2% | 69.0% | 10.7% | 50.3% | 56.4% | 0.1% | 0.5% | 41.9% | 39.0% |
| **Class 2/Total** | 1.12 | 0.88 | 3.48 | 1.38 | 0.89 | N/A | N/A | 0.39 | 1.12 |

Source: ABS4602 internal cross tabs, with author estimates in red. "Other" constitutes a very small share (much less than 1%) in most jurisdictions. Note that this is very old data.

The important values to compare are the proportion of Class 2 dwellings with a gas connection with the overall average gas connections in the state. Class 2 gas water connection rates are higher in NSW, Queensland, South Australia, Tasmania and NT while they are lower in Victoria, Western Australia and the ACT. This data is quite old and may not reflect the trends in the large increase in Class 2 construction over the past decade. Most of these larger developments are in the capital cities, so the gas connections rates could be expected to be broadly reflective of the state average connection rate for gas water heaters (or higher). The Class 2/Total multiplier below has been used to adjust the overall expected rates for new residential in 2020 to account for gas water heaters in Class 2. As expected, LPG was almost never used for gas water heating in Class 2 buildings (cylinders are not permitted indoors). The proportion of Class 2 households with a mains gas connection that used main gas water heaters was also examined. For the larger states, the rate was very similar to the state average, with all at around 80% of households with a mains gas connection using a gas water heater. This data confirms that the data in **Figure 32** can be applied to both Class 1 and Class 2 dwellings.

### Other types of water heaters

The previous section covers gas water heaters in some detail for each state and territory. The main types of water heaters of interest for this project are as follows:

- Electric Storage (continuous)
- Electric Storage (controlled)
- Heat Pump (Standard)
- Solar electric (Standard)
- Gas storage
- Gas Instantaneous
- Solar Gas.

In the following sections, each dwelling is allocated into one of these water heater bins. Sometimes this requires assumptions about how to lump or split categories that do not completely align with these seven main types.

EES has a state and territory model of penetration of each of these water heater types over time based on the best available data sources, primarily ABS4602 and BIS Oxford Economics. It should be noted that identifying the type of water heater installed in a specific household is not always simple and some householders are not aware of the type of system installed, so this make some questionnaires slightly less robust. Also note that ABS record all fuels used for water heating, so solar thermal with electric boost is recorded as both solar and electricity, so various corrections are required to get a more accurate share of system type recorded and remove double counting, depending on the survey. The core primary fuels for water heating are electricity, gas and solar. A very small share of systems are classified as other fuels: these are mostly wood and in all states except Tasmania (where it is 1.2%) the share is less than 0.5% so has been ignored for this study.

For the purposes of tracking different types over time, heat pump, solar electric boost and solar gas boost are all classified as "solar" and the share of gas boost solar, solar thermal electric boost and heat pump are also separately tracked.  Similarly, for electric water heaters, the share of controlled load and continuous tariff units are separately tracked. Electric storage (continuous) includes some electric instantaneous (no storage). Gas water heaters include mains gas (methane) and LPG. As shown in the previous section, for most states, LPG is only a small share of gas water heaters. Gas water heaters are split into instantaneous and storage systems.

### Water heaters in new Class 2 dwellings

While tracking the stock of water heaters by type is somewhat useful, it does not necessarily provide an accurate picture of what is going into new homes. The overall approach for this study is to look at new Class 2 dwellings initially and allocate the likely share of water heater types to those dwellings. Class 2 are subjected to a number of substantial constraints with respect to water heating:

- LPG is almost never used as cylinders cannot be stored indoors for safety reasons – all the ABS and state based data confirms this assumption. So all gas water heaters in Class 2 dwellings are mains gas only.
- The rate of gas water heaters for households with a mains gas connection varies a little in Class 2 dwellings by state, but is generally consistent with the state average (tends to be a bit higher as Class 2 appear are usually constructed in higher density parts of major cities that are more likely to have gas).
- The prevalence of solar systems in Class 2 dwellings will be very low to negligible. This is because accessing the roof space is very difficult for residents in the top storey of a multi-story dwelling and impossible for residents on lower floors. This has been confirmed through multiple sources, although central heat pump systems seem to be used in some larger developments in Sydney and Melbourne.
- There will be fewer controlled load electric storage systems in Class 2 dwellings as larger tanks sizes cannot fit into the allocated space, especially for smaller dwellings. This is less of an issue in Queensland and NSW, where extended off peak tariffs are available (typically engergised 18 hours per day), allowing smaller tanks to be utilised on controlled load tariffs.
- Similarly, gas storage systems will be less prevalent in Class 2 dwellings due to space constraints.

Fortunately, NSW and Victoria have some data collections that reveal the actual rate of installation of water heater types in new Class 2 dwellings. These are outlined in the following sections.

### *10.6.7 NSW BASIX scheme*

The New South Wales Building Sustainability Index (BASIX) scheme establishes a minimum energy efficiency standard for the construction and renovation of residential dwellings in NSW. BASIX includes an efficiency score, which is based on expected energy savings for the dwelling against a 2004 baseline, and a thermal comfort score, which measures the thermal efficiency of the dwelling, based on the NatHERS rating or equivalent. All dwellings must achieve a minimum score for both efficiency and thermal comfort. BASIX compliance is typically achieved through the installation of energy efficient appliances (such as an efficient hot water system) and improved building shell thermal efficiency (such as insulation). Therefore the scheme requires mandatory reporting on building shell, space conditioning and water heating equipment.

A summary of data for recent years was kindly provided by Dr Kevin Yee at the NSW Department of Planning, Industry and Environment (DPIE). This covered all installations in new dwellings for financial years 2017-18 and 2018-19 and was provided in the form of a Power BI Desktop file that allowed interactive interrogation of the detailed data summaries. The data was split into a multi-dwelling file and a single dwelling file. The sub-types within each file were:

1. Single sub-category attached
2. Single sub-category separate house
3. Single sub-category single unit
4. Multi sub-category Multi
5. Multi sub-category single (attached)
6. Multi sub-category flat (units)

After discussions with DPIE, it was agreed that these categories be allocated into the main housing types of interest for this project on a weighted basis:

- Categories 3 and 6 to be allocated to Class 2
- Other categories to be allocated to Class 1.

After weighting, the share of each water heater type was calculated as set out in **Table 67**.

**Table 67: Estimated share of water heater types in new homes in NSW from BASIX**

| System type | Class 2 | Class 1 |
|---|---|---|
| Electric Storage (continuous) | 4.09% | 1.07% |
| Electric Storage (controlled) | 13.59% | 0.60% |
| Heat Pump (Standard) | 0.34% | 8.28% |
| Solar electric (Standard) | 0.30% | 7.77% |
| Gas storage | 10.53% | 1.21% |
| Gas Instantaneous | 70.75% | 78.77% |
| Solar Gas | 0.39% | 2.30% |
| Total | 100.00% | 100.00% |

Table notes: Data provided by NSW DPIE. Assumptions for Class 2: share of central hot water => gas = 75% (balance electric), share of central gas hot water => storage = 20% (balance instantaneous), share of central electric hot water => controlled load = 80% (balance continuous). Assumptions for Class 1: share of electric storage hot water => controlled load = 70% (balance continuous).

### *10.6.8 Victorian Building Authority*

Data on approval for new dwellings is collected by the Victoria Building Authority. Data on building permits collected by private building surveyors is submitted to VBA and then compiled and published (see https://www.vba.vic.gov.au/about/data ). The data does not appear to have strong quality control on inputs and the data includes from very small renovations up to large multi-dwelling developments, infill construction, greenfield developments, demolitions and everything in between. However, it does provide some indication of water heater data for many of the developments. As noted previously, since 2005, Victorian building regulations for new Class 1 buildings have been required to install either a solar water heating (SWH) system or a rainwater tank (RWT) connected to a toilet, which gives two pathways to compliance for new dwellings. A further option was made available in Practice Note 55-2018 “Residential Sustainability Measures” released by the VBA which allows that “a Performance Solution for the use of grey water treatment systems or dual water reticulation and water recycling systems connected to toilet flushing systems.” Where the solar water heater option is chosen and the house is connected to a reticulated gas supply is available, the solar water heater system must be gas-boosted (“the gas requirement”). This effectively means that heat pump systems are not permitted in new Class 1 dwellings where the solar water heater compliance path is selected (heat pumps are permitted if the rainwater tank compliance option is selected).

As noted in the plumbing code for NCC, there are no requirements for Class 2 dwellings. However, VBA noted that some 1.55% of new Class 2 dwellings in calendar 2020 had selected a solar water heater option. It is assumed that 75% of these will be solar gas systems.

For Class 1 dwellings, VBA data indicates that around 65.4% of new Class 1 dwelling had selected the solar water heater compliance pathway (interestingly, this includes 6.1% of approvals that selected both the solar and the rainwater tank compliance pathways). As per the larger scale gas connection analysis, it is estimated that around 70% of new Class 1 dwellings will be connected to mains gas. While DELWP has commissioned some deeper investigation of this approvals data, it appears that, at this stage, there is no specific data on water heater selections for households that select the rainwater tank compliance pathway.

### *10.6.9 Victoria BESS*

Some local governments in Victoria require certain developments to be modelled and approved under the Built Environment Sustainability Scorecard (BESS) scheme (see https://bess.net.au/ ). BESS is an assessment tool created by local governments in Victoria. It assists builders and developers to show how a proposed development demonstrates sustainable design at the planning permit stage. At this stage only a limited number of councils use BESS and not all new developments or planning applications trigger a BESS assessment, so there are gaps in the data. According to the Victorian Department of Environment, Land, Water and Planning (DELWP), BESS data for Class 2 dwellings are broadly representative. However, data for Class 1 dwellings is mostly very limited to established inner city LGAs which are not representative of the larger scale greenfield developments on the urban fringes, so Class 1 BESS data has not been analysed for this project.

Based on submissions for 20,000 Class 2 new dwellings in 2019 that has been carefully reviewed by the Municipal Association of Victoria (MAV) and DELWP, the following breakdown of water heaters was recorded as shown in **Table 68**.

**Table 68: Estimated share of water heater types in new Class 2 homes in Victoria from BESS**

| System type | Share |
|---|---|
| Electric Storage (continuous) | 2.58% |
| Electric Storage (controlled) | 0.48% |
| Heat Pump (Standard) | 8.57% |
| Solar electric (Standard) | 0.39% |
| Gas storage | 29.25% |
| Gas Instantaneous | 57.57% |
| Solar Gas | 1.16% |
| Total | 100.00% |

Table notes: Data provided by DELWP. Assumptions for Class 2: share of central electric storage hot water => controlled load = 80% (balance continuous), share of electric storage hot water => controlled load = 20% (balance continuous). Solar thermal rates adjusted after review of VBA data.

### *10.6.10 Clean Energy Regulator*

Data on new solar and heat pump water heaters is collected by the Clean Energy Regulator (CER). The CER awards Renewable Energy Certificates (RECs) under the Small Scale Renewable Energy Scheme (SRES), which is part of the Renewable Energy Target (RET). While it is possible that some solar systems installed are not recorded through the CER, it is thought that almost all solar thermal water heaters and heat pump water heaters are recorded under that scheme as RECs provide a significant incentive for purchasers. The CER publishes postcode lists of where solar water heaters are installed[30]. A small number of postcodes listed by the CER do not exist in Australia Post listings. A small number of postcodes have localities in more than one state or territory. The historical breakdown of all solar thermal and heat pump installations since 2001 is shown in **Table 69**.

**Table 69: Historical solar and heat pump installations by state**

| Installations | NSW | VIC | QLD | SA | WA | TAS | NT | ACT |
|---|---|---|---|---|---|---|---|---|
| Total solar+HP 2001-19 | 290611 | 344822 | 294634 | 65380 | 186184 | 15569 | 20428 | 10710 |
| Solar+HP per year 2001-19 | 15295 | 18149 | 15507 | 3441 | 9799 | 819 | 1075 | 564 |
| Solar+HP installed 2020 | 6715 | 32771 | 11240 | 4668 | 9101 | 1126 | 856 | 1471 |
| Share heat pump 2001-19 | 27.2% | 13.9% | 30.8% | 30.4% | 12.5% | 52.8% | 8.4% | 22.5% |
| Share heat pump 2020 | 45.6% | 39.3% | 47.8% | 85.1% | 32.2% | 91.1% | 2.3% | 81.0% |
| Total solar installs/ household increase in 2020 | 12% | 57% | 31% | 72% | 70% | 47% | 104% | 43% |

Table notes: solar installs per household increase is based on projected household increases in 2020 based on 2016 ABS3236 data, so will not have included any impacts from COVID-19. Many of the solar systems will be replacement systems for existing households, so this only provides a cap on the estimate of solar systems being installed in new homes. Air source heat pumps were introduced into the Small-scale Renewable Energy Scheme in 2005 so there is no installation data available pre-2005 for this fuel source. Therefore historical rates of installation for heat pumps will naturally be lower. Heat pump performance has also improved dramatically in recent years making their performance and cost effectiveness superior in many cases.

There are a number of interesting observations from this data. Firstly, the historical rate of installation had a large peak in around 2009, which was driven largely by federal and some state subsidies, as illustrated in **Figure 35**. The current rate of installation is around 65,000 systems per year (nationally) and this has been increasing slowly for the past seven years. Note that the expected number of water heater installations in 2020 (replacement of existing systems and new households) is around 1,000,000 units a year, so solar and heat pump systems constitute around 6.5% of all water heaters sold.

[30] See CER website http://www.cleanenergyregulator.gov.au/RET/Forms-and-resources/Postcode-data-for-small-scale-installations

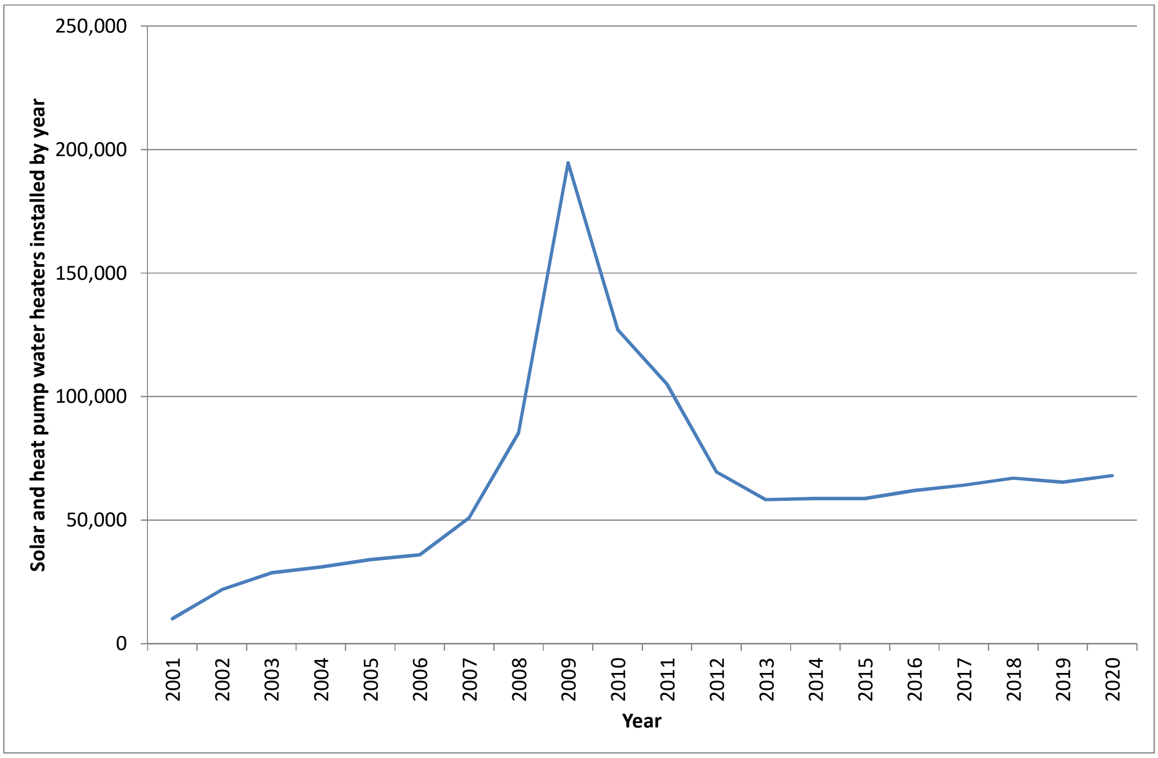



**Figure 35: Installation of solar and heat pump water heaters by year, Australia**

The 2020 state share of installed solar thermal and heat pump water heaters is shown in **Figure 36**.

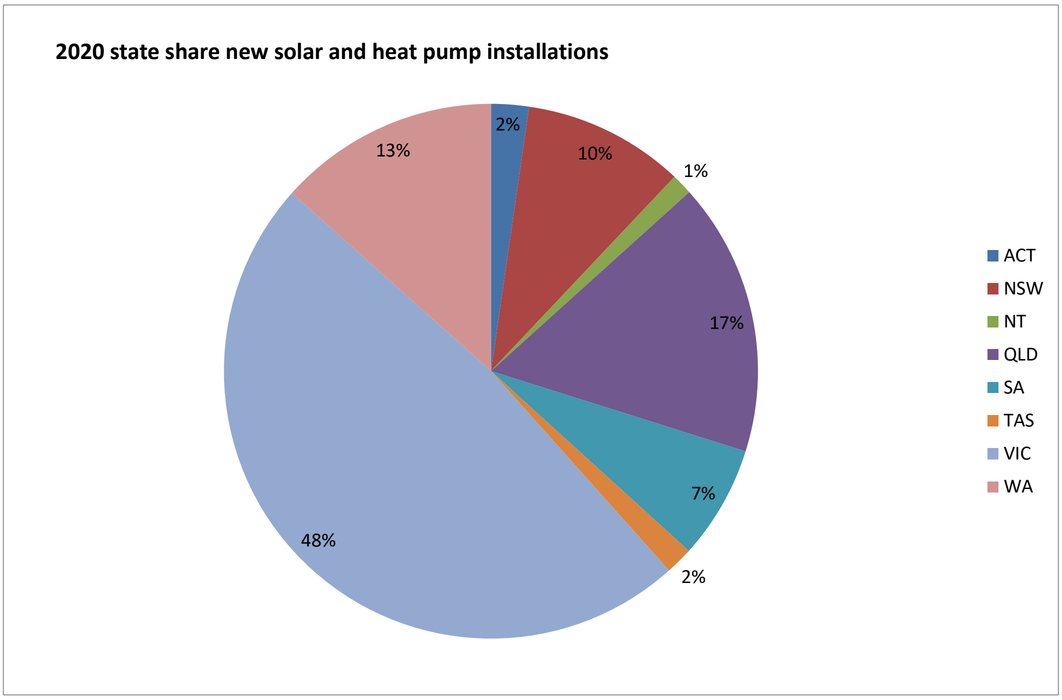



**Figure 36: State share of all solar and heat pump water heater installations in 2020**

**Figure 36** shows that Victoria accounts for about half of all solar water heaters installed in Australia. This is more obvious if the rate of solar installation per 1,000 existing households in 2020 is examined as shown in **Figure 37**.

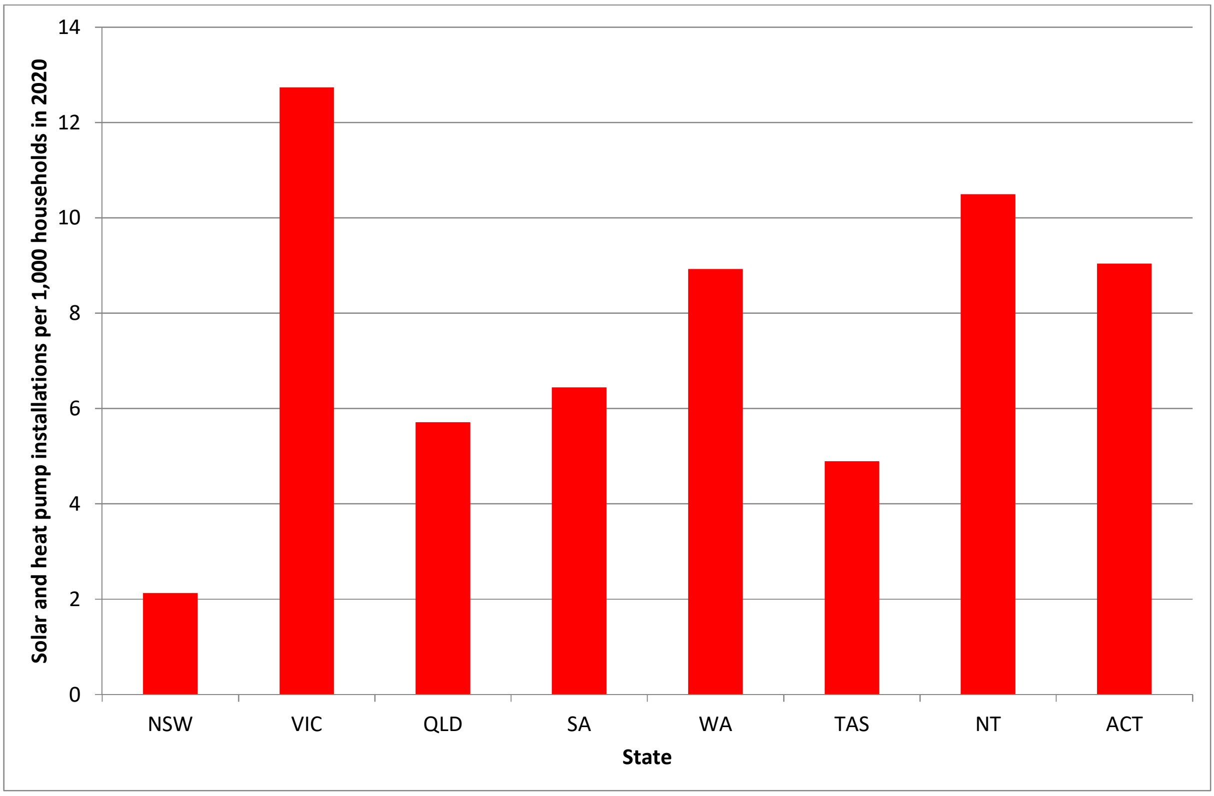



**Figure 37: Solar and heat pump installations per 1,000 households in 2020**

The CER separately lists solar thermal and heat pump installations in the postcode files, which take a little bit of effort to process. Interestingly, it appears the share of heat pump systems is very high in South Australia, Tasmania and the ACT (80% or more), while NSW, Victoria, Queensland and WA are lower at around 30% to 50%, as shown in **Figure 38**. Unsurprisingly, the share of heat pump water heaters in the Northern Territory is very low. The share heat pump systems in 2020 is substantially higher than the historical share (2001-2019) in all states and territories except the Northern Territory, as shown in **Table 69**. Policies on water heaters vary significantly by state and this appears to have an influence on installations. The ACT, South Australia and and Victoria have white certificate schemes that provide incentives to install high efficiency heat pump systems to replace existing gas or electric storage systems. As noted above, heat pump water heaters do not currently qualify as a solar water heater for compliance purposes for new Class 1 dwellings in Victoria.

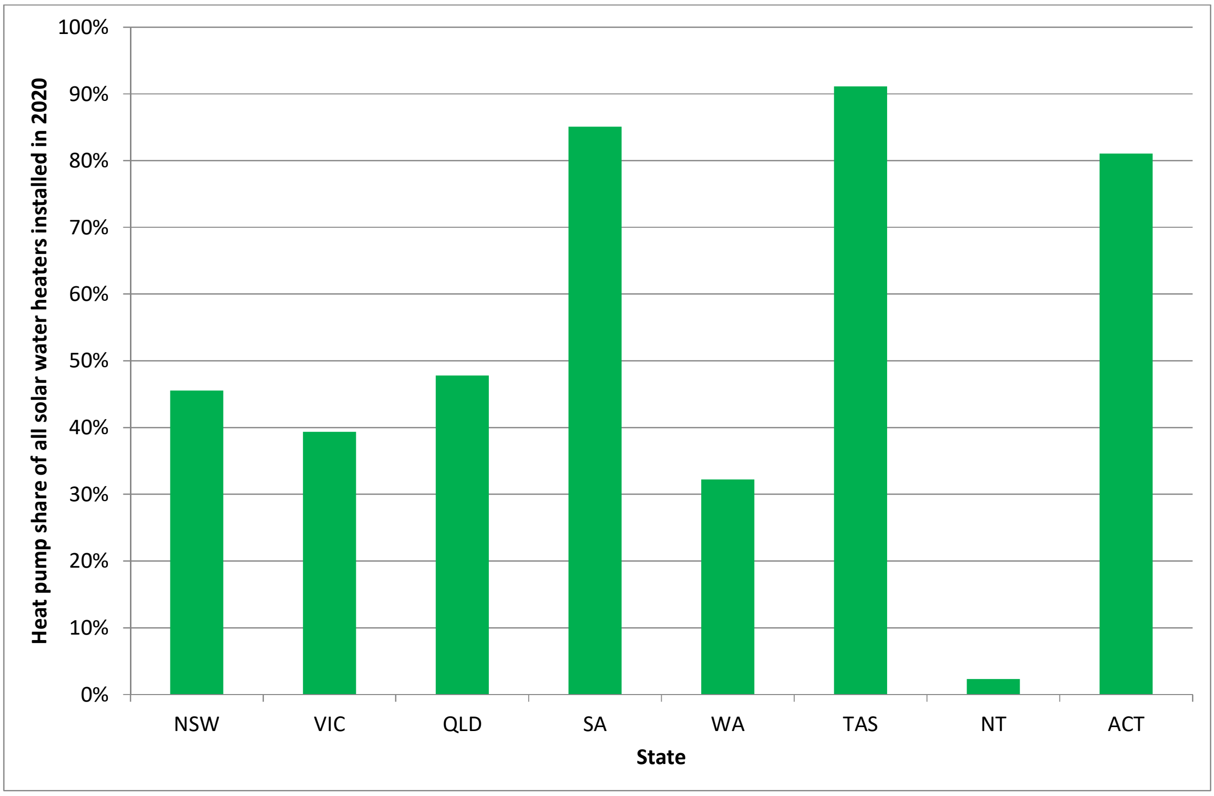



**Figure 38: Share of heat pump water heaters installed by state**

While the CER data is quite interesting and useful, it is of limited use for this project as there is no record whether the systems installed are in new homes or existing homes (or Class 1 or Class 2 buildings). It does provide some indirect evidence of activity at a state level.

### *10.6.11 Energy efficiency registration databases*

Apart from solar and heat pump systems, which are covered by the CER, the Greenhouse and Minimum Standards Act (GEMS, 2012) does regulate the efficiency of other water heater types such as gas and electric storage systems. While these databases do provide a list of models and some of their energy performance characteristics, there is no data to indicate the number of sales by model or in which state systems are installed or whether they are replacement systems or in installed new homes.

### *10.6.12 Approach to estimating water heater types by state*

For all new dwellings, the type of water heater is essentially split into 3 types: solar, gas and electric. A range of sources are used to estimate gas first, then solar, with the residual being allocated to electric. The share of each sub-type is then estimated based on available data by building Class and state.

The first step is to estimate the number of gas connections in each state and territory as set out in the previous section. A split of gas connection shares for Class 2 and Class 1 is then made (Class 2 is usually expected to be higher than the state average as they are built in higher density inner city suburbs which are more likely to have access to main gas). This allows the share of gas water heaters to be estimated for each state and territory. Actual data has been used for NSW new Class 1 and Class 2 and sample data has been used for new Victoria Class 2 dwellings. The share of instantaneous versus storage is then made for gas. Only data on stock share of instantaneous versus storage gas is available for most states. This shows that the stock trend in most jurisdictions in moving towards instantaneous, which suggests a quite high share of new sales. The known stock share of instantaneous gas had therefore been adjusted upwards to take account of the likely share installed in new dwellings.

The next step is to estimate the share of solar systems in each state and territory. Installation data at a state level from CER gives us a hint of likely rate of installation of solar (which includes solar-electric, solar-gas and heat pump). As noted previously, it is expected that the rate of solar installation shown in last row of **Table 69** will be a cap, as a significant number of installations recorded by CER will be into existing dwellings (although it is expected that the majority will be installed in new dwellings). In most states the share of solar gas is quite low as these are considerably more expensive. The exception is for Victoria, where a solar thermal with gas boost is mandatory if the dwelling has a mains gas connection and the solar water compliance pathway for a new Class 1 dwelling is selected. The share of heat pump systems can be estimated indirectly from the CER data on heat pump share installed in 2020 as shown in **Table 69**. It is important to note that the CER data is state wide, so corrections need to be made for the proportion of solar systems installed (or not installed) in both Class 2 and Class 1 dwellings.

**Table 70** and **Table 71** show the input data assumptions to estimate the share of water heater types in new Class 1 and Class 2 dwellings.

**Table 70: Input assumptions for estimating water heater share for each state, new Class 2 dwellings**

| State | Class 2 share 2022 | State gas new conn | Class 2 Gas conn adj | Class 2 Gas conn | Gas WH Class 2 | Gas WH estimate | Share solar WH | Share electric WH | Share electric controlled | Share gas instant | Share solar gas | Share Solar heat pump | Share solar electric |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NSW | 38.7% | 85% | 1.10 | 93.5% | 85% | 81.28% | 1.04% | 17.68% | 76.9% | 87.0% | 37.9% | 32.9% | 29.2% |
| VIC | 20.9% | 70% | 1.40 | 97.4% | 85% | 86.82% | 10.12% | 3.06% | 15.5% | 66.3% | 11.5% | 84.7% | 3.8% |
| QLD | 21.8% | 3% | 1.35 | 4.1% | 85% | 3.44% | 15% | 81.56% | 60% | 85% | 3% | 42% | 55.0% |
| SA | 10.0% | 85% | 1.25 | 106.3% | 85% | 90.31% | 3% | 6.69% | 70% | 85% | 11% | 75% | 14.0% |
| WA | 16.0% | 90% | 1.10 | 99.0% | 85% | 84.15% | 3% | 12.85% | 10% | 85% | 21% | 25% | 54.2% |
| TAS | 3.1% | 18% | 1.35 | 24.3% | 85% | 20.62% | 8% | 71.38% | 30% | 80% | 5% | 85% | 10.0% |
| NT | 15.0% | 2% | 1.35 | 3.1% | 85% | 2.66% | 30% | 67.34% | 7% | 60% | 1% | 2% | 97.0% |
| ACT | 48.2% | 42% | 1.35 | 56.7% | 85% | 48.24% | 12% | 39.76% | 40% | 85% | 15% | 80% | 5.0% |

Table notes: Data in red for NSW is based on BASIX and data for Victoria is based on BESS. Solar shares add to 100%. Gas storage share is 1 – instantaneous share. Electric continuous share is 1 – controlled. High share of solar in Victoria is a mix of heat pump and central heat pump.

**Table 71: Input assumptions for estimating water heater share for each state, new Class 1 dwellings**

| State | Share Class 1 2022 | State new gas conn | Class 1 Gas conn adj | Class 1 Gas conn | Gas WH Class 1 | Gas WH estimate | Share solar WH | Share electric WH | Share electric controlled | Share gas instant | Share solar gas | Share Solar heat pump | Share solar electric |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NSW | 61.3% | 85% | 0.937 | 79.6% | 62.6% | 78.03% | 20.16% | 1.81% | 46.3% | 97.9% | 13.2% | 44.4% | 42.3% |
| VIC | 79.1% | 70% | 0.894 | 62.2% | 30.0% | 18.66% | 70% | 11.34% | 80% | 77% | 70% | 9% | 21% |
| QLD | 78.2% | 3% | 0.903 | 2.7% | 71.2% | 1.93% | 30% | 68.07% | 80% | 84% | 1% | 26% | 73% |
| SA | 90.0% | 85% | 0.972 | 82.6% | 30.0% | 24.79% | 65% | 10.21% | 90% | 90% | 10% | 75% | 15% |
| WA | 84.0% | 90% | 0.981 | 88.3% | 25.0% | 22.07% | 70% | 7.93% | 10% | 77% | 26% | 25% | 49% |
| TAS | 96.9% | 18% | 0.989 | 17.8% | 56.7% | 10.08% | 40% | 49.92% | 50% | 80% | 3% | 91% | 6% |
| NT | 85.0% | 2% | 0.938 | 2.2% | 48.9% | 1.06% | 90% | 8.94% | 7% | 56% | 1% | 2% | 97% |
| ACT | 51.8% | 42% | 0.675 | 28.4% | 69.3% | 19.67% | 60% | 20.33% | 60% | 78% | 15% | 81% | 4% |

Table notes: Data in red for NSW is based on BASIX. Solar shares add to 100%. Gas storage share is 1 – instantaneous share. Electric continuous share is 1 – controlled. Installation rate for gas in NSW is higher than indirect estimates. Gas rate for Victoria lower than historically due to gas-solar requirement for new Class 1.

### 10.6.13 Share of water heater types in new Class 2 and Class 1 dwellings

The data in **Table 70** and **Table 71** has been used to generate the share of water heater type in new Class 2 and Class 1 dwellings as shown in **Table 72** and **Table 73**.

**Table 72: Estimated Share of water heater type in new Class 2 dwellings in 2022**

| State | Electric continuous | Electric controlled | Heat pump | Solar electric | Gas storage | Gas instant | Solar gas |
|---|---|---|---|---|---|---|---|
| NSW | 4.09% | 13.59% | 0.34% | 0.30% | 10.53% | 70.75% | 0.39% |
| VIC | 2.58% | 0.48% | 8.57% | 0.39% | 29.25% | 57.57% | 1.16% |
| QLD | 32.62% | 48.93% | 6.30% | 8.25% | 0.52% | 2.93% | 0.45% |
| SA | 2.01% | 4.68% | 2.25% | 0.42% | 13.55% | 76.77% | 0.33% |
| WA | 11.57% | 1.29% | 0.75% | 1.63% | 12.62% | 71.53% | 0.63% |
| TAS | 49.97% | 21.41% | 6.80% | 0.80% | 4.12% | 16.49% | 0.40% |
| NT | 62.63% | 4.71% | 0.60% | 29.10% | 1.06% | 1.59% | 0.30% |
| ACT | 23.86% | 15.91% | 9.60% | 0.60% | 7.24% | 41.00% | 1.80% |

**Table 73: Estimated Share of water heater type in new Class 1 dwellings in 2022**

| State | Electric continuous | Electric controlled | Heat pump | Solar electric | Gas storage | Gas instant | Solar gas |
|---|---|---|---|---|---|---|---|
| NSW | 0.97% | 0.84% | 8.96% | 8.53% | 1.62% | 76.41% | 2.67% |
| VIC | 2.27% | 9.07% | 6.30% | 14.70% | 4.29% | 14.37% | 49.00% |
| QLD | 13.61% | 54.46% | 7.80% | 21.90% | 0.31% | 1.62% | 0.30% |
| SA | 1.02% | 9.19% | 48.75% | 9.75% | 2.48% | 22.31% | 6.50% |
| WA | 7.14% | 0.79% | 17.50% | 34.30% | 5.08% | 16.99% | 18.20% |
| TAS | 24.96% | 24.96% | 36.40% | 2.40% | 2.02% | 8.06% | 1.20% |
| NT | 8.31% | 0.63% | 1.80% | 87.30% | 0.47% | 0.60% | 0.90% |
| ACT | 8.13% | 12.20% | 48.60% | 2.40% | 4.33% | 15.35% | 9.00% |

### 10.6.14 Trends in space conditioning types

As with water heaters, the most comprehensive long term data set for water heater ownership by type in the residential sector is from the series of Australian Bureau of Statistics surveys from 1994 to 2014 ABS4602.0 *Environmental Issues: Energy Use and Conservation* (Australian Bureau of Statistics 2014). This provides detailed stock data for each state and territory, and in some cases, at capital city and balance of state sub-regions. EES has undertaken detailed analysis of this data for many years and has also obtained detailed private cross tabs to provide a more detailed picture of water heater data at a state level as illustrated below.  This is the best and most reliable long term data set for space heating and cooling stock by type in all states.

Unfortunately, the Australian Bureau of Statistics ceased collecting household ownership data in 2014 and has not conducted any related surveys on appliance ownership since that year. The only other source of data on household space conditioning in recent years is a series of reports by BIS Oxford Economics (BIS Oxford Economics 2020b, 2018b). This provides data on the installed stock across 5 states (NSW, Victoria, Queensland, South Australia and Western Australia). Various editions of the report give data on type of system installed for years 2014 and 2020. Each survey is based on a national sample of around 5,000 households, but the numbers of some heating and cooling sub-types are very low.

Detailed analysis of the BIS data revealed some discrepancies with ABS data in 2014. There were also some discrepancies from survey to survey, which appeared to show more volatility for some parameters than is likely to be possible in terms of stock changes. This varied by state and product type. It is unclear what has generated these differences. So for this report, the data from ABS4602 was used to 2014 and the BIS data was used to establish trends of ABS data for each of the space heating and cooling types over time from 2014 to 2020.

### 10.6.15 Space heating

- **Gas space heaters**

While solid ownership data is now rare in the residential sector for all states, data on gas connections can provide a useful approach to estimate the share of gas space heaters as a starting point (see **Figure 30**). Unlike gas water heater, gas space heating data is less stable over time. From all available data sources, we can establish the total number of gas heating appliances in a household over time as illustrated in **Figure 39**. As with gas water heaters, we can examine the share of mains gas and LPG by state and make some estimates of these trends over time as shown in **Figure 40**. Note that overall penetration of gas space heating is very low in Queensland, Tasmania and Northern Territory. Using these two data sets, we can establish the share of households with a mains gas connection that have a mains gas space heating for all state and territories as shown in **Figure 41**. The first clear observation is that many states appear to have a decline in the number of mains gas connected households that use mains gas for heating. This is particularly evident in Victoria and the ACT, but also in South Australia and Western Australia – all of these states have extensive gas networks. Even in NSW, where there is a relatively aggressive rollout of gas reticulation to new dwellings (and existing dwellings), the share of gas space heaters is relatively low and not increasing.

This suggests that gas space heating is likely to be very much lower new dwellings. This is confirmed by BASIX data in NSW and BESS data in Victoria, which confirm that gas space heating is only found in less than 4% of new homes. The share of gas space heaters (or water heaters) in new homes can be estimated where the share of the stock is stable over time, but as stock share is a lagging indicator, a strong decline in the stock tends to indicate very low levels of installation in new homes. As per water heating, LPG is not used in Class 2 buildings for space heating or water heating.

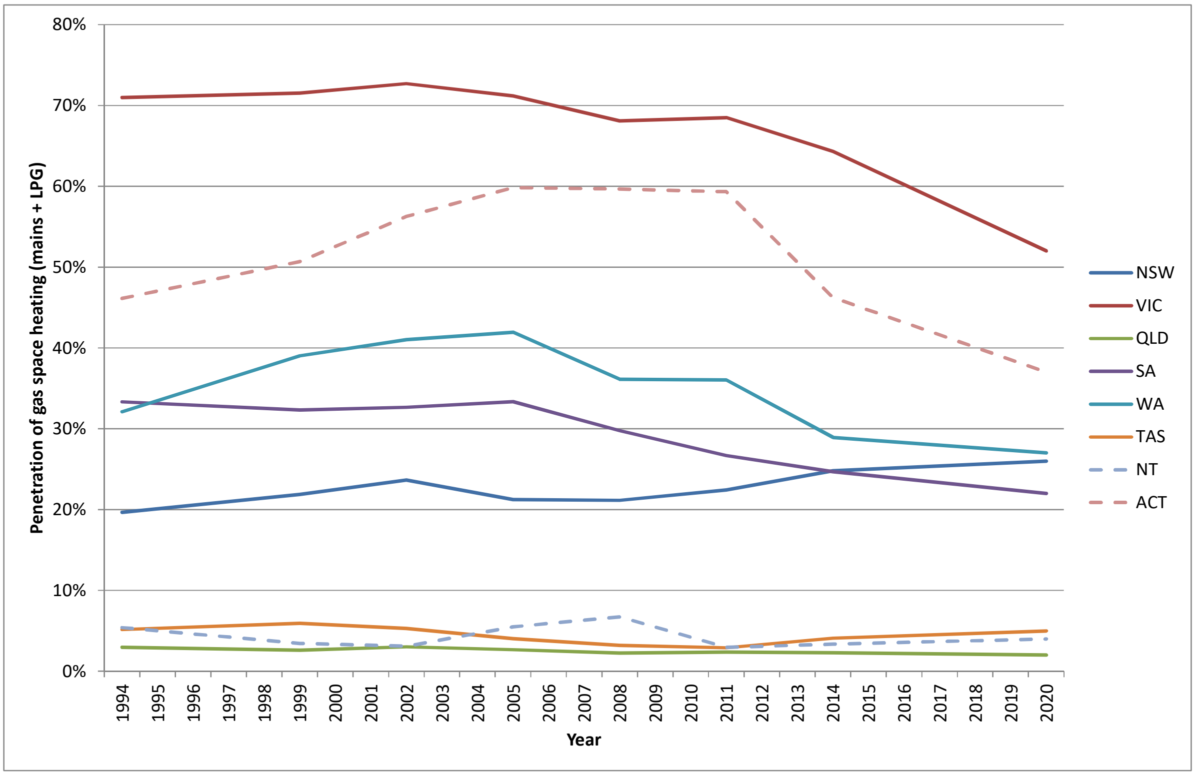



**Figure 39: Penetration of gas space heating by state and territory (mains gas and LPG)**

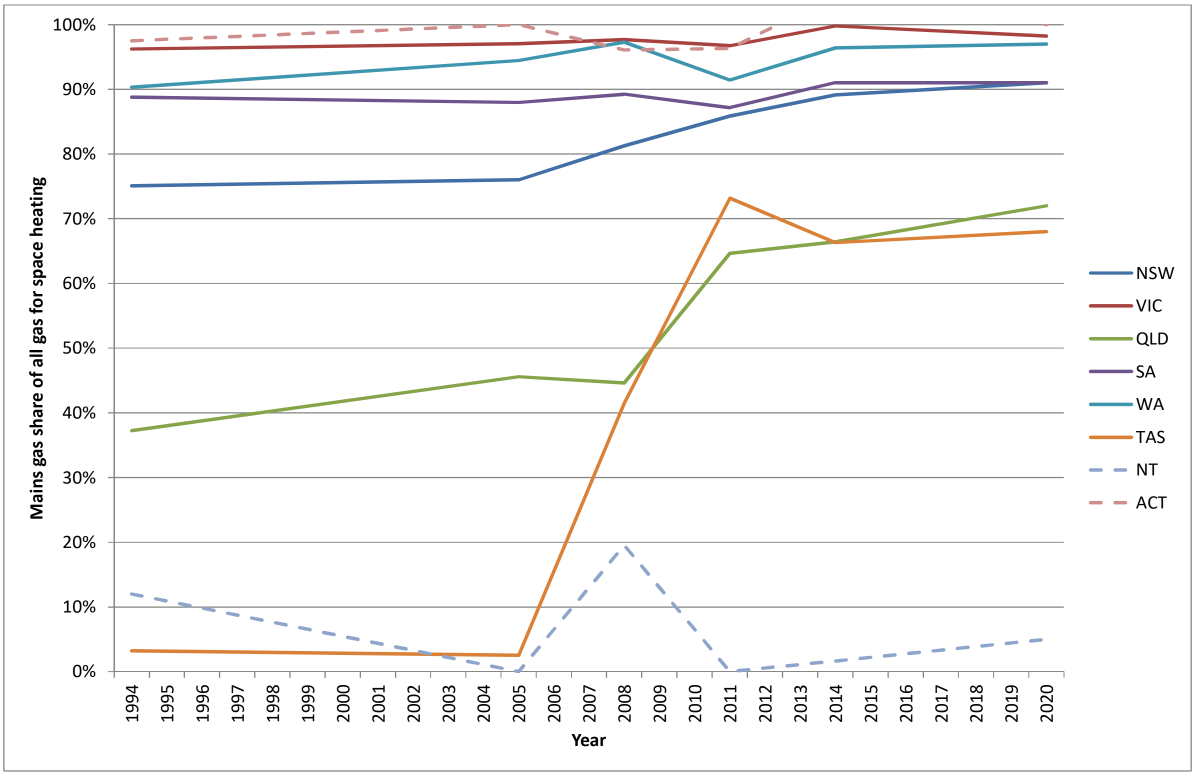



**Figure 40: Mains gas share of all gas space heaters by state and territory**

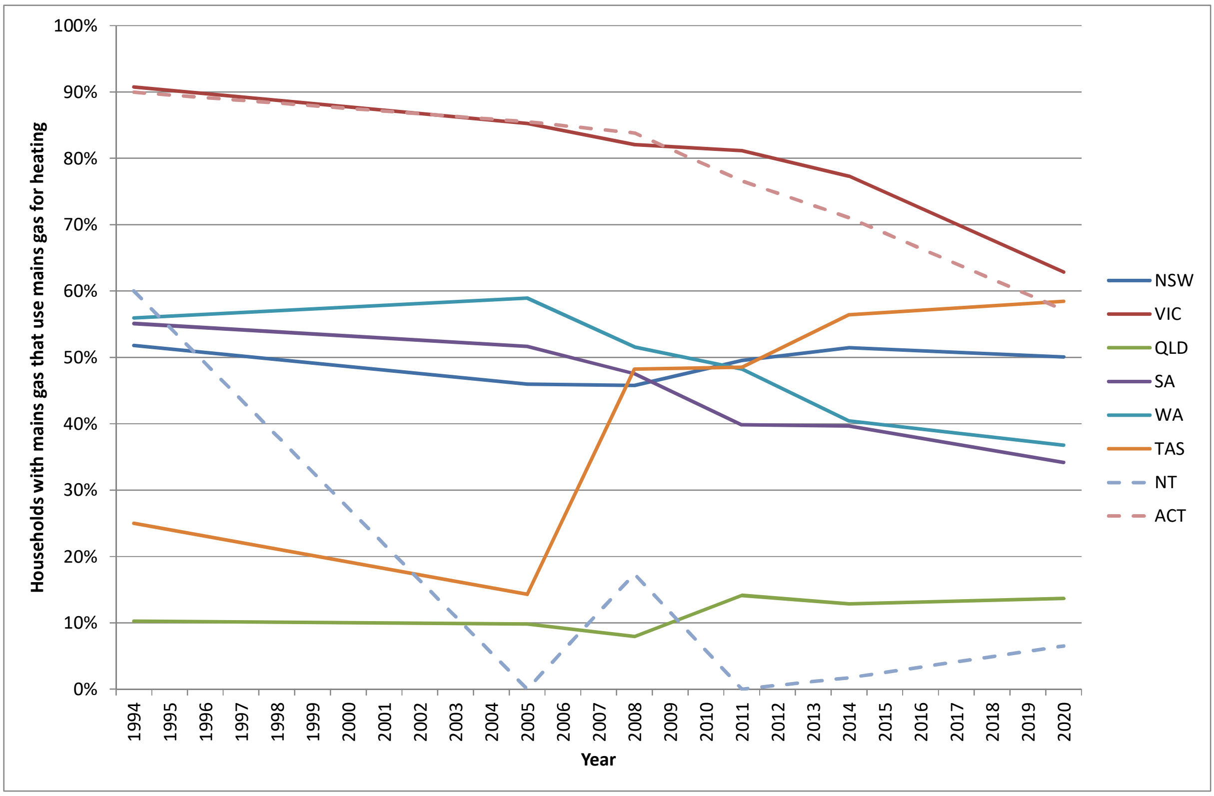



**Figure 41: Share of mains gas heating in houses with a mains gas connection**

## • Other forms of space heating

Apart from gas, the other main fuels used for space heating are electricity and wood. All of the available data suggests that wood as the main source of heating is low but stable in most states as shown in **Figure 42**. All of the available data (ABS cross tabs, BESS, BASIX) suggests that wood is almost never used in Class 2 dwellings, which is unsurprising. So all wood installations are in Class 1 dwellings. As the ownership is stable, this is likely to reflect the installation rate in new Class 1 dwellings.

Electricity is becoming the dominant heating form for residential dwellings as shown in **Figure 43**. An increasing majority of electric heating is provided by reverse cycle air conditioning as shown in **Figure 44**. The stock of main electric heating is now more than 80% reverse cycle air conditioning in nearly all states and territories. This suggests that the vast majority of heating systems in new homes are reverse cycle air conditioners. Analysis undertaken for AEMO in 2020 showed that the vast majority of new air conditioners being installed in Australia are split systems, as illustrated in **Figure 45**. Most ducted systems and many window wall systems will be installed in residential dwellings. Split systems will be installed in a mixture of residential and commercial buildings. This still data still suggests that over 80% of installations in the residential sector will be split systems.

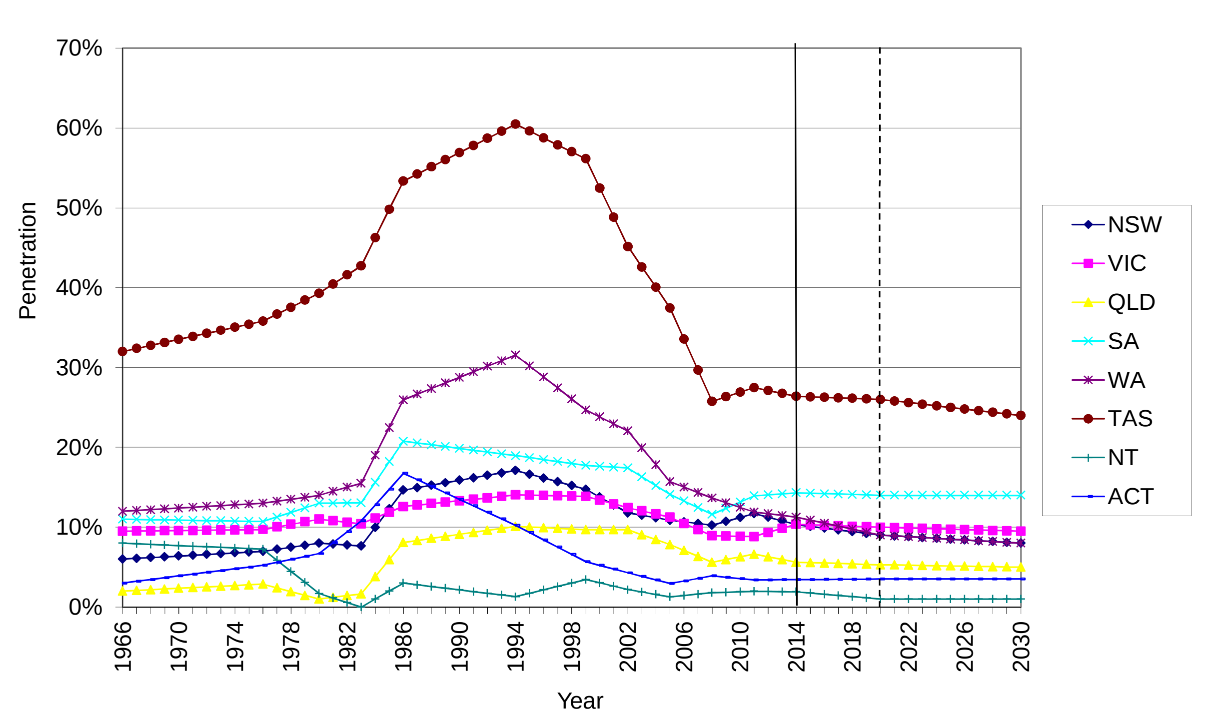



**Figure 42: Share of wood as the main heating source by state**

Figure notes: Data to 2014 from ABS (Australian Bureau of Statistics 2014) with data to 2020 from BIS Oxford (BIS Oxford Economics 2020b, 2018b) for selected states.

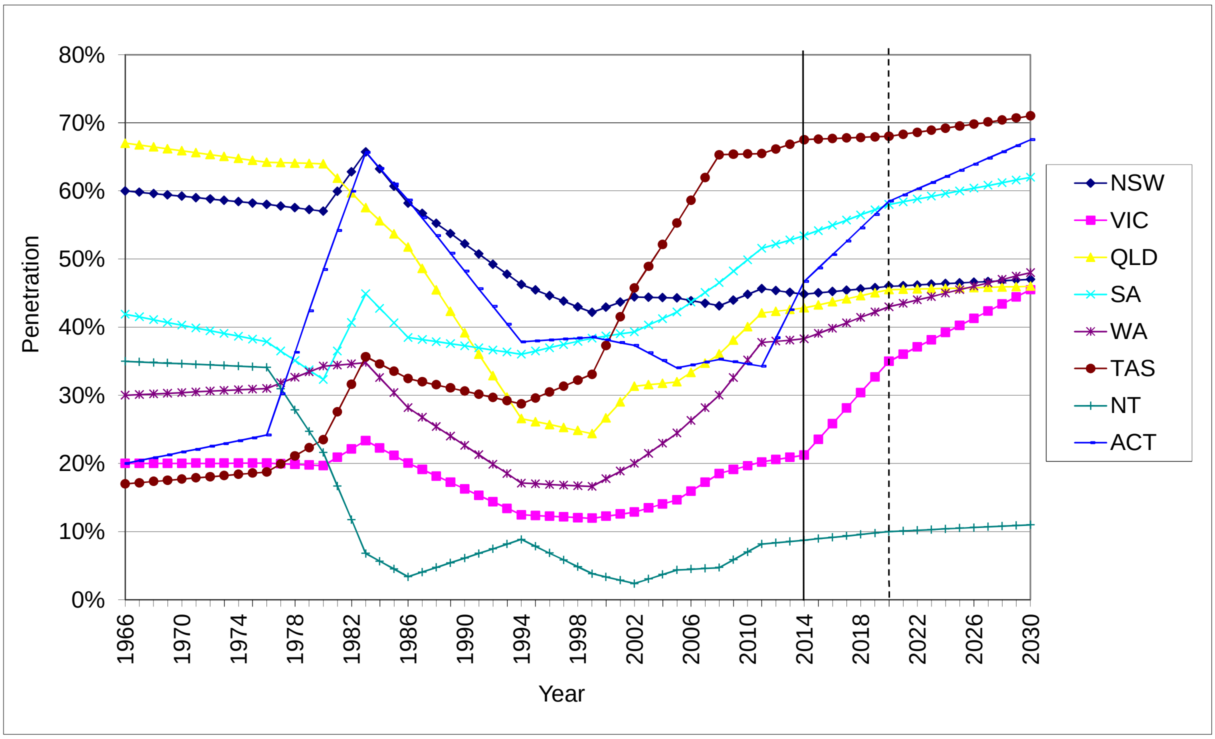



**Figure 43: Share of electricity as the main heating source by state**

Figure notes: Data to 2014 from ABS (Australian Bureau of Statistics 2014) with data to 2020 from BIS Oxford (BIS Oxford Economics 2020b, 2018b). The majority of electric heating is now reverse cycle air conditioning. See Figure 44.

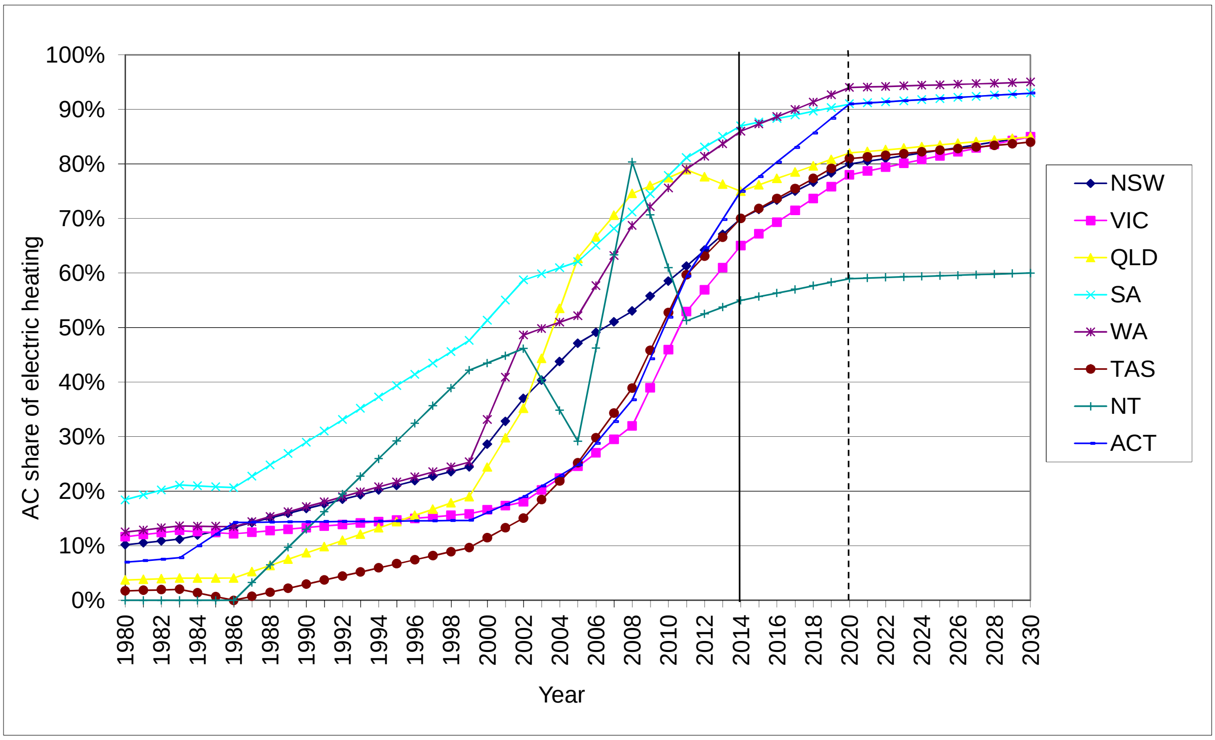



**Figure 44: Share of reverse cycle air conditioners as the main form of electric heating by state**

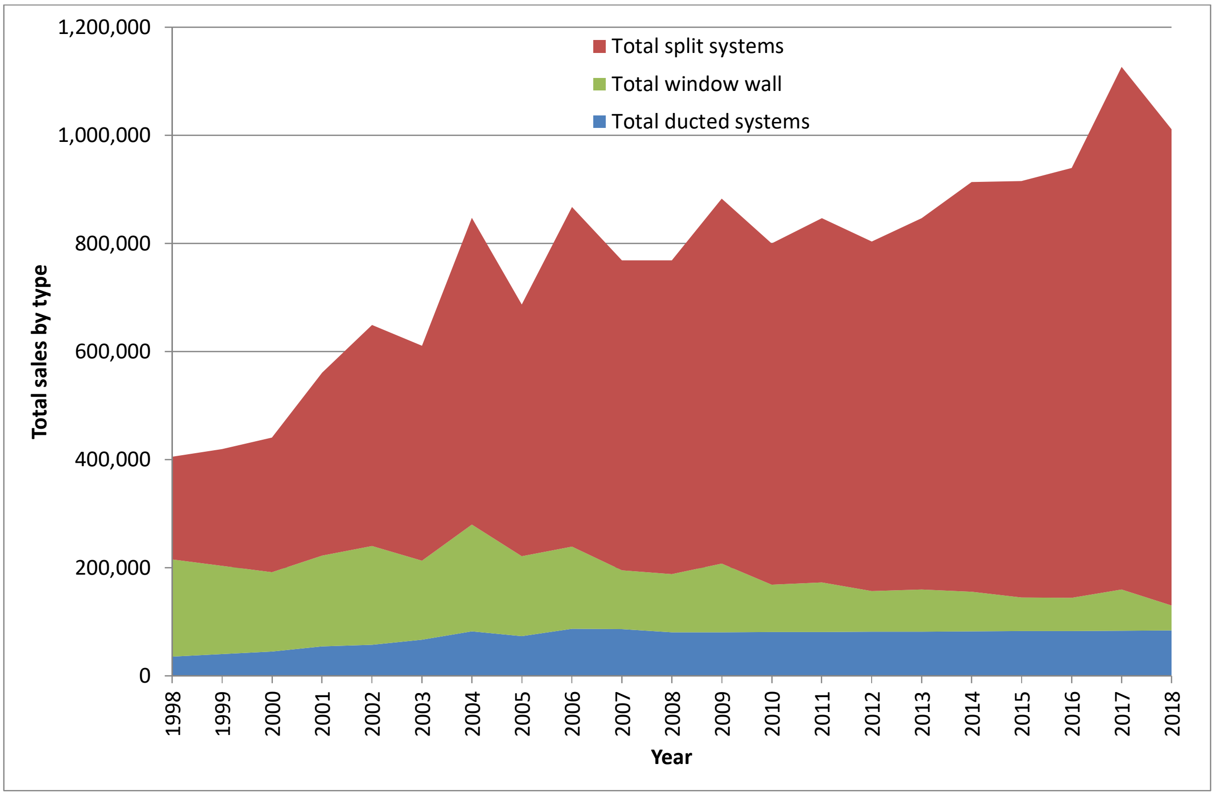



**Figure 45: Total air conditioner sales by type, Australia**

Figure notes: Analysis by the author as published by AEMO (Energy Efficient Strategies 2020)

The final element to consider for heating systems is dwellings that do not have a main heating system. Almost all dwellings in colder states (Tasmania, Victoria) have a main heating system, but the share of households without a main heating system increases as the climate become warmer (as expected) – see **Figure 46**. Data also shows that having no main heating system is more prevalent in Class 2 dwellings, as would be expected. As the stock share of dwellings over time without a main heating system is relatively stable, this can be used to predict the share of new dwellings that do not have a main heating system. Many of the houses that do not have a main heating system will have some form of secondary heating (such as portable electric resistance heaters), but these have not be tracked or estimated for this project.

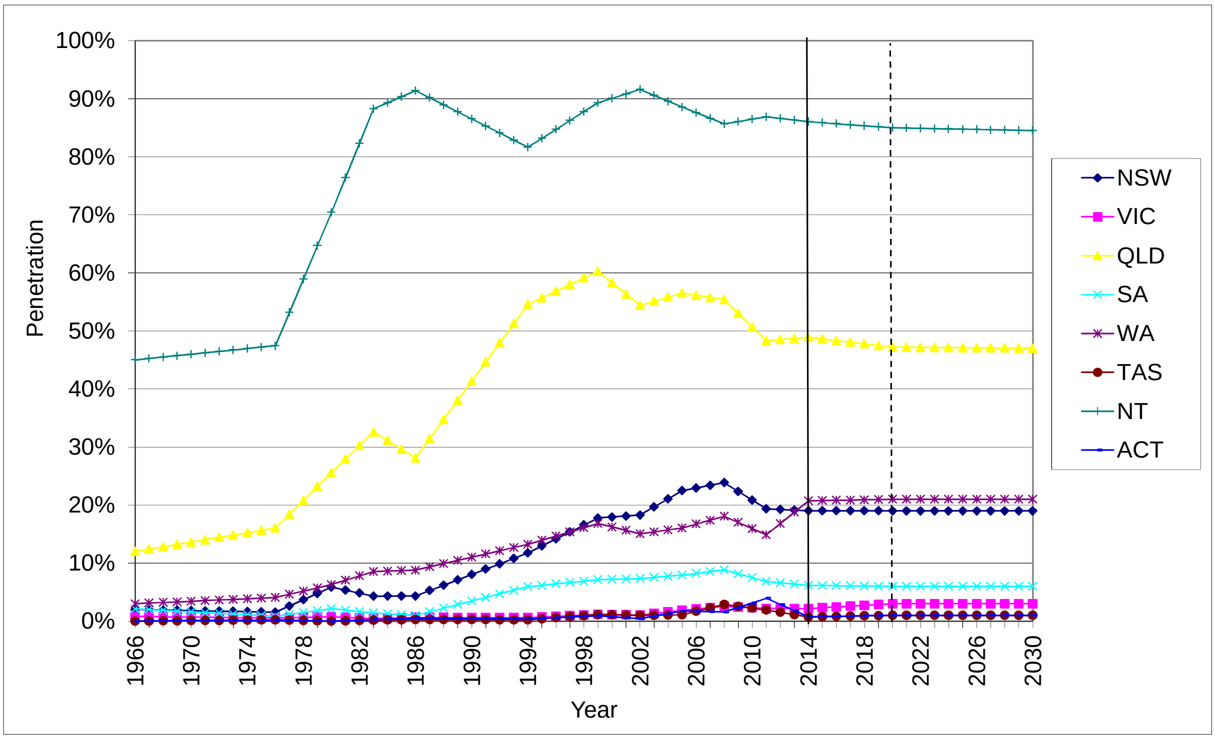



**Figure 46: Share of households without a main heating source by state and territory**

Figure notes: Data to 2014 from ABS (Australian Bureau of Statistics 2014) with data to 2020 from BIS Oxford (BIS Oxford Economics 2020b, 2018b). Households without main heating may have some secondary heating source.

### *10.6.16 Air conditioning*

Air conditioning penetration has increased dramatically over the past 20 years and is now very common in all states and territories as illustrated in **Figure 47**. Climate appears to have some impact on air conditioner ownership, but there are other factors that are driving trends. Given that penetration of the stock is still increasing, this suggests that air conditioners will be very common in new homes.

There are two main types of air conditioners: refrigerative and evaporative. Evaporative systems tend to be central systems (usually ducted) and concentrated in those states with hot, dry summers (mainly Victoria, the ACT, South Australia and Western Australia). Evaporative systems are rarely used on the Eastern seaboard as they are not very effective in humid climates. Even in the states where they are common, evaporative systems only make up around 25% of systems installed. There is a definite trend towards a lower share of evaporative air conditioners over time, so this suggests that very few will be installed in new homes.

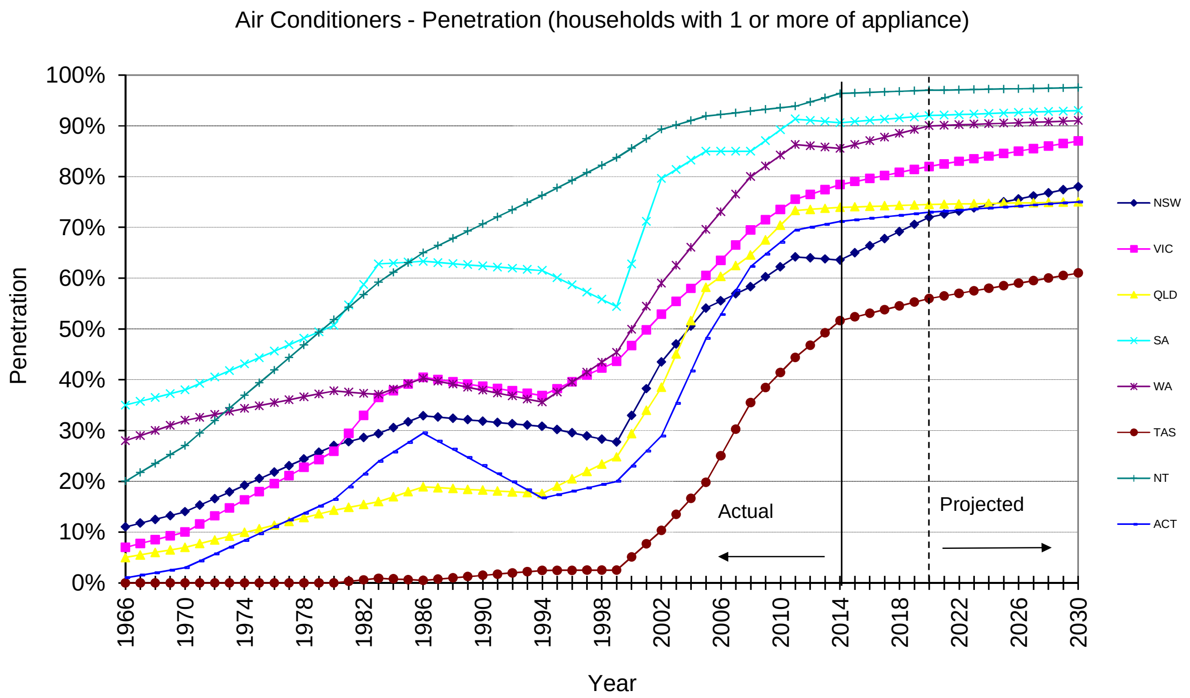



**Figure 47: Trends in air conditioner penetration by state and territory**

Figure notes: Data to 2014 from ABS (Australian Bureau of Statistics 2014) with data to 2020 from BIS Oxford (BIS Oxford Economics 2020b, 2018b). 1 minus penetration indicates households that have no air conditioning.

Refrigerative types can be split into ducted and non-ducted systems. Each of these can be split into cooling only and reverse cycle. Non ducted systems can be split further into window wall systems and split systems. These sub-types are not important for this study. As illustrated in **Figure 45**, split systems are now the predominant type of air conditioner installed in Australia and the overwhelming majority of these have an inverter driven compressor (Energy Efficient Strategies 2020). Cooling only systems (both ducted and non-ducted) have a relatively low share in all states and territories except the Northern Territory. Ducted reverse cycle systems are moderately common and are typically between 10% and 20% of all air conditioners in all states and territories except the Northern Territory and Queensland. Ducted systems and non-ducted cooling only systems appear to have a stable share over time, while non-ducted reverse cycle systems are showing a strong increase in share over time (see **Figure 48**), which again suggests that these systems will account for the vast majority of installations in new homes, as well as picking up additional share from the decline in evaporative systems.

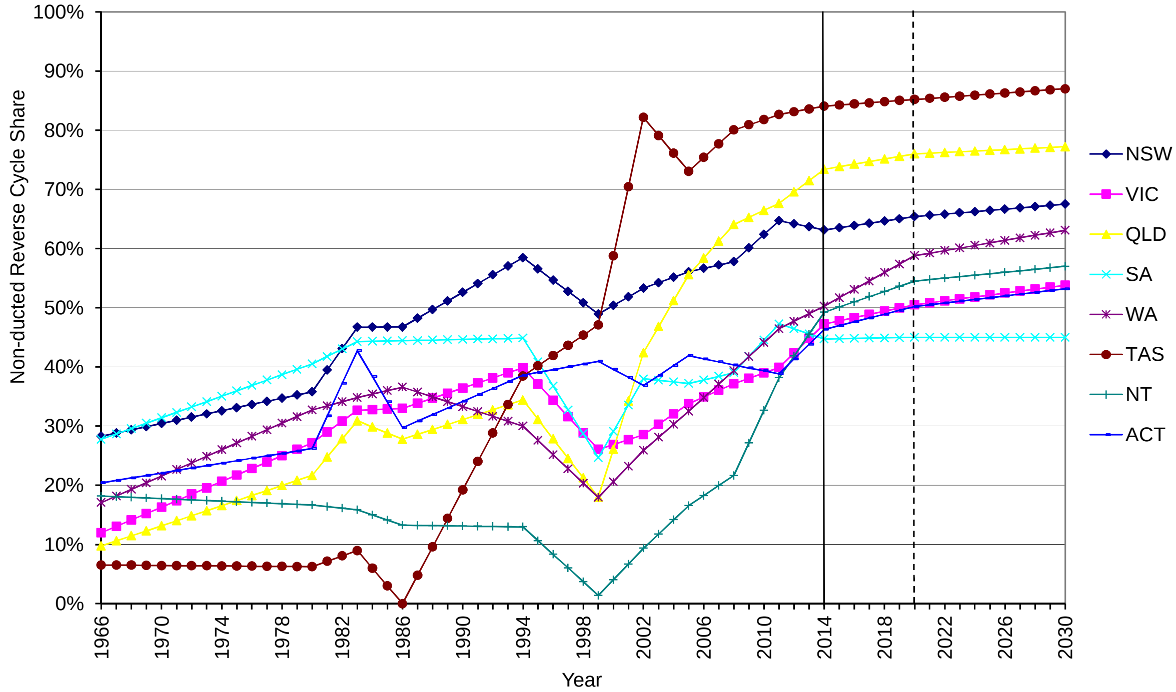



**Figure 48: Non ducted reverse cycle share of all air conditioner stock**

- **Other data sources for air conditioners**

Data on air conditioner sales (see **Figure 45**) gives an impression of what is entering the stock. However, there is no data on replacement versus new home installations and no data on the state and territory units where the units are installed.

As for water heaters, the Greenhouse and Minimum Standards Act (GEMS, 2012) does regulate the efficiency of air conditioners. While the registration databases do provide a list of models and data on energy performance characteristics, there is no data to indicate the number of sales by model or in which state systems are installed or whether they are replacement systems or in new homes. So GEMS data is useful for performance modelling (which is required for overall energy estimates for this project) but is of no value to establish the prevalence in new homes.

### *10.6.17 Establishing the types of space conditioning equipment installed in new homes*

- **Space conditioning in new Class 2 dwellings**

While tracking the stock of space conditioning equipment by type is somewhat useful, it does not necessarily provide an accurate picture of what is going into new homes. The overall approach for this study is to look at new Class 2 dwellings initially and allocate the likely share of space conditioning equipment into those dwellings. Class 2 are subjected to a number of substantial constraints with respect to space conditioning with data sources from ABS cross tabs and BIS Oxford (BIS Oxford Economics 2020b, 2018b):

- LPG is almost never used as cylinders cannot be stored indoors for safety reasons – all the ABS and state based data confirms this assumption. So all gas space heaters in Class 2 dwellings are mains gas.
- No space heating and no space cooling is more prevalent in Class 2 buildings than Class 1 buildings (around twice the incidence).
- All types of ducted systems are much less common in Class 2 dwellings (around half the incidence).
- Gas space heating appears to be less common in Class 2 dwellings compared to Class 1 dwellings (around half the incidence).
- Wood heating is almost never used in Class 2 dwellings.
- Window wall air conditioners are relatively unusual in Class 2 dwellings
- Ducted evaporative systems are very rare in Class 2 buildings.

Fortunately, NSW and Victoria have some data collections that reveal the actual rate of installation of water heater types in new Class 2 dwellings. These are outlined in the following sections.

### • NSW BASIX scheme

The New South Wales Building Sustainability Index (BASIX) scheme establishes a minimum energy efficiency standard for the construction and renovation of residential dwellings in NSW. BASIX includes an efficiency score, which is based on expected energy savings for the dwelling against a 2004 baseline, and a thermal comfort score, which measures the thermal efficiency of the dwelling, based on the NatHERS rating or equivalent. All dwellings must achieve a minimum score for both efficiency and thermal comfort. BASIX compliance is typically achieved through the installation of energy efficient appliances (such as an efficient hot water system) and improved building shell thermal efficiency (such as insulation). Therefore the scheme requires mandatory reporting on building shell, space conditioning and water heating equipment.

A summary of data for recent years was kindly provided by Dr Kevin Yee at the NSW Department of Planning, Industry and Environment (DPIE). This covered all installations for financial years 2017-18 and 2018-19 and was provided in the form of a Power BI Desktop file that allowed interactive interrogation of the detailed data summaries. The data was split into a multi-dwelling file and a single dwelling file. The sub-types within each file were:

1. Single sub-category attached
2. Single sub-category separate house
3. Single sub-category single unit
4. Multi sub-category Multi
5. Multi sub-category single (attached)
6. Multi sub-category flat (units)

After discussions with DPIE, it was agreed that these categories be allocated into the main housing types of interest for this project on a weighted basis:

- Categories 3 and 6 to be allocated to Class 2
- Other categories to be allocated to Class 1.

The types of heating and cooling systems recorded in the BASIX data are:

- 1-phase air conditioning
- 3-phase air conditioning
- air conditioning ducted
- ceiling fans
- ceiling fans + 1-phase air conditioning
- ceiling fans + 3-phase air conditioning
- central cooling system
- central heating system
- electric floor heating
- evaporative cooling
- gas fixed flued heater
- gas hydronic system
- ground source heat pump (closed loop)
- ground source heat pump (direct exchange)
- no active cooling
- no active heating
- wood heater.

BASIX recorded heating and cooling systems types in both the living areas and bedrooms. For this study, only data for the living area was compiled and analysed.

After weighting, the share of each space heater type was calculated as set out in **Table 74** when organised into the six standardised categories for heating used in this project.

**Table 74: Estimated share of space heater types in new homes in NSW from BASIX**

| System type | Class 2 | Class 1 |
|---|---|---|
| Central Gas | 0.73% | 0.36% |
| Room Gas | 0.06% | 3.33% |
| Central HP | 4.51% | 3.20% |
| Room HP | 88.10% | 72.67% |
| Wood Central | 0.00% | 2.84% |
| No Heating | 6.60% | 17.61% |
| Total | 100.00% | 100.00% |

Table notes: Data provided by NSW DPIE. Assumptions for Class 2: share of central heating => heat pump =85%. The share of no heating appears to be higher than expected for Class 1. This may require further analysis.

After weighting, the share of each space cooling type was calculated as set out in **Table 75** when organised into the four standardised categories for cooling used in this project.

**Table 75: Estimated share of space cooling types in new homes in NSW from BASIX**

| System type | Class 2 | Class 1 |
|---|---|---|
| Room HP (Cool) | 88.05% | 75.10% |
| Evaporative | 0.00% | 1.93% |
| No cooling | 6.64% | 19.61% |
| Central HP (Cool) | 5.31% | 3.36% |
| Total | 100.00% | 100.00% |

Table notes: Data provided by NSW DPIE. No cooling includes fans and no active cooling options.

- ### Victoria BESS

Some local governments in Victoria require certain developments to be modelled and approved under the Built Environment Sustainability Scorecard (BESS) scheme (see https://bess.net.au/ ). BESS is an assessment tool created by local governments in Victoria. It assists builders and developers to show how a proposed development demonstrates sustainable design at the planning permit stage. At this stage only a limited number of councils use BESS and not all new developments or planning applications trigger a BESS assessment, so there are gaps in the data. According to the Victorian Department of Environment, Land, Water and Planning (DELWP), BESS data for Class 2 dwellings are broadly representative. However, data for Class 1 dwellings is mostly very limited to established inner city LGAs, which are not representative of the larger scale greenfield developments on the urban fringes, so Class 1 BESS data has not been analysed for this project.

Based on submissions for 20,000 Class 2 new dwellings in 2019 that has been carefully reviewed by the Municipal Association of Victoria (MAV) and DELWP, the following breakdown of space heaters was recorded as shown in **Table 76** when organised into the six standardised categories for heating used in this project.

**Table 76: Estimated share of space heater types in new Class 2 homes in Victoria from BESS**

| System type | Share |
|---|---|
| Central Gas | 3.6% |
| Room Gas | 0.1% |
| Central HP | 14.2% |
| Room HP | 81.1% |
| Wood Central | 0% |
| No Heating | 1.1% |
| Total | 100.00% |

Table notes: Data provided by DELWP. Assumptions for Class 2: a total of around 1% of households had electric slab heating or electric resistance heating. For the purposes of this report, these heating types were allocated to the “no heating” category.

Based on submissions for 20,000 Class 2 new dwellings in 2019, the following breakdown of space cooling was recorded as shown in **Table 77** when organised into the four standardised categories for cooling used in this project.

**Table 77: Estimated share of space cooling types in new Class 2 homes in Victoria from BESS**

| System type | Share |
|---|---|
| Room HP (Cool) | 84.56% |
| Evaporative | 0.55% |
| No cooling | 0.57% |
| Central HP (Cool) | 14.33% |
| Total | 100.00% |

Table notes: Data provided by DELWP.

- ### Approach to estimating space conditioning types by state

For all new dwellings, the type of space heating is split into four types: gas, reverse cycle air conditioning, wood and none. Gas and air conditioners are then split into central (ducted) and room (non-ducted) types. The share of each sub-type being installed in new homes has been estimated based on the trends in the stock at a state level. A declining share in the stock suggest a very low rate in new homes, an increasing share in the stock indicates a high rate in new homes, while a steady share in the stock indicates that the share in new homes is likely to be comparable.

As the previous analysis on gas space heating showed, almost all of the major gas using states are showing a substantial decline in the share of the gas space heating stock over time. This means that data on gas connections may be less useful for space heating than it was for water heating. As per water heaters, actual data has been used for NSW new Class 1 and Class 2 and sample data has been used for new Victoria Class 2 dwellings for space heating and cooling equipment.

The input assumptions to estimate the share of the share of space heating and cooling equipment share in new Class 1 and Class 2 dwellings in each state and territory are set out in **Table 78**, **Table 79**, **Table 80** and **Table 81**.

**Table 78: Input assumptions for estimating space heating share for each state, new Class 2 dwellings**

| State | Share Class 2 2022 | State new houses with gas conn. | Gas heater estimate | Wood heater estimate | No heating estimate | Electric heating estimate | Gas duct share of gas | Central HP share of electric |
|---|---|---|---|---|---|---|---|---|
| NSW | 38.7% | 85% | 0.79% | 0.00% | 6.60% | 92.61% | 92.65% | 4.87% |
| VIC | 20.9% | 70% | 3.61% | 0.00% | 1.12% | 95.27% | 98.36% | 14.92% |
| QLD | 21.8% | 3% | 0.2% | 0.0% | 50% | 49.8% | 3% | 5% |
| SA | 10.0% | 85% | 8.0% | 0.0% | 8% | 84.0% | 8% | 15% |
| WA | 16.0% | 90% | 14.0% | 0.0% | 23% | 63.0% | 5% | 7% |
| TAS | 3.1% | 18% | 2.0% | 0.0% | 1% | 97.0% | 20% | 6% |
| NT | 15.0% | 2% | 0.0% | 0.0% | 85% | 15.0% | 0% | 5% |
| ACT | 48.2% | 42% | 4.0% | 0.0% | 1% | 95.0% | 50% | 14% |

Table notes: Data in red for NSW is based on BASIX and data for Victoria is based on BESS. Assumes all electric heating is supplied by some form of reverse cycle air conditioning. Resistive space heating in new homes is small and has been included in no heating.

**Table 79: Input assumptions for estimating space heating share for each state, new Class 1 dwellings**

| State | Share Class 1 2022 | State new houses with gas conn. | Gas heater estimate | Wood heater estimate | No heating estimate | Electric heating estimate | Gas duct share of gas | Central HP share of electric |
|---|---|---|---|---|---|---|---|---|
| NSW | 61.3% | 85% | 3.68% | 2.84% | 17.61% | 75.87% | 9.67% | 4.21% |
| VIC | 79.1% | 70% | 7% | 6% | 1% | 86.0% | 75% | 15% |
| QLD | 78.2% | 3% | 0.50% | 2% | 35% | 62.5% | 5% | 8% |
| SA | 90.0% | 85% | 15% | 10% | 5% | 70.0% | 16% | 22% |
| WA | 84.0% | 90% | 23% | 5% | 18% | 54.0% | 8% | 12% |
| TAS | 96.9% | 18% | 3.50% | 18% | 0.50% | 78.0% | 42% | 10% |
| NT | 85.0% | 2% | 0% | 0.50% | 85% | 14.5% | 0% | 5% |
| ACT | 51.8% | 42% | 7% | 2.50% | 0.50% | 90.0% | 80% | 20% |

Table notes: Data in red for NSW is based on BASIX. Assumes all electric heating is supplied by some form of reverse cycle air conditioning. Resistive space heating in new homes is small and has been included in no heating.

**Table 80: Input assumptions for estimating space cooling share for each state, new Class 2 dwellings**

| State | Share Class 2 2022 | Evaporative estimate | No cooling estimate | Electric heat pump estimate | Central HP share |
|---|---|---|---|---|---|
| NSW | 38.7% | 0.00% | 6.64% | 93.36% | 5.7% |
| VIC | 20.9% | 0.55% | 0.57% | 98.89% | 14.5% |
| QLD | 21.8% | 0% | 30% | 70.0% | 4.3% |
| SA | 10.0% | 2% | 12% | 86.0% | 17.3% |
| WA | 16.0% | 1% | 14% | 85.0% | 9.5% |
| TAS | 3.1% | 0% | 50% | 50.0% | 6.2% |
| NT | 15.0% | 0% | 8% | 92.0% | 1.7% |
| ACT | 48.2% | 1% | 30% | 69.0% | 12.8% |

Table notes: Data in red for NSW is based on BASIX and data for Victoria is based on BESS.

**Table 81: Input assumptions for estimating space cooling share for each state, new Class 1 dwellings**

| State | Share Class 2 2022 | Evaporative estimate | No cooling estimate | Electric heat pump estimate | Central HP share |
|---|---|---|---|---|---|
| NSW | 61.3% | 1.93% | 19.61% | 78.46% | 4.3% |
| VIC | 79.1% | 23% | 8% | 69.0% | 18.7% |
| QLD | 78.2% | 2% | 20% | 78.0% | 8.2% |
| SA | 90.0% | 21% | 5% | 74.0% | 33.3% |
| WA | 84.0% | 14% | 6% | 80.0% | 18.3% |
| TAS | 96.9% | 0.50% | 42% | 57.5% | 12.0% |
| NT | 85.0% | 3% | 4% | 93.0% | 3.2% |
| ACT | 51.8% | 15% | 20% | 65.0% | 24.6% |

Table notes: Data in red for NSW is based on BASIX.

- ### Share of space heating types in new Class 2 and Class 1 dwellings

The data in and **Table 78**, **Table 79**, **Table 80** and **Table 81** have been used to generate the share of space heating and cooling equipment types in new Class 2 and Class 1 dwellings as shown in **Table 82**, **Table 83**, **Table 84** and **Table 85**.

**Table 82: Share of space heating equipment type for each state, new Class 2 dwellings**

| State | Central Gas | Room Gas | Central Heat pump | Room heat pump | Wood | No Heating |
|---|---|---|---|---|---|---|
| NSW | 0.73% | 0.06% | 4.51% | 88.10% | 0.00% | 6.60% |
| VIC | 3.55% | 0.06% | 14.21% | 81.05% | 0.00% | 1.12% |
| QLD | 0.01% | 0.19% | 2.49% | 47.31% | 0.00% | 50.00% |
| SA | 0.64% | 7.36% | 12.60% | 71.40% | 0.00% | 8.00% |
| WA | 0.70% | 13.30% | 4.41% | 58.59% | 0.00% | 23.00% |
| TAS | 0.40% | 1.60% | 5.82% | 91.18% | 0.00% | 1.00% |
| NT | 0.00% | 0.00% | 0.75% | 14.25% | 0.00% | 85.00% |
| ACT | 2.00% | 2.00% | 13.30% | 81.70% | 0.00% | 1.00% |

Table notes: Data in red for NSW is based on BASIX and data for Victoria is based on BESS.

**Table 83: Share of space heating equipment type for each state, new Class 1 dwellings**

| State | Central Gas | Room Gas | Central HP | Room HP | Wood Central | No Heating |
|---|---|---|---|---|---|---|
| NSW | 0.36% | 3.33% | 3.20% | 72.67% | 2.84% | 17.61% |
| VIC | 5.25% | 1.75% | 12.90% | 73.10% | 6.00% | 1.00% |
| QLD | 0.03% | 0.48% | 5.00% | 57.50% | 2.00% | 35.00% |
| SA | 2.40% | 12.60% | 15.40% | 54.60% | 10.00% | 5.00% |
| WA | 1.84% | 21.16% | 6.48% | 47.52% | 5.00% | 18.00% |
| TAS | 1.47% | 2.03% | 7.80% | 70.20% | 18.00% | 0.50% |
| NT | 0.00% | 0.00% | 0.73% | 13.78% | 0.50% | 85.00% |
| ACT | 5.60% | 1.40% | 18.00% | 72.00% | 2.50% | 0.50% |

Table notes: Data in red for NSW is based on BASIX.

**Table 84: Share of space cooling equipment type for each state, new Class 2 dwellings**

| State | Room heat pump | Evaporative | No cooling | Central heat pump |
|---|---|---|---|---|
| NSW | 88.05% | 0.00% | 6.64% | 5.31% |
| VIC | 84.56% | 0.55% | 0.57% | 14.33% |
| QLD | 67.0% | 0.0% | 30.0% | 3.0% |
| SA | 71.1% | 2.0% | 12.0% | 14.9% |
| WA | 76.9% | 1.0% | 14.0% | 8.1% |
| TAS | 46.9% | 0.0% | 50.0% | 3.1% |
| NT | 90.5% | 0.0% | 8.0% | 1.5% |
| ACT | 60.2% | 1.0% | 30.0% | 8.8% |

Table notes: Data in red for NSW is based on BASIX and data for Victoria is based on BESS.

**Table 85: Share of space cooling equipment type for each state, new Class 1 dwellings**

| State | Room heat pump | Evaporative | No cooling | Central heat pump |
|---|---|---|---|---|
| NSW | 75.10% | 1.93% | 19.61% | 3.36% |
| VIC | 56.1% | 23.0% | 8.0% | 12.9% |
| QLD | 71.6% | 2.0% | 20.0% | 6.4% |
| SA | 49.4% | 21.0% | 5.0% | 24.6% |
| WA | 65.3% | 14.0% | 6.0% | 14.7% |
| TAS | 50.6% | 0.5% | 42.0% | 6.9% |
| NT | 90.0% | 3.0% | 4.0% | 3.0% |
| ACT | 49.0% | 15.0% | 20.0% | 16.0% |

Table notes: Data in red for NSW is based on BASIX.

### 10.6.18 *Allocation of product share across all of the combinations modelled*

For the purposes of economic modelling, various combinations of water heating, space heating and space cooling were devised that would best reflect real combinations of hot water/heating/cooling installed in the new homes in Australia. All seven types of water heaters were assumed to be present in all heating/cooling combinations. The 11 heating-cooling combinations modelled are set out in **Table 86**.

**Table 86: Combinations of heating and cooling system modelled**

| Case | Heating system | Cooling system |
|---|---|---|
| 1 | Central Gas | Room HP (Cool) |
| 2 | Central Gas | Central evaporative |
| 3 | Central Gas | No cooling |
| 4 | Room Gas | Room HP (Cool) |
| 5 | Room Gas | No cooling |
| 6 | Central HP | Central HP (Cool) |
| 7 | Room HP | Room HP (Cool) |
| 8 | Wood Central | Room HP (Cool) |
| 9 | Wood Central | Central evaporative |
| 10 | Wood Central | No cooling |
| 11 | No Heating | No cooling |

Along with the 7 types of water heaters modelled, there were a possible 77 combinations for each jurisdiction. The 8 jurisdictions were also split into Class 1 and Class 2, so this represented 1,232 separate weightings that had to be determined.

The overall weightings of each type of hot water, heating and cooling system were generally considered to be independent of each other except for the follow three cases, where there was likely to be strong interaction. The allocation of data for each combination is described below.

**Cases 1 to 5: Gas water heaters and gas space heating**: In all jurisdictions and dwelling types, the share of gas space heating (room and central) was substantially less that the share of gas water heating (gas storage, gas instantaneous or gas solar). Therefore, all gas space heating occurrences were allocated into one of the three gas boosted water heater types, leaving the other four types of water heaters empty in those gas heating households (electric storage × 2, solar and heat pump). This has been done on the basis that households that use gas heating are also most likely to use gas water heating. The data clearly shows that most households with gas water heating use other forms of space heating (not gas).

**Case 6: central heat pump cooling and central heat pump heating**: For most jurisdictions and dwelling types, the share of central heat pump heating and cooling was approximately equal, although this varied a little by climate. As there was only one allocation bin for these options (Case 6), all central heat pump heating and cooling were allocated to the specific bin for this technology combination.

**Cases 1, 4, 7 and 8: room heat pump cooling and room heat pump heating**: For most jurisdictions and dwelling types, the share of room heat pump heating and cooling was approximately equal, although this varied a little by climate. As there was only a single category created for room heat pump heating (Case 7), all room heat pump heating was allocated to that bin. For room heat pump cooling, where the jurisdiction/house type cooling share in Case 7 was **less than** room heat pump heating, then all cooling was allocated to Case 7 and zero cooling was allocated to other room heat pump cooling bins (Cases 1, 4 and 8). The other situation for room heat pumps was where the jurisdiction/house type cooling share was more than heating share: in this case the share of room heat pump cooling allocated to Case 7 was equal to room heat pump heating with the balance of cooling (room heat pump cooling minus room heat pump heating) allocated evenly to other room heat pump cooling options in Cases 1, 4 and 8.

This appendix makes estimates of the share of water heater types and space heating types in new Class 1 and Class 2 dwellings in each state and territory to allow modelling of the impacts. Public data sources for new homes are relatively scarce, so the best available data sources have been used as documented. All sources used have been documented in this report. This is an internal report and is not intended for publication in its current form. Various reports prepared by BIS Oxford Economics have been cited. These are commercial reports only available by subscription – access has been given to these reports for this project only by selected state agencies.