

Nationwide House Energy Rating Scheme (NatHERS)

DRAFT NatHERS Whole of Home National Calculation Methods

**Please note that parts of this document and the methods outlined within it may be revised and updated prior to the commencement of the NCC 2022.**

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**Abbreviations and Definitions**

|  |  |
| --- | --- |
| AS/NZS | Joint Australian-New Zealand Standard |
| AS | Australian Standard |
| Chenath | A simulation tool that models heating and cooling loads in a specified building (used as the basis for NatHERS ratings) |
| COP | Coefficient of Performance (AC efficiency in heating mode) - dimensionless |
| CSIRO | Commonwealth Scientific and Industrial Research Organisation |
| DTS | Deemed to satisfy provisions |
| E3 | Equipment Energy Efficiency Committee (Australia and NZ) |
| EER | Energy Efficiency Ratio (AC efficiency in cooling mode) - dimensionless |
| EES | Energy Efficient Strategies P/L |
| GEMS | Greenhouse and Energy Minimum Standards (Federal) |
| GJ | Giga-Joule (109 Joules) (energy for a specific fuel) |
| HE | High Efficiency |
| HSPF | Heating Seasonal Performance Factor |
| kWh | Kilowatt hour |
| MEPS | Minimum Energy Performance Standards |
| MWh | Megawatt hour |
| NatHERS | Nationwide House Energy Rating Scheme |
| NCC | National Construction Code for residential buildings |
| Scratch file | Detailed hourly output file from a NatHERS (Chenath) simulation |
| SRI | Star Rating Index |
| TCSPF | Total Cooling Seasonal Performance Factor |
| W | Watt |
| ZNC | Zero Net Carbon (Sustainability Victoria) |

# Introduction

The Nationwide House Energy Rating Scheme (NatHERS) is being expanded to include an assessment and rating of the whole home.

NatHERS will continue to provide an assessment and star rating of a home’s thermal performance. In addition, NatHERS will also provide an assessment and rating of the whole home. The Whole of Home assessment will include information about the energy performance of common household appliances. The Whole of Home performance rating will combine the thermal performance heating and cooling energy loads with the energy performance of the home’s appliances.

## About this document

This document outlines the methods that underpin the NatHERS Whole of Home benchmark tool (AccuRate) and accredited software tools under the NatHERS Whole of Home framework.

*Part 1: Whole of Home Modules* provides an overview of each of the modules, including the context and explanation as to how these methods were derived. *Part 2: Technical Specifications* provides the equations and assumptions that support the modelling of energy performance for each of the modules and other key settings.

It includes methods for calculating the energy demand of a home’s:

* heating and cooling appliances
* hot water system
* lighting
* pool pump (pool heating future development)
* spa pump and heating (future module)
* on-site solar PV system
* on-site battery
* plug loads (plug-in appliances)
* cooking appliances.

It also outlines the method used for calculating the occupancy of a home for a Whole of Home assessment.

In the future this document will include a method for calculating the Whole of Home performance rating.

Please note that these methods are for Whole of Home assessments only. While they leverage aspects of the NatHERS Thermal performance methods, the two are separate resources. The NatHERS Thermal performance methods are available at: <https://www.hstar.com.au/Chenath/AccuRateChenathRepository.htm>

Separate methods are also available for NatHERS In Home assessments.

## Background

In 2019, Energy Ministers agreed the *Trajectory for Low Energy Buildings* (the Trajectory). In summary, the Trajectory proposed:

* Setting a trajectory towards zero energy (and carbon) ready buildings;
* Implementing cost effective increases to the energy efficiency provisions in the National Construction Code (NCC) for residential and commercial buildings from 2022; and
* Expanding NatHERS to offer nationally accredited whole‑of‑home tools to enable verification of requirements in the NCC.

In August 2021, the Australian Building Codes Board (ABCB) released for consultation draft provisions for NCC 2022. This included proposed amendments to the energy efficiency provisions which introduces a whole-of-home annual energy use budget for Class 1 and Class 2 dwellings. The annual energy use budget is based on ‘societal cost of energy’. Societal cost includes the cost of energy used by the building and the broader ‘cost’ to society for the use of that energy[[1]](#footnote-2). It applies to heating and cooling appliances, hot water systems, lighting and pool and spa pumps. If the house is to have on-site renewable electricity generation system, such as rooftop PV, this can provide an offset to the societal cost of the energy used in the home.

To support the objectives of the Trajectory, including the proposed energy efficiency provisions for NCC 2022, the NatHERS is being expanded to provide Whole of Home energy assessments and ratings.

## Updates to these Methods

The methods outlined in this document may be revised and updated prior to the commencement of the NCC 2022.

The methods may also be updated as new information, data and modelling methods becomes available. More areas of residential energy use may also be included in the future. Any updates will need to be balanced against the need to maintain time‑series consistency of the data as far as possible. Reflecting the need for this balance, it is planned that these Methods will be reviewed regularly.

Updates to the Methods will be reviewed by the NatHERS Technical Advisory Committee (TAC) and agreed by the NatHERS Steering Committee.

## Approach to expanding NatHERS

The expansion of NatHERS to Whole of Home assessments and ratings builds off and leverages the established NatHERS framework and processes.

The principles that guided the development of these calculation methods are:

* Support alignment with the proposed NCC 2022 energy efficiency provisions
* Utilise the expertise of the NatHERS TAC and other industry experts
* Deliver methods appropriate for a national scheme
* Support the objectives of the Trajectory
* Utilise established data and calculation methods
* Build off and leverage established NatHERS processes.

The Whole of Home framework builds on the existing NatHERS framework and technology. NatHERS currently conducts thermal assessments using the CSIRO Chenath Engine, which calculates the hourly energy required to maintain the set comfort levels in each thermal zone of the home. The NatHERS Whole of Home benchmark tool (AccuRate) uses the Chenath Engine to calculate the heating and cooling energy loads and conduct an hour-by-hour calculation of the energy demands of the home. The heating and cooling loads used by the Whole of Home tools are slightly different to those used for NatHERS thermal assessments, and are intended to more accurately reflect how the average home is heated and cooled.

Hourly calculations of energy demand allows for reasonable modelling of on-site energy generation and storage influences on the final rating and other assessment outputs. They allow for the calculation of electricity imported from the grid at any given hour, and accurately account for the influence of solar PV and battery systems on household electricity import and export. In turn, this allows for accurate calculations of societal cost, greenhouse gas emissions and total energy use.

Using an hourly calculation also supports the tool to deliver outputs that can be used to demonstrate compliance with the proposed energy efficiency provision for NCC 2022.

## Acknowledgements

These methods have been developed in collaboration with the NatHERS TAC, Energy Efficient Strategies (EES), IT Power (Australia), and other industry experts from the residential building and appliance sector. The NatHERS Administrator acknowledges the extensive input from these organisations and committees. A complete list of those involved in the development of these methods is at Appendix F

# Part 1: Whole of Home Modules

The modules included a Whole of Home assessment are:

* Heating
* Cooling
* Hot Water
* Lighting
* Pool pumps and heating (heating is a future method)
* Spa pumps and heating (future module)
* On-Site Energy Generation (Solar PV)
* On-site storage (battery systems)
* Plug Loads
* Cooking

In addition to these modules, the Whole of Home assessment must make a number of assumptions regarding occupancy patterns, including:

* Number of occupants per home
* Hours of occupation
* Patterns of use (i.e. which zones in the dwelling at which times)
* Comfort bands (i.e. thermostat settings)

The list of modules is likely to expand in the future. The current list reflects the most common aspects of energy use.

## Occupancy

### Overview

The broad aim of the Whole of Home occupancy settings is to identify settings that are a reasonable representation of how the home may be used across its lifetime. It is important to remember that this is unlikely to be an exact representation of how any specific occupant or group of occupants will use the home, but provides a consistent statistical basis from which comparisons of home energy use may be made.

Currently, the NatHERS thermal performance calculation assumes the home is fully occupied all the time (24 hours per day, 365 days per year), and the Chenath Engine therefore ensures that the temperature remains within the comfort band at all times. This is done on a zone-by-zone basis, and whilst it is assumed that the home is occupied at all times, not every room is occupied at all times. The assumption of continuous occupation maximises the energy requirement for space conditioning over a year and provides a solid basis for the development of a comparative rating metric such as star rating.

However, assuming the home is always occupied may not be appropriate for a Whole of Home assessment where the time of occupancy can have a material impact on dwelling operational costs, particularly in relationship to solar PV output utilization. Stakeholder feedback suggests the fully occupied profile may be appropriate for some household types, but is not necessarily representative of occupancy in other household structures where absence during the day will impact on how and when energy is used in the home.

### Number of Occupants

NatHERS Whole of Home assessments use floor area as the basis for estimating the expected number of occupants in a home. This is the same approach as used for the NatHERS Thermal performance assessment. The expected number of occupants has an impact on the water heating energy consumption, as it determines the assumed amount of hot water used, and also has an impact on the estimated energy consumption for plug-in appliances and cooking equipment.

Two methods were considered for estimating the expected number of occupants in a dwelling: number of bedrooms or floor area. Each of these could be varied in a number of ways, for example by postcode or dwelling type.

Use of bedrooms was ruled out due to the risk of inconsistencies across assessments. For example, decisions over what is considered, for modelling purposes, to be a bedroom or not is subjective and therefore not always entered consistently by the assessor. Floor area has its own shortcomings, but should be able to be applied more consistently across a range of dwellings.

The number of occupants within a dwelling is an important input into three calculations as follows:

* As a determinant of the internal heat loads within the dwellings.
* As a determinant of the likely hot water consumption as part of the Whole of Home assessment of water heating energy consumption.
* As a determinant of the likely electrical plug load and cooking energy consumption.

In relation to calculating internal heat loads, no change to the current methodology is proposed.

Some whole of home tools use a different curve to determine number of occupants from floor area when compared to that currently used in NatHERS Thermal performance assessments. Analysis undertaken by EES determined that the current NatHERS equation for determining number of occupants should be used for both calculating internal heat loads and as the basis for the Whole of Home hot water consumption calculation and plug loads (see Equation 1 and Equation 2). This was due to the NatHERS equation being more representative beyond 600 m2 of floor area than some other tools.

At this stage no adjustment to the occupant per floor area calculation has been made based on postcode or dwelling type. While some data exists, particularly in NSW, the data gathering exercise required for a national framework using this information is too great at this time. There are also concerns that using point-in-time statistics for a particular location may be out of step with the lifecycle of the NatHERS scheme, and assumptions may become rapidly outdated.

### Pattern of Occupation

Pattern of occupation refers to the assumptions the calculation engine applies about when people are home and what this means in terms of heating and cooling the home.

The NatHERS Thermal performance calculation assumes full occupancy at all times; that is, someone is home and heating or cooling at least part of the home 24 hours per day, 365 days per year. This approach is not considered suitable for Whole of Home assessments due to the need to reflect the hourly energy balance of the home (e.g. imports and exports). Stakeholder feedback suggests the fully occupied profile is not representative of typical occupancy behaviours and how and when energy is used in the home.

A number of whole of home methodologies such as that used to develop the WoH provisions for NCC 2022, use two different occupancy profiles in combination to undertake calculations of energy use (in NCC 2022 these are referred to as an “All-day” and a “Work-Day” profile), rather than a single profile as currently used in the NatHERS thermal simulation method.

Changing the current NatHERS thermal simulation calculation to a dual occupancy profile approach would be impractical at this time as this would involve re-grading of the established star bands for new homes. However, the Whole of Home Occupancy Working Group recommended that any Whole of Home calculations undertaken in NatHERS should use a dual occupancy profile approach as the basis for estimating thermal loads that are used to calculate heating and cooling equipment energy use.

Consequently, this means that NatHERS tools will now need to undertake two separate calculations using differing occupancy profile setting assumptions. The two separate calculations are:

1. A thermal performance assessment (thermal loads) using a single occupancy profile (i.e. the current calculation used to determine the performance of the dwelling shell and the dwelling’s thermal performance star rating).
2. A Whole of Home assessment (energy consumption and production from appliances and equipment) using dual profiles.

It should also be noted that the “Fully Occupied” profile currently used in the Chenath Engine thermal simulation methodology to determine the dwelling shell star rating does not exactly match the “All Day” occupancy profile to be used in the Whole of Home assessment. For example, one major difference between the existing building shell settings and the Whole of Home settings is the overnight behaviour. The existing NatHERS assumption used in the thermal simulation is that, while living rooms are not heated or cooled overnight, bedrooms are conditioned. For NatHERS Whole of Home, it was recommended that bedrooms would not be heated overnight, but would be cooled. This means that a thermostat would be set for overnight cooling, and if the temperature exceeds this temperature, the Chenath Engine would cool the zone and calculate the energy required (using the usual process of assuming passive cooling approaches first, then mechanical cooling if temperature still exceeds the thermostat setting). It is assumed that the heating does not operate overnight.

## Thermal Simulation Settings

### Ventilation and Shading

Definition of the thermostat settings in the Chenath Engine for different NatHERS Whole of Home profiles is straight forward. The definition of when windows and doors are opened and closed to provide ventilation, and when curtains are opened and closed is different, and results in some technical limitations.

Firstly, there are no complications for the All Day profile. However, the Work Day profile requires assumptions about what occupants will do to the home before they leave for the day, and how this may be applied in the Chenath Engine.

When the dwelling is assumed to be unoccupied, windows and doors cannot be opened (as no one is there to open them). The process within NatHERS to this point has been to assume active occupants (i.e. opening and closing windows and curtains as required to maintain comfort, rather than simply engage the heating or cooling system immediately). It is therefore reasonable to assume occupants would close curtains before leaving the house on hot days. It is not possible, however, to write these instructions into the Chenath Engine scratch file. To approximate this behaviour, the Chenath Engine will operate curtains as needed (i.e. in the same manner as if someone was home). It is assumed that if the Chenath Engine closes the curtains on a hot day, the occupant would have done this before leaving the house. This is likely to result in higher cooling loads than if occupants closed windows at 8am (before leaving for the day), as the home will heat up more due to solar gains through the windows while the curtains are open. However, it is a more accurate approximation of an active occupant than leaving curtains open all day instead. In simulation modes where internal shading may be chosen (rather than Regulation mode where Holland Blinds are mandatory for rating purposes) this will also reward designs for using shading where it is required, which is a good design outcome.

## Heating and Cooling Modules

The thermal calculation conducted by the Chenath Engine is appliance and fuel neutral (i.e. it measures the energy, in Megajoules (MJ), required to raise or lower the air temperature to achieve the desired comfort conditions). This is known as the thermal load, and Chenath calculates both the cooling load and the heating load. This is different to the energy drawn from the grid or supply network, which is used by heating and cooling equipment to provide the required heating or cooling. The heating and cooling modules define the type and, where relevant, efficiency level of the appliances service which zones of the dwelling, allowing the calculation of actual energy use required to meet the thermal loads in each hour calculated by the Chenath Engine.

Not all dwellings have dedicated heating and cooling devices (e.g. air conditioners, gas heaters, electric heaters or wood fires) installed. To maintain a fair and comparable scheme, assumptions must be made if the assessor does not indicate that a heating or cooling device is present in the zone. Even if these are not present when the house is first built, if the zone is too hot or too cold, it is likely that the occupant will eventually install a device to make it more comfortable. A set of defaults has been assumed to cover these scenarios – see Section 3.2.2.

In some climates, the thermal load for certain zones will be quite small (< 20 MJ/m2). Consideration was given to excluding such zones from the Whole of Home assessment calculation, but it was decided that such an approach was not warranted because:

* Excluding such zones would add unnecessary complexity to the calculation process
* Loads of < 20 MJ/m2 would in any case only have a minor impact on total energy consumption
* Imposing a threshold such as 20 MJ/m2 means that the assumed service provision will differ depending on whether a zone has a load of 19 MJ/year/m2 or 21 MJ/year/m2. Truly comparative type efficiency schemes should be predicated on an assessment that assumes the same level of service for all dwellings.

Consideration was also given to requiring assessors to specify the capacity of the installed heating/cooling equipment in each zone and then compare that to the calculated maximum hourly demand for that zone with a view to making up any shortfall with either resistance electric heating or MEPS level heat pump cooling, but it was decided that such an approach was not ideal because:

* The actual capacity of the equipment to be installed at the design stage may be unknown, making a requirement to provide such input potentially onerous.
* Correct sizing of equipment is a matter for the relevant contractor/engineer and is not generally considered to be within the domain of the NatHERS tool.
* The assumption in relation to heating that any shortfall will be made up by resistance electric heating is potentially very unfavourable from an efficiency perspective.

Consequently, the heating and cooling module simply assumes that the specified space conditioning equipment (or default equipment where none is specified) will have adequate capacity to meet the heating/cooling needs of the particular zone/s throughout the year (i.e. only the type and performance characteristics of the heating/cooling equipment need to be input by the user). However, it is proposed that (as a future feature) the software could provide qualified guidance to assessors on appropriate heating and cooling sizing (see Section 3.2.9).

User inputs for either heating or cooling equipment include:

* Appliance type
* Appliance reported conversion efficiency for heating (or “star rating” if applicable) in the relevant climate zone
* Appliance reported conversion efficiency for cooling (or “star rating” if applicable) in the relevant climate zone
* Zones serviced by appliance.

It is noted that for air-conditioners registered under the *Greenhouse and Energy Minimum Standards Act 2012 (GEMS Act),* ratings may be to either to the old standard (GEMS 2013 Determination[[2]](#footnote-3)) or the new seasonal performance standard (GEMS 2019 Determination[[3]](#footnote-4)) – all new air conditioner models that came onto the market since April 2020 are required to be registered against the 2019 GEMS Determination, but older models will remain in the market for a few years. The new (GEMS 2019) ratings are zoned energy ratings that are based on seasonal energy performance, and different ratings are provided for cold, average and hot climate zones. The calculation method uses the newer seasonal performance rating values. Where only older values are available (input), then the calculation engine converts (approximately) old ratings to equivalent new seasonal performance ratings for the purpose of conducting a NatHERS Whole of Home assessment.

Finally, the heating and cooling module in assessing heating and cooling energy consumption also takes into account two factors in addition to the conversion efficiency of the equipment, where applicable, namely:

* Systems losses
* Ancillary energy consumption.

System losses include such things as duct or pipework losses or conduction losses from concrete slabs to the ground where slab heating is employed. Generally a set of default loss factors are applied to the energy consumption formula (see Section 3.2.5).

Ancillary energy consumption relates to such things as electric fans in gas heaters or electric pumps in hydronic heaters. Generally a set of default ancillary load factors are used to determine the expected ancillary loads (see Section 3.2.5). In many cases the ancillary energy will be electricity and the main heating energy source will be some other fuel (e.g. gas or wood). Cases where ancillary energy is already included in the rated energy input are specifically noted.

## Hot Water Module

A gap in the knowledge base was identified when calculating the energy used by a given hot water service. Research carried out by Energy Efficient Strategies in 2019[[4]](#footnote-5) identified a recommended daily hot water allowance per occupant, and a set of equations to determine the annual energy use of different hot water systems across different hot water demands was developed. This approach was confirmed by the NatHERS Whole of Home Water Heater Working Group in 2021. It was determined that while good performance data and accessible information existed for some types of water heaters, this was not available across all technologies. During the early development phase of the hot water module there was no distinction between performance levels of the following water heater types:

* Heat Pump, including systems on a peak or off-peak tariff
* Gas boosted solar
* Electric boosted solar, including systems on a peak or off-peak tariff
* Off peak electric (Large electric storage)
* Instantaneous electric
* Small electric storage
* Solid fuel.

Further, as the scheme is aimed at new homes, it was originally determined that only gas water heaters rated at 5 stars or greater would be included. This has now been expanded to include 4 and 4.5 star heaters.

Following more detailed analysis by the Water Heater Working Group during 2021, the performance range of some water heater types have been expanded. This updated specification covers a wider performance range of gas water heaters, solar thermal electric boost, solar thermal gas boost and heat pump systems. Extensive analysis and modelling of solar and heat pump systems was provided by the water heater industry and this has been used to expand the range of system performance that is available for selection by users, including a range of system sizes and performance levels (based on the number of Small-scale Technology Certificates earned) in all relevant climates.

## Lighting Module

Although energy use from lighting is dropping, lighting is still an important consideration if a design-aid tool is being used to assist designers and consumers to make effective decisions of how they could achieve a net-zero energy home. Calculating all of the energy uses in the home (including fixed appliances, lighting, white goods, cooking and plug appliances) to estimate how much energy a home may use, allows solar PV sizing and the amount of solar needed to achieve a net-zero energy home to be determined.

There are many options for how to model lighting density across the house. Examples discussed during early consultation with NatHERS stakeholders included selections of individual light fittings in each zone, selecting a lamp type that would be applied across the home, or making an assumption regarding the maximum power density.

It was considered that, given the proportion of energy attributed to lighting in a whole of home calculation, it was best to adopt a simpler method to maintain speed of assessment for the NatHERS Assessors. The energy saved by selecting specific lamps was not great enough to offset the high time-cost of modelling to this level of detail. Review of existing NCC requirements and research indicated that using a default standard of 5W/m2 lighting density would maintain sufficient accuracy, and provide the same stringency level as already exists in the NCC. In future, users may be able to override this default value. In line with the approach taken in the NCC lights are assumed to be used for an average of 1.6 hours per day[[5]](#footnote-6). This is however likely to vary across the seasons (i.e. more in winter, less in summer), and in different rooms.

The lighting module for NatHERS Whole of Home supports modelling of an average lighting level across the home for the whole year. This is spread out on an hourly basis to match expected seasonal behaviour. The annual lighting energy use is based on the size of the dwelling. A daily and seasonal allocation of total lighting energy has been based on long term monitoring in homes, but adjusted for LED lighting that is now used in new homes (Pacific Power[[6]](#footnote-7), REMP[[7]](#footnote-8)).

## Pool and Spa Equipment Module

Where pools are present, they use a large amount of energy. Calculating the energy used by the pool system can be very complex. There are many sections of the pool configuration and pipe layout that can increase or decrease the efficiency of the overall system.

External consultation was undertaken to determine a series of default factors that may be applied. This work also aimed to align the calculations with the latest Pool Pump Determination and reporting of star ratings for pool pumps. Assessors should be able to choose between different technology types, efficiency levels and pool cleaners. As smaller pumps tend to be more efficient, it was determined that pump size would be determined based on the size of the pool. This assists in maintaining speed for the assessor and consistency between assessments.

Key assumptions in this module are:

* Larger pools require larger pumps
* Pool volume must be cycled minimum once per day.

In future this module will also include energy used by pool heating. An additional module will also be developed for spa pumps and heating.

## On-site Energy Generation and Storage

On-site energy generation is a critical part of the Whole of Home equation, especially in the context of a net-zero energy or carbon home. Solar photovoltaic systems (solar PV) are currently the only mainstream technology available for a residential application. Therefore the scheme only currently includes solar PV electricity generation systems, but this does not preclude other on-site energy generation technologies to be made available in the future. The specification also includes a PV diverter module, which can direct excess on-site PV generation to heat electric storage water heaters.

The available PV generated electricity is derived for each hour of the year. This electricity may be used to offset on-site consumption from any electrical end use, including any plug loads (but generally excluding usage by any equipment connected as a controlled load e.g. “off peak” water heating). Any PV generation that is surplus to on-site requirements is then assumed to be delivered to an on-site battery, where one is installed, up to the available storage capacity of the battery. Where there is no on-site battery, or if the surplus generation exceeds the on-site battery’s capacity to accept that charge in a given hour, then the remaining surplus generation is assumed to be exported to the grid. Export to the grid, where it does occur, is subject to any cap based on the rated capacity of the inverter and/or the network’s export limit in that particular location or for that system. The hot water PV diverter module also provides an additional sink for excess on-site PV generation.

The calculation of the hourly available electrical supply from a PV installation takes into account four main elements:

1. The theoretical hourly output from a PV panels using the solar PV module already existing within the CSIRO AusZEH Design tool.
2. The ambient air temperature
3. Potential loss due to overshadowing (shading) (under development)
4. System losses
5. Limitations imposed by the capacity of the installed inverter
6. Limitations imposed by the network on the export of excess electricity production to the grid.

On-site energy storage has also been included as an option in the scheme. This consists of a battery connected to a solar PV system. Batteries are modelled as simple energy tanks (with electrical characteristics based on Lithium-ion batteries) and the battery control system is assumed to be a basic system not responsive to either expected future load profile or dynamic or future network price signals. Whenever excess generation is available, it is stored and whenever on-site demand exceeds available supply from a PV system, then the battery is used to make up, as far as possible, any shortfall (all subject to the charge, discharge and capacity limitations of the battery).

## Plug Load Module

“Plug loads” cover all other plug-in electrical equipment, apart from equipment already covered in the previous sections, and includes items such as whitegoods, audio visual, small appliances, computers and peripherals, other electronics and standby power.

At this stage, performance and capacity data relating to these end uses is not taken into account. Instead, a stock average annual electrical load (based on the number of occupants) and hourly load profile is assumed for all dwellings. These loads are particularly important in relation to Solar PV generation (where installed) as they can consume a considerable amount of PV generation, thereby reducing the need for grid supplied electricity to the home. Accounting for plug loads in the context of PV generation also has the effect of reducing the amount of solar PV generation that is exported to the grid.

## Cooking Module

Under development.

# Part 2: Technical Specifications

This section details the technical specifications for calculating Whole of Home energy in NatHERS.

## Occupancy and Thermal Simulation Settings

Thermal simulation using Chenath requires specific inputs. This section provides the details for thermostat, internal heat gains, ventilation and shading settings in the Scratch file.

For all tables in this specification, the ‘Hour’ number indicates the hour of the day ending in the specified clock time – i.e. Hour 1 is the hour between Midnight and 1am, unless otherwise specified. This is the notation usually adopted for energy meter readings. This means that hours are numbered from 1 to 24 in this specification and these all cover the period between midnight and midnight. It is important to note that the Chenath simulation tool and the Australian Climate Database climate files that are used as inputs into Chenath and NatHERS use the notation of hour 0 to 23 to cover a 24 hour period from midnight to midnight. This is effectively the hour beginning the specified clock time.

Thermostat settings and Heat Gains are calculated and applied for each zone for each hour of the day.

### Number of Occupants

For the purposes of thermal simulation modelling (internal heat loads) in either a thermal performance assessment or a Whole of Home assessment, the number of occupants in the home is defined using Equation 1 and Equation 2:

Equation 1: Valid range for number of occupants

Equation 2: Number of occupants determined from floor area

Where:

NOcc = Number of occupants in the home

AD = Area of Dwelling

Area of Dwelling is defined as the sum of the floor area of all zones, excluding the garage.

NOcc shall be rounded the nearest 2nd decimal – i.e. #.xx

Note: These equations are also used to determine the hot water load and also have an impact on the plug-load and cooking energy consumption.

### Pattern of Occupation

Two new daily profiles have been defined for use in the WoH Chenath thermal assessment calculation used to determine heating and cooling energy consumption. That is, the WoH Chenath thermal assessment calculation used to determine heating and cooling energy uses an entirely separate and new set of two occupancy profiles (in contrast to the single profile used in the current Chenath thermal performance assessment). Separate Chenath simulation runs are therefore required when conducting a WoH assessment, as compared to conducting the current thermal performance assessment to determine the building shell star rating. The means for processing data from the two occupancy profile Chenath runs used in a WoH assessment is detailed in Section 3.1.3.

The two daily profiles to be used in the WoH calculation method are as follows:

***All Day Profile***

The All Day Profile assumes at least one person is at home for the whole 24 hours. Whilst this profile is very similar to that used in the thermal performance assessment, there are small differences in assumed hours of operation of heating and cooling equipment and thermostat settings (see following sections). Consequently, the profile used for the thermal performance assessment cannot also be used for the WoH assessment.

***Work Day Profile***

The Work Day Profile assumes no occupants are home between 9am and 5pm (clock time, which corresponds to hours 10 to 17 inclusive). The house is assumed to not be conditioned during these hours. With respect to the set-up of a work day profile in the Chenath engine, ventilation on/off settings and window and blind opening and closing assumptions will need to be adjusted to account for the fact that the dwelling will not be occupied during nominated hours of the day.

### Calculation of WoH Performance Using the Two Occupation Profiles

When calculating the building’s WoH performance, entirely separate WoH performance assessments must be undertaken in parallel for each of the occupant profiles noted in Section 3.1.2 (All day and Work day).

To obtain a single combined WoH assessment result for any parameter of interest (e.g. heating energy consumption) the values obtained for each of the separate performance assessments (All Day and Work Day) must be weighted in accordance with Equation 3 as follows:

Equation 3: Weighting of all day and work day profiles

PWoH = PALLDAY x 0.6 + PWORKDAY x 0.4

Where

PWoH = The weighted value of the subject parameter i.e. the final WoH assessment value

PALLDAY = The value of the subject parameter as assessed using the All-day occupancy profile only

PWORKDAY  =The value of the subject parameter as assessed using the Work day occupancy profile only

### Thermostat Settings

NatHERS thermal zone types are listed in Table 1.

Table 1: NatHERS Thermal Zones

| **Zone** | **Conditioned** | **Internal Heat Gains** |
| --- | --- | --- |
| Living/Kitchen | Yes | Yes |
| Living | Yes | Yes |
| Daytime | Yes | No |
| Bedroom | Yes | Yes |
| Night time | Yes | No |
| Unconditioned | No | No |
| Garage | No | No |
| Garage Conditioned | Yes | No |

Note that the other zone types (Sub-Floor, Roof Space, Glazed Common Area, Basement Carpark) are not influenced by the occupant assumptions.

**HEATING**

Heating Thermostats are defined in Table 2 for all climate zones.

Table 2: Heating Thermostat Settings

| **Zone** | **Thermostat Setting (°C)** |
| --- | --- |
| Living/Kitchen | 20 |
| Living | 20 |
| Daytime | 20 |
| Bedroom | 18 |
| Night time | 18 |
| Garage Conditioned | 20 |

**COOLING**

Cooling thermostat settings for use in a WoH calculation are detailed in Appendix A - Cooling Thermostat settings by NatHERS climate zone for Whole of Home rating, ZERL Zones and Evaporative Cooler Applicability.

Note that these values are different (generally lower) than the cooling thermostat values currently used for a NatHERS thermal performance simulation.

### Pattern of Conditioning

Patterns of conditioning are based on the occupancy profiles defined in Section 3.1.2.

Living/Kitchen, Living, Daytime and Garage Conditioned are considered ‘Day Time Conditioned’ zones, and Bedroom and Night time are considered ‘Night Time Conditioned’ zones. Patterns of heating are defined in Table 3 and cooling in Table 4. Note that the bolded values in the tables indicate where the pattern to be applied to WoH assessments is at variance with the pattern used for a thermal performance assessment.

Table 3: Heating Pattern by hour for each occupancy profile

| **Hour** | **All Day Profile** | | **Work Day Profile** | |
| --- | --- | --- | --- | --- |
| **Daytime Conditioned** | **Night time Conditioned** | **Daytime Conditioned** | **Night time Conditioned** |
| 1 | No | No | No | No |
| 2 | No | No | No | No |
| 3 | No | No | No | No |
| 4 | No | No | No | No |
| 5 | No | No | No | No |
| 6 | No | No | No | No |
| 7 | **Yes** | **Yes** | **Yes** | **Yes** |
| 8 | Yes | Yes | Yes | Yes |
| 9 | Yes | Yes | No | No |
| 10 | Yes | No | No | No |
| 11 | Yes | No | No | No |
| 12 | Yes | No | No | No |
| 13 | Yes | No | No | No |
| 14 | Yes | No | No | No |
| 15 | Yes | No | No | No |
| 16 | Yes | No | No | No |
| 17 | Yes | **No** | No | No |
| 18 | Yes | Yes | Yes | Yes |
| 19 | Yes | Yes | Yes | Yes |
| 20 | Yes | Yes | Yes | Yes |
| 21 | Yes | Yes | Yes | Yes |
| 22 | Yes | Yes | Yes | Yes |
| 23 | **No** | **No** | Yes | Yes |
| 24 | **No** | **No** | **No** | **No** |

Table notes: Hour definition is hour ending the specified hour number as clock time (refer to Section 3.1 regarding hour notation). Shaded cells with **bold text** denote differences between the NatHERS thermal simulation and the NatHERS Whole of Home methodology.

Table 4: Cooling Pattern by hour for each occupancy profile

| **Hour** | **All Day Profile** | | **Work Day Profile** | |
| --- | --- | --- | --- | --- |
| **Daytime Conditioned** | **Nighttime Conditioned** | **Daytime Conditioned** | **Nighttime Conditioned** |
| 1 | No | Yes | No | Yes |
| 2 | No | Yes | No | Yes |
| 3 | No | Yes | No | Yes |
| 4 | No | Yes | No | Yes |
| 5 | No | Yes | No | Yes |
| 6 | No | Yes | No | Yes |
| 7 | **Yes** | Yes | **Yes** | Yes |
| 8 | Yes | Yes | Yes | Yes |
| 9 | Yes | Yes | No | No |
| 10 | Yes | No | No | No |
| 11 | Yes | No | No | No |
| 12 | Yes | No | No | No |
| 13 | Yes | No | No | No |
| 14 | Yes | No | No | No |
| 15 | Yes | No | No | No |
| 16 | Yes | No | No | No |
| 17 | Yes | **No** | No | No |
| 18 | Yes | Yes | Yes | Yes |
| 19 | Yes | Yes | Yes | Yes |
| 20 | Yes | Yes | Yes | Yes |
| 21 | Yes | Yes | Yes | Yes |
| 22 | Yes | Yes | Yes | Yes |
| 23 | **No** | Yes | Yes | Yes |
| 24 | **No** | Yes | **No** | Yes |

Table notes: Hour definition is hour ending the specified hour number as clock time (refer to Section 3.1 regarding hour notation). Shaded cells with **bold text** denote differences between the NatHERS thermal simulation and the NatHERS Whole of Home methodology.

### Internal Heat Gains

Internal Heat Gains are based on heat gains in AccuRate Sustainability v2.3.3.13 (Chen, 2018).

Internal gains are applied only to Living/Kitchen, Living and Bedroom zones. Internal gains for other zones may be ignored (i.e. not written to the Scratch file) or set to 0.

Number of Occupants, NOcc is defined in Section 3.1.1.

**Base Data[[8]](#footnote-9)**

Base information for defining sensible and latent heat gains based on people, lights, cooking and appliances is defined in Table 5 to Table 10.

Table 5: Kitchen heat gains, All Day Profile

| **Hour** | **Sensible heat load (Watts)** | | | | **Latent heat load (Watts)** BLat |
| --- | --- | --- | --- | --- | --- |
| **Appliances and cooking** BS.Tot | **Lighting** BLight | **People** BPeople | **Total** |
| 1 | 100 | 0 | 0 | 100 | 0 |
| 2 | 100 | 0 | 0 | 100 | 0 |
| 3 | 100 | 0 | 0 | 100 | 0 |
| 4 | 100 | 0 | 0 | 100 | 0 |
| 5 | 100 | 0 | 0 | 100 | 0 |
| 6 | 100 | 0 | 0 | 100 | 0 |
| 7 | 100 | 180 | 280 | 560 | 200 |
| 8 | 400 | 180 | 280 | 860 | 400 |
| 9 | 100 | 180 | 280 | 560 | 200 |
| 10 | 100 | 0 | 140 | 240 | 100 |
| 11 | 100 | 0 | 140 | 240 | 100 |
| 12 | 100 | 0 | 140 | 240 | 100 |
| 13 | 100 | 0 | 140 | 240 | 100 |
| 14 | 100 | 0 | 140 | 240 | 100 |
| 15 | 100 | 0 | 140 | 240 | 100 |
| 16 | 100 | 0 | 140 | 240 | 100 |
| 17 | 100 | 0 | 140 | 240 | 100 |
| 18 | 100 | 300 | 210 | 610 | 150 |
| 19 | 1100 | 300 | 210 | 1610 | 750 |
| 20 | 250 | 300 | 210 | 760 | 150 |
| 21 | 250 | 300 | 210 | 760 | 150 |
| 22 | 250 | 300 | 210 | 760 | 150 |
| 23 | 100 | 0 | 0 | 100 | 0 |
| 24 | 100 | 0 | 0 | 100 | 0 |

Table notes: Hour definition is hour ending the specified hour number as clock time (refer to Section 3.1 regarding hour notation).

Table 6: Kitchen heat gains, Work Day Profile

| **Hour** | **Sensible heat load (Watts)** | | | | **Latent heat load (Watts)** |
| --- | --- | --- | --- | --- | --- |
| **Appliances and cooking** | **Lighting** | **People** | **Total** |
| 1 | 100 | 0 | 0 | 100 | 0 |
| 2 | 100 | 0 | 0 | 100 | 0 |
| 3 | 100 | 0 | 0 | 100 | 0 |
| 4 | 100 | 0 | 0 | 100 | 0 |
| 5 | 100 | 0 | 0 | 100 | 0 |
| 6 | 100 | 0 | 0 | 100 | 0 |
| 7 | 100 | 180 | 280 | 560 | 200 |
| 8 | 400 | 180 | 280 | 860 | 400 |
| 9 | 100 | 0 | 0 | 100 | 0 |
| 10 | 100 | 0 | 0 | 100 | 0 |
| 11 | 100 | 0 | 0 | 100 | 0 |
| 12 | 100 | 0 | 0 | 100 | 0 |
| 13 | 100 | 0 | 0 | 100 | 0 |
| 14 | 100 | 0 | 0 | 100 | 0 |
| 15 | 100 | 0 | 0 | 100 | 0 |
| 16 | 100 | 0 | 0 | 100 | 0 |
| 17 | 100 | 0 | 0 | 100 | 0 |
| 18 | 100 | 300 | 210 | 610 | 150 |
| 19 | 1100 | 300 | 210 | 1610 | 750 |
| 20 | 250 | 300 | 210 | 760 | 150 |
| 21 | 250 | 300 | 210 | 760 | 150 |
| 22 | 250 | 300 | 210 | 760 | 150 |
| 23 | 250 | 300 | 210 | 760 | 150 |
| 24 | 100 | 0 | 0 | 100 | 0 |

Table notes: Hour definition is hour ending the specified hour number as clock time (refer to Section 3.1 regarding hour notation).

Table 7: Living heat gains, All Day Profile

| **Hour** | **Sensible heat load (Watts)** | | | **Latent heat load (Watts)** |
| --- | --- | --- | --- | --- |
| **Lighting** | **People** | **Total** |
| 1 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 |
| 7 | 180 | 280 | 460 | 140 |
| 8 | 180 | 280 | 460 | 140 |
| 9 | 180 | 280 | 460 | 140 |
| 10 | 0 | 140 | 140 | 70 |
| 11 | 0 | 140 | 140 | 70 |
| 12 | 0 | 140 | 140 | 70 |
| 13 | 0 | 140 | 140 | 70 |
| 14 | 0 | 140 | 140 | 70 |
| 15 | 0 | 140 | 140 | 70 |
| 16 | 0 | 140 | 140 | 70 |
| 17 | 0 | 140 | 140 | 70 |
| 18 | 300 | 210 | 510 | 105 |
| 19 | 300 | 210 | 510 | 105 |
| 20 | 300 | 210 | 510 | 105 |
| 21 | 300 | 210 | 510 | 105 |
| 22 | 300 | 210 | 510 | 105 |
| 23 | 0 | 0 | 0 | 0 |
| 24 | 0 | 0 | 0 | 0 |

Table notes: Hour definition is hour ending the specified hour number as clock time (refer to Section 3.1 regarding hour notation).

Table 8: Living heat gains, Work Day Profile

| **Hour** | **Sensible heat load (Watts)** | | | **Latent heat load (Watts)** |
| --- | --- | --- | --- | --- |
| **Lighting** | **People** | **Total** |
| 1 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 | 0 |
| 4 | 0 | 0 | 0 | 0 |
| 5 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 |
| 7 | 180 | 280 | 460 | 140 |
| 8 | 180 | 280 | 460 | 140 |
| 9 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 0 |
| 16 | 0 | 0 | 0 | 0 |
| 17 | 0 | 0 | 0 | 0 |
| 18 | 300 | 210 | 510 | 105 |
| 19 | 300 | 210 | 510 | 105 |
| 20 | 300 | 210 | 510 | 105 |
| 21 | 300 | 210 | 510 | 105 |
| 22 | 300 | 210 | 510 | 105 |
| 23 | 300 | 210 | 510 | 105 |
| 24 | 0 | 0 | 0 | 0 |

Table notes: Hour definition is hour ending the specified hour number as clock time (refer to Section 3.1 regarding hour notation).

Table 9: Bedroom heat gains, All Day Profile

| **Hour** | **Sensible heat load (Watts)** | | | **Latent heat load (Watts)** |
| --- | --- | --- | --- | --- |
| **Lighting** | **People** | **Total** |
| 1 | 0 | 200 | 200 | 100 |
| 2 | 0 | 200 | 200 | 100 |
| 3 | 0 | 200 | 200 | 100 |
| 4 | 0 | 200 | 200 | 100 |
| 5 | 0 | 200 | 200 | 100 |
| 6 | 0 | 200 | 200 | 100 |
| 7 | 0 | 200 | 200 | 100 |
| 8 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 0 |
| 16 | 0 | 0 | 0 | 0 |
| 17 | 0 | 0 | 0 | 0 |
| 18 | 0 | 0 | 0 | 0 |
| 19 | 0 | 0 | 0 | 0 |
| 20 | 100 | 0 | 100 | 0 |
| 21 | 100 | 0 | 100 | 0 |
| 22 | 100 | 0 | 100 | 0 |
| 23 | 0 | 200 | 200 | 100 |
| 24 | 0 | 200 | 200 | 100 |

Table notes: Hour definition is hour ending the specified hour number as clock time (refer to Section 3.1 regarding hour notation).

Table 10: Bedroom heat gains, Work Day Profile

| **Hour** | **Sensible heat load (Watts)** | | | **Latent Heat load (Watts)**  **(Watts)** |
| --- | --- | --- | --- | --- |
| **Lighting** | **People** | **Total** |
| 1 | 0 | 200 | 200 | 100 |
| 2 | 0 | 200 | 200 | 100 |
| 3 | 0 | 200 | 200 | 100 |
| 4 | 0 | 200 | 200 | 100 |
| 5 | 0 | 200 | 200 | 100 |
| 6 | 0 | 200 | 200 | 100 |
| 7 | 0 | 200 | 200 | 100 |
| 8 | 0 | 0 | 0 | 0 |
| 9 | 0 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 |
| 13 | 0 | 0 | 0 | 0 |
| 14 | 0 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 0 |
| 16 | 0 | 0 | 0 | 0 |
| 17 | 0 | 0 | 0 | 0 |
| 18 | 0 | 0 | 0 | 0 |
| 19 | 0 | 0 | 0 | 0 |
| 20 | 100 | 0 | 100 | 0 |
| 21 | 100 | 0 | 100 | 0 |
| 22 | 100 | 0 | 100 | 0 |
| 23 | 100 | 200 | 300 | 100 |
| 24 | 0 | 200 | 200 | 100 |

Table notes: Hour definition is hour ending the specified hour number as clock time (refer to Section 3.1 regarding hour notation).

**Adjustment Factors[[9]](#footnote-10)**

Occupancy factor, FOcc, is defined in Equation 4:

Equation 4: Occupancy factor for internal heat gains

Where

Nocc = number of occupants (see Equation 2)

Family Factor, FFam is defined in Equation 5:

Equation 5: Family factor for internal heat gains

Where

Nocc = number of occupants (see Equation 2)

Area Factor, FA is defined in Equation 6 and Equation 7:

Equation 6: Area factor range for internal heat gains

Equation 7: Area factor for internal heat gains

Where:

AZone = Total floor area of specific Zone in m2.

**Living/Kitchen Heat Gains**

Base data is taken from Table 5 or Table 6 for each hour of the day for each of the variables specified below.

Lighting Factor, FLight, is defined in Equation 8:

Equation 8: Lighting factor for internal heat gains

Where *BLight* is the relevant hourly value specified in Table 5 or Table 6 as applicable.

People Factor, FPeople is defined in Equation 9:

Equation 9: People factor for internal heat gains

Total Sensible Heat Gain is defined in Equation 10:

Equation 10: Total sensible heat gain for internal heat loads in kitchen

Where:

BS.Tot = Base Sensible Heat Load Total is the relevant hourly value specified in Table 5 or Table 6 as applicable.

Total Latent Heat Gain is defined in Equation 11:

Equation 11: Total latent heat gain for internal heat loads in kitchen

Where:

BLat = Latent Heat Load is the relevant hourly value specified in Table 5 or Table 6 as applicable.

**Living and Bedroom Heat Gains**

Base data is taken from Table 7, Table 8, Table 9, and Table 10.

Total Sensible Heat Gain is defined in Equation 12:

Equation 12: Total sensible heat gain for internal heat loads in living and bedroom areas

Where:

BLight = Base Sensible Heat Load Lighting is the relevant hourly value specified in Table 7, Table 8, Table 9, or Table 10 as applicable.

BPeople = Base Sensible Heat Load People is the relevant hourly value specified in Table 7, Table 8, Table 9, or Table 10 as applicable.

Total Latent Heat Gain is defined in Equation 13:

Equation 13: Total latent heat gain for internal heat loads in living and bedroom areas

### Ventilation

Ventilation is the opening and closing of windows and doors.

Ventilation on and off times are defined in Table 11.

Table 11: Ventilation Settings

|  | **On** | **Off** |
| --- | --- | --- |
| **Occupied all day** | 0 | 24 |
| **Unoccupied during day** | 18 | 7 |

### Shading

Technical constraints limit the control over shading from indoor and outdoor curtains or blinds. These operable shade devices are assumed to be operated all the time. This simulates occupants shutting blinds before they leave the house on hot days, rather than simulating blinds being open at all times. Settings are therefore defined in the Chenath Scratch documentation.

Note: For the Work Day Profile, Chenath will operate curtains as needed even though it is assumed that nobody is present and conditioning equipment will not be operated (i.e. in the same manner as if someone was home). It is assumed that if Chenath closes the curtains on a hot day, the occupant would have done this before leaving the house.

## Heating and Cooling Modules

Additional types of heating and cooling appliances may be added in the future.

### Required User Inputs

User inputs for heating and cooling modules are:

* Appliance type
* Appliance reported conversion efficiency for Heating (or “star rating” if applicable) in the relevant climate zone
* Appliance reported conversion efficiency for cooling (or “star rating” if applicable) in the relevant climate zone
* Zones serviced by appliance

Appliance fuel type is derived from the Appliance type.

Note that that all zones (except NatHERS designated unconditioned zones) will be heated and cooled irrespective of the size of the heating and cooling load in that zone (see Section 2.3).

### Default Appliances

The default heating and cooling devices, in cases where equipment characteristics are not specified by the user, are defined in Table 12.

Table 12: Default heating and cooling devices

|  | **Description** | **Fuel Type** | **Cold climate** | **Mixed climate** | **Hot/humid climate** |
| --- | --- | --- | --- | --- | --- |
| **Heating HSPF** | MEPS level non-ducted reverse-cycle air conditioner (heat pump) | Electric | 2.85 | 3.35 | 3.85 |
| **Cooling TCSPF** | MEPS level non-ducted refrigerative air conditioner (heat pump). | Electric | 3.6 | 3.7 | 4.2 |

Table notes: All values are seasonal performance factors as per AS/NZS3823.4 for climate zones defined under the Zoned Energy Rating Label (ZERL). Refer to Appendix A - Cooling Thermostat settings by NatHERS climate zone for Whole of Home rating, ZERL Zones and Evaporative Cooler Applicability for a full concordance of NatHERS climates with GEMS ZERL climates. Heating HSPF and TCSPF are used to calculate the hourly energy as specified in Section 3.2.5.

Note that unlimited capacity simulates an occupant installing a device large enough to cover the required load, or installing multiple devices such that the load is met. Further work on guidance regarding the sizing of heating and cooling equipment is under investigation and may be included in a future update. The whole of home tools determine the maximum hourly heating/cooling load in the specified heating/cooling zones, and this information should be able to be used as the basis of providing advice to tool users.

### Hourly Loads

The hourly loads are calculated by the Chenath engine based on inputs defined in Section 3.1

### Annual Energy Load

The annual energy load for each zone is the sum of the energy loads in each hour for the entire year.

### Energy Use

Calculating end energy use requires definitions of the appliance to be entered by the user. Appliances may service a single zone, or multiple zones. A single zone is assumed to be serviced only by one appliance.

Hourly energy use for a zone is calculated using Equation 14:

Equation 14: Calculation of hourly energy input for heating and cooling equipment



Where:

*Ez.hr* = hourly energy use (energy input) for the zone (MJ)

*Lz.hr* = hourly energy load for the zone, from Chenath simulation (heating or cooling).

*COPA* = Coefficient of performance for the specified appliance (units W/W)

*LS* = the system loss, where specified for the system type (e.g. ductwork), with a valid range from 0 to 1

Note: A loss of 20% would equate to a value of *LS* = 0.2.

Default losses for specified equipment types are set out in Table 13.

Table 13: Default system losses for specified equipment types

| **Equipment type** | **Default system loss *LS*** |
| --- | --- |
| Ducted systems (less than 10 years old) | 15% |
| Ducted systems (more than 10 years old) | 25% |
| Hydronic heaters (panel type) | 10% |
| Concrete slab heating (any type) | 15% |
| Other non-ducted systems | 15% |

Where a heating system uses a fuel other than electricity as the main energy source, the ancillary electrical load is calculated in accordance with Equation 15:

Equation 15: Calculation of ancillary energy for heating and cooling equipment



*EA.hr* = Hourly electrical ancillary energy (MJ)

*Ez.hr* = hourly energy use for the zone (MJ)

*A* = Ancillary electrical energy consumption factor e.g. for electric fans.

Default ancillary loads for specified equipment types are set out in Table 14.

Table 14: Default ancillary loads for specified equipment types

| **Equipment type** | **Default ancillary load *A*** |
| --- | --- |
| Fans for gas ducted systems | 0.0104 + 0.0044 × *GER* |
| Fans for GEMS regulated heat pumps \* | 0% |
| Fans for evaporative coolers \* | 0% |
| Fans for any other ducted system | 3% |
| Fans for non-ducted systems | 1% |
| Pumps for hydronic systems | 1% |
| Any other type of ancillary system | 2% |

Table notes: \* For heat pumps and evaporative systems, ancillary energy consumption is already included in the overall system energy estimates. *GER* is the Australian Gas Association gas star rating (as a decimal). Ancillary loads are assumed to be electricity in cases where the main fuel used is not electricity.

Notes regarding operating efficiency for specific heating and cooling systems are set out in the following sections.

#### Air conditioners (heat pumps) used for heating

For air conditioners used for heating, the *COPA* (assumed operating efficiency as set out in Equation 14) is to be based on the Heating Seasonal Performance Factor (HSPF) as specified in the 2019 GEMS Determination for air conditioners (Greenhouse and Energy Minimum Standards (Air Conditioners up to 65kW) Determination 2019 for the relevant Zoned Energy Rating Label (ZERL) climate zone (cold, mixed or hot/humid). The relevant ZERL climate zone for each of the 69 NatHERS climate zones is set out in Appendix A - Cooling Thermostat settings by NatHERS climate zone for Whole of Home rating, ZERL Zones and Evaporative Cooler Applicability. The NatHERS assessment software should flag the relevant ZERL climate zone to the user.

Where available, the HSPF for the relevant ZERL climate zone for the equipment type selected for the rating shall be provided. Where only the ZERL star rating is specified, the HSPF values shall be determined from Table 15.

Table 15: HSPF values for specified star ratings under the ZERL for air conditioners

| **Heating star rating in specified ZERL climate zone** | **HSPF** |
| --- | --- |
| 1.0 | 2.5 |
| 1.5 | 3.0 |
| 2.0 | 3.5 |
| 2.5 | 4.0 |
| 3.0 | 4.5 |
| 3.5 | 5.0 |
| 4.0 | 5.5 |
| 4.5 | 6.0 |
| 5.0 | 6.5 |
| 5.5 | 7.0 |
| 6.0 | 7.5 |
| 6.5 | 8.0 |
| 7.0 | 8.5 |
| 7.5 | 9.0 |
| 8.0 | 9.5 |
| 8.5 | 10.0 |
| 9.0 | 10.5 |
| 9.5 | 11.0 |
| 10.0 | 11.5 |

Table notes: Star rating as per applicable ZERL climate zone.

Where the HSPF value of the selected heat pump equipment exceeds the applicable value in Table 16, the software system shall issue a warning to flag that the claimed efficiency may be beyond that currently available on the market. The applicable capacity for this assessment process is proposed to be determined from the hourly heating load data set for the particular zone or zones in a future update. The method for doing this is yet to be determined. In the interim, a warning flag should be issued if the HSPF value exceeds the highest possible value for each GEMS zone for cases where capacity is not defined (last row of the table below).

Table 16: Maximum values for HSPF for air conditioners

| **Capacity range** | **Cold** | **Mixed** | **Hot & humid** |
| --- | --- | --- | --- |
| 0 – 2.99 kW | 5.4 | 5.7 | 6.1 |
| 3 – 5.99 kW | 5.2 | 5.6 | 6.7 |
| 6 – 9.99 kW | 4.6 | 5.4 | 6.7 |
| 10 – 20 kW | 4.7 | 5.3 | 6.0 |
| > 20 kW | 5.9 | 6.8 | 8.1 |
| Where capacity is not defined | 5.9 | 6.8 | 8.1 |

Table note: Values in this table will need to be updated periodically as the market changes over time.

Where only the star rating or ACOP from the previous rating system is available (2010 star rating, 2013 Determination (Greenhouse and Energy Minimum Standards (Air Conditioners and Heat Pumps) Determination 2013), these values (rounded down to the nearest 0.5 star or 0.25 ACOP) are converted to equivalent HSPF values in accordance with .

Table 17.

Table 17: Equivalent HSPF values where only previous star rating or ACOP value is known

| **Old rating** | | **ZERL Cold climate - HSPF** | | | | **ZERL Mixed climate – HSPF** | | | | **ZERL Hot climate - HSPF** | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **2010 Star rating** | **ACOP (H1)** | **Non-ducted single speed** | **Non-ducted inverter** | **Ducted single speed** | **Ducted inverter** | **Non-ducted single speed** | **Non-ducted inverter** | **Ducted single speed** | **Ducted inverter** | **Non-ducted single speed** | **Non-ducted inverter** | **Ducted single speed** | **Ducted inverter** |
| 1 | 2.75 | 1.986 | 2.608 | 2.162 | 2.443 | 2.137 | 3.125 | 2.310 | 2.809 | 2.329 | 3.771 | 2.340 | 3.352 |
| 1.5 | 3 | 2.166 | 2.823 | 2.358 | 2.629 | 2.331 | 3.359 | 2.520 | 3.017 | 2.541 | 4.001 | 2.553 | 3.550 |
| 2 | 3.25 | 2.347 | 3.034 | 2.555 | 2.809 | 2.525 | 3.584 | 2.730 | 3.217 | 2.753 | 4.213 | 2.766 | 3.731 |
| 2.5 | 3.5 | 2.527 | 3.241 | 2.751 | 2.983 | 2.720 | 3.802 | 2.940 | 3.410 | 2.965 | 4.405 | 2.979 | 3.893 |
| 3 | 3.75 | 2.708 | 3.445 | 2.948 | 3.151 | 2.914 | 4.011 | 3.150 | 3.594 | 3.176 | 4.579 | 3.191 | 4.038 |
| 3.5 | 4 | 2.888 | 3.645 | 3.144 | 3.314 | 3.108 | 4.211 | 3.360 | 3.770 | 3.388 | 4.734 | 3.404 | 4.165 |
| 4 | 4.25 | 3.069 | 3.841 | 3.341 | 3.470 | 3.302 | 4.403 | 3.570 | 3.939 | 3.600 | 4.870 | 3.617 | 4.274 |
| 4.5 | 4.5 | 3.249 | 4.034 | 3.537 | 3.620 | 3.497 | 4.587 | 3.780 | 4.100 | 3.812 | 4.987 | 3.830 | 4.365 |
| 5 | 4.75 | 3.430 | 4.222 | 3.734 | 3.764 | 3.691 | 4.763 | 3.990 | 4.253 | 4.023 | 5.085 | 4.042 | 4.439 |
| 5.5 | 5 | 3.610 | 4.408 | 3.930 | 3.903 | 3.885 | 4.930 | 4.200 | 4.398 | 4.235 | 5.165 | 4.255 | 4.495 |
| 6 | 5.25 | 3.791 | 4.589 | 4.127 | 4.035 | 4.079 | 5.089 | 4.410 | 4.535 | 4.447 | 5.226 | 4.468 | 4.533 |
| 6.5 | 5.5 | 3.971 | 4.767 | 4.323 | 4.161 | 4.274 | 5.239 | 4.620 | 4.664 | 4.659 | 5.268 | 4.681 | 4.553 |
| ≥7 | ≥5.75 | 4.332 | 5.111 | 4.716 | 4.396 | 4.662 | 5.515 | 5.040 | 4.898 | 5.082 | 5.296 | 5.106 | 4.541 |

Where no equipment is specified, the equipment characteristics set out in Section 3.2.2 will be assumed.

#### Air conditioners (heat pumps) used for cooling

For refrigerative air conditioners used for cooling, the *COPA* (assumed operating efficiency as set out in Equation 14) is to be based on the Total Cooling Seasonal Performance Factor (TCSPF) as specified in the 2019 GEMS Determination for air conditioners (Greenhouse and Energy Minimum Standards (Air Conditioners up to 65kW) Determination 2019) for the relevant ZERL climate zone (cold, mixed or hot/humid). The relevant ZERL climate zone for each of the 69 NatHERS climate zones is set out in Appendix A - Cooling Thermostat settings by NatHERS climate zone for Whole of Home rating, ZERL Zones and Evaporative Cooler Applicability. The NatHERS assessment software should flag the relevant ZERL climate zone to the user.

Where available, the TCSPF for the relevant ZERL climate zone for the equipment type selected for the rating shall be provided. Where only the ZERL star rating is specified, the TCSPF values shall be determined from Table 18.

Table 18: TCSPF values for specified star ratings under the ZERL for air conditioners

| **Cooling star rating in specified ZERL climate zone** | **TCSPF** |
| --- | --- |
| 1.0 | 2.5 |
| 1.5 | 3.0 |
| 2.0 | 3.5 |
| 2.5 | 4.0 |
| 3.0 | 4.5 |
| 3.5 | 5.0 |
| 4.0 | 5.5 |
| 4.5 | 6.0 |
| 5.0 | 6.5 |
| 5.5 | 7.0 |
| 6.0 | 7.5 |
| 6.5 | 8.0 |
| 7.0 | 8.5 |
| 7.5 | 9.0 |
| 8.0 | 9.5 |
| 8.5 | 10.0 |
| 9.0 | 10.5 |
| 9.5 | 11.0 |
| 10.0 | 11.5 |

Table notes: Star rating as per applicable ZERL climate zone.

Where the TCSPF value of the selected heat pump equipment exceeds the applicable value in Table 19, the system shall issue a warning to flag that the claimed efficiency may be beyond that currently available on the market. The applicable capacity for this assessment process is proposed to be determined from the hourly heating load data set for the particular zone or zones in a future update. The method for doing this is yet to be determined. In the interim, a warning flag should be issued if the TCSPF value exceeds the highest possible value for each GEMS zone for cases where capacity is not defined (last row of the table below).

Table 19: Maximum values for TCSPF for air conditioners

| **Capacity range** | **Cold** | **Mixed** | **Hot & humid** |
| --- | --- | --- | --- |
| 0 – 2.99 kW | 8.7 | 8.4 | 8.8 |
| 3 – 5.99 kW | 7.1 | 6.8 | 7.1 |
| 6 – 9.99 kW | 6.6 | 6.1 | 6.5 |
| 10 – 20 kW | 5.9 | 5.7 | 6.5 |
| > 20 kW | 5.1 | 5.0 | 6.3 |
| Where capacity is not defined | 8.7 | 8.4 | 8.8 |

Table note 1: Values in this table will need to be updated periodically as the market changes over time.

Where only the star rating or Annual Energy Efficiency Ratio (AEER) from the previous rating system (GEMS 2013 Determination) is available, these values (rounded down to the nearest 0.5 star or 0.25 AEER) are converted to equivalent TCSPF values in accordance with .

Table 20.

Table 20: Equivalent TCSPF values where only old star rating or AEER value is known

| **Old rating** | | **ZERL Cold climate - TCSPF** | | | | **ZERL Mixed climate – TCSPF** | | | | **ZERL Hot climate - TCSPF** | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **2010 Star rating** | **AEER (T1)** | **Non-ducted single speed** | **Non-ducted inverter** | **Ducted single speed** | **Ducted inverter** | **Non-ducted single speed** | **Non-ducted inverter** | **Ducted single speed** | **Ducted inverter** | **Non-ducted single speed** | **Non-ducted inverter** | **Ducted single speed** | **Ducted inverter** |
| 1 | 2.75 | 2.813 | 3.438 | 2.747 | 3.053 | 2.797 | 3.355 | 2.736 | 3.317 | 2.959 | 3.685 | 2.893 | 3.663 |
| 1.5 | 3 | 3.069 | 3.750 | 2.997 | 3.330 | 3.051 | 3.660 | 2.985 | 3.618 | 3.228 | 4.020 | 3.156 | 3.996 |
| 2 | 3.25 | 3.325 | 4.063 | 3.247 | 3.608 | 3.305 | 3.965 | 3.234 | 3.920 | 3.497 | 4.355 | 3.419 | 4.329 |
| 2.5 | 3.5 | 3.581 | 4.375 | 3.497 | 3.885 | 3.560 | 4.270 | 3.483 | 4.221 | 3.766 | 4.690 | 3.682 | 4.662 |
| 3 | 3.75 | 3.836 | 4.688 | 3.746 | 4.163 | 3.814 | 4.575 | 3.731 | 4.523 | 4.035 | 5.025 | 3.945 | 4.995 |
| 3.5 | 4 | 4.092 | 5.000 | 3.996 | 4.440 | 4.068 | 4.880 | 3.980 | 4.824 | 4.304 | 5.360 | 4.208 | 5.328 |
| 4 | 4.25 | 4.348 | 5.313 | 4.246 | 4.718 | 4.322 | 5.185 | 4.229 | 5.126 | 4.573 | 5.695 | 4.471 | 5.661 |
| 4.5 | 4.5 | 4.604 | 5.625 | 4.496 | 4.995 | 4.577 | 5.490 | 4.478 | 5.427 | 4.842 | 6.030 | 4.734 | 5.994 |
| 5 | 4.75 | 4.859 | 5.938 | 4.745 | 5.273 | 4.831 | 5.795 | 4.726 | 5.729 | 5.111 | 6.365 | 4.997 | 6.327 |
| 5.5 | 5 | 5.115 | 6.250 | 4.995 | 5.550 | 5.085 | 6.100 | 4.975 | 6.030 | 5.380 | 6.700 | 5.260 | 6.660 |
| 6 | 5.25 | 5.371 | 6.563 | 5.245 | 5.828 | 5.339 | 6.405 | 5.224 | 6.332 | 5.649 | 7.035 | 5.523 | 6.993 |
| 6.5 | 5.5 | 5.627 | 6.875 | 5.495 | 6.105 | 5.594 | 6.710 | 5.473 | 6.633 | 5.918 | 7.370 | 5.786 | 7.326 |
| ≥7 | ≥5.75 | 6.138 | 7.500 | 5.994 | 6.660 | 6.102 | 7.320 | 5.970 | 7.236 | 6.456 | 8.040 | 6.312 | 7.992 |

Where no equipment is specified, the equipment characteristics set out in Section 3.2.2 will be assumed.

#### Ducted gas heaters

For ducted gas heaters, the *COPA* (assumed operating efficiency as set out in Equation 14) is based on the star rating of the equipment as assessed by the Australian Gas Association. The value for *COPA* for a ducted gas heater rated from 1 to 3 stars is set out in Equation 16:

Equation 16: Operating efficiency for ducted gas heaters from 1 to 3 stars



The value for *COPA* for a ducted gas heater rated from 3 to 7 stars is set out in Equation 17:

Equation 17: Operating efficiency for ducted gas heaters from 3 to 7 stars



Where GER is the AGA gas star rating for the appliance and LN is the natural logarithm (base e).

In addition, the relevant loss factor from Table 13 and the ancillary energy factor from Table 14 shall be applied to ducted gas heaters.

Indicative values for *COPA* for ducted gas heaters of various star ratings are shown in Table 21.

Table 21: Nominal values of COPA for ducted gas heaters by star rating

| **Stars** | ***COPA*** |
| --- | --- |
| 1 | 50.0% |
| 2 | 60.0% |
| 3 | 70.0% |
| 4 | 79.0% |
| 5 | 85.9% |
| 6 | 91.6% |
| 7 | 96.4% |

Notes: GER can be a decimal value between 1.0 and 7.0. . The Australian Gas Association publishes the **Directory of AGA Certified Products**, which is updated periodically. This shows decimal star ratings from all ducted gas heaters (which are called “Indirect Fired Air Heaters”). See <https://www.aga.asn.au/product_directory/>

#### Non-ducted gas heaters

For non-ducted gas heaters, the *COPA* (assumed operating efficiency as set out in Equation 14) is based on the star rating of the equipment as assessed by the Australian Gas Association. The value for *COPA* for a non-ducted gas heater is set out in Equation 18:

Equation 18: Operating efficiency for non-ducted gas heaters



Where GER is the AGA gas star rating for the appliance.

Where applicable (where the non-ducted gas heater has a fan), the ancillary energy factor from Table 14 shall be applied.

Indicative values for *COPA* for non-ducted gas heaters of various star ratings are shown in Table 22.

Table 22: Nominal values of COPA for non-ducted gas heaters by star rating

| **Stars** | ***COPA*** |
| --- | --- |
| 1 | 61% |
| 2 | 63% |
| 3 | 73% |
| 4 | 79% |
| 5 | 85% |
| 6 | 91% |

Notes: GER can be a decimal value between 1.0 and 6.0. The Australian Gas Association publishes the **Directory of AGA Certified Products**, which is updated periodically. This shows decimal star ratings from all non-ducted gas heaters (which are called “Space Heating Appliances”). See <https://www.aga.asn.au/product_directory/>

#### Wood heaters

For wood heaters, the *COPA* (assumed operating efficiency as set out in Equation 14) is based on published efficiency rating values as compiled by the Australian Home Heating Association when tested in accordance with AS/NZS 4012. Wood heaters shall be classified into one of three types as follows:

* Radiant wood heaters (no fan or electrical connection)
* Fan assisted wood heaters – these systems are assumed to have ancillary electrical consumption as specified in Table 14 (fans for any other non-ducted system type).
* Ducted wood heaters - these systems are assumed to have ancillary electrical consumption as specified in Table 14 (fans for any other ducted system type) plus overall duct losses as specified in Table 13.

Where a wood heater is specified by the user but specific system performance is not entered by the user, the default value for *COPA* is to be set to 60% and the system is assumed to be a fan assisted wood heater (with ancillary electrical consumption as specified in Table 14).

Notes: Current products are listed on <https://www.homeheat.com.au/wood-heaters/certified-wood-heaters/> Note that the efficiency rating value is given on this listing is an integer generally ranging from 60 to 85. This needs to be divided by 100 to derive a valid value for *COPA* (e.g. an AHHA efficiency rating of 75 equates to a *COPA* value of 0.75 or 75%). Unfortunately, this website does not usually indicate whether the unit has a fan (or not) so additional information from the supplier may be required.

#### Evaporative coolers

For evaporative coolers, the *COPA* (assumed operating efficiency as set out in Equation 14) shall be set at a default value of 15 for all system types. Note that this includes ancillary electrical energy (as noted in Table 14) as ancillary load *A* is set to zero for evaporative systems.

For evaporative ducted systems, the assumed system losses are as set out in Table 13.

Evaporative systems are most suited to hotter and dryer climates. Where the user has selected an evaporative cooler and the flag in Appendix A - Cooling Thermostat settings by NatHERS climate zone for Whole of Home rating, ZERL Zones and Evaporative Cooler Applicability indicates that evaporative coolers are not recommended for the specific climate zone that is being assessed, the software system should flag to the user that evaporative coolers are not normally recommended in that climate.

### Appliance Demand

Appliance demand is the sum of the loads in each zone an appliance is servicing at a given hour.

### Heating and Cooling Load Limitations

Note that there are no minimum heating or cooling loads in a conditioned zone below which the load is ignored in the WoH calculation of heating and cooling energy consumption. All zones (except NatHERS designated unconditioned zones) are assumed to be heated and cooled irrespective of the size of the load in that zone.

### Zones without conditioning devices

Zones where no conditioning device has been specified will have a default appliance specified (refer to Section 3.2.2).

### Heating and Cooling Unit Capacity

The capacity of a heater or cooler serving a zone or set of zones is not a required input into the calculation at this stage. Only the type and performance characteristics of the heating/cooling equipment (as detailed in the preceding sections) need to be input. The calculation shall assume that the system capacity will be adequate to meet the load at the end of any given hour in the year.

It is proposed (as a future feature) that the software should provide guidance to assessors on appropriate plant sizing (as screen based advice during data entry and/or as part of the NatHERS Certificate). This should be based on the hourly heating/cooling load data set for the particular zone or zones derived from the Chenath simulation. The maximum hourly load across the entire year with some tolerance built in (e.g. 0% to +15%) (with modifiers as appropriate) should be used as the assumed required system capacity. Where a reverse cycle heat pump is proposed for installation, then the recommendation shall have a cooling capacity that exceeds the maximum hourly cooling load and a heating capacity that exceeds the maximum hourly heating. Such guidance, if provided to builders or owners, should come with caveats relating to the use of such capacity estimates (i.e. this information should be provided to and assessed by the system specifiers and/or installers.

## Hot Water Module

The energy used by the hot water system has three main components:

* Hot water demand (by households)
* Location (Solar climate zones 1-4 + Heat Pump zone HP5-AU)
* Hot water system type.

### Hot water demand

Delivered hot water is assumed to be a nominal 40 litres per person per day winter peak demand. The number of occupants is NOcc as defined in Section 3.1.1.

### Location

Hot water location is mapped against the postcode of the building. Note that postcode is also used to identify the correct climate file for thermal calculation. Hot water locations are listed in Table 23 for Heat Pump systems and Table 24 for all other systems. Zones HP1-AU to HP5-AU are as defined in AS/NZS4234 Heated water systems – Calculation of energy consumption (2008) as amended.

Table 23: Water heater zone for heat pump systems by postcode

| **Postcode** | | **Zone** |
| --- | --- | --- |
| **From** | **To** |
| 800 | 854 | HP1-AU |
| 860 | 860 | HP2-AU |
| 862 | 862 | HP1-AU |
| 870 | 875 | HP2-AU |
| 880 | 886 | HP1-AU |
| 2000 | 2347 | HP3-AU |
| 2350 | 2350 | HP5-AU |
| 2352 | 2361 | HP3-AU |
| 2365 | 2369 | HP5-AU |
| 2370 | 2579 | HP3-AU |
| 2580 | 2581 | HP5-AU |
| 2582 | 2582 | HP3-AU |
| 2583 | 2583 | HP5-AU |
| 2584 | 2594 | HP3-AU |
| 2600 | 2617 | HP5-AU |
| 2618 | 2618 | HP3-AU |
| 2619 | 2633 | HP5-AU |
| 2640 | 2648 | HP3-AU |
| 2649 | 2649 | HP5-AU |
| 2650 | 2652 | HP3-AU |
| 2653 | 2653 | HP5-AU |
| 2655 | 2717 | HP3-AU |
| 2720 | 2720 | HP5-AU |
| 2721 | 2727 | HP3-AU |
| 2729 | 2730 | HP5-AU |
| 2731 | 2786 | HP3-AU |
| 2787 | 2792 | HP5-AU |
| 2793 | 2794 | HP3-AU |
| 2795 | 2800 | HP5-AU |
| 2803 | 2844 | HP3-AU |
| 2845 | 2847 | HP5-AU |
| 2848 | 2898 | HP3-AU |
| 2900 | 2914 | HP5-AU |
| 3000 | 3115 | HP4-AU |
| 3116 | 3116 | HP5-AU |
| 3121 | 3136 | HP4-AU |
| 3137 | 3140 | HP5-AU |
| 3141 | 3156 | HP4-AU |
| 3158 | 3160 | HP5-AU |
| 3161 | 3287 | HP4-AU |
| 3289 | 3289 | HP5-AU |
| 3292 | 3292 | HP4-AU |
| 3293 | 3301 | HP5-AU |
| 3302 | 3312 | HP4-AU |
| 3314 | 3315 | HP5-AU |
| 3317 | 3345 | HP4-AU |
| 3350 | 3350 | HP5-AU |
| 3351 | 3351 | HP4-AU |
| 3352 | 3358 | HP5-AU |
| 3360 | 3361 | HP4-AU |
| 3363 | 3370 | HP5-AU |
| 3371 | 3371 | HP4-AU |
| 3373 | 3373 | HP5-AU |
| 3374 | 3374 | HP4-AU |
| 3375 | 3379 | HP5-AU |
| 3380 | 3381 | HP4-AU |
| 3384 | 3384 | HP3-AU |
| 3385 | 3387 | HP4-AU |
| 3388 | 3396 | HP3-AU |
| 3400 | 3401 | HP4-AU |
| 3407 | 3407 | HP5-AU |
| 3409 | 3413 | HP4-AU |
| 3414 | 3424 | HP3-AU |
| 3427 | 3429 | HP4-AU |
| 3430 | 3463 | HP5-AU |
| 3464 | 3465 | HP3-AU |
| 3467 | 3469 | HP5-AU |
| 3472 | 3520 | HP3-AU |
| 3521 | 3522 | HP4-AU |
| 3523 | 3649 | HP3-AU |
| 3658 | 3658 | HP4-AU |
| 3659 | 3673 | HP3-AU |
| 3675 | 3678 | HP5-AU |
| 3682 | 3695 | HP3-AU |
| 3697 | 3723 | HP5-AU |
| 3725 | 3730 | HP3-AU |
| 3732 | 3746 | HP5-AU |
| 3747 | 3749 | HP3-AU |
| 3750 | 3762 | HP4-AU |
| 3763 | 3763 | HP5-AU |
| 3764 | 3764 | HP4-AU |
| 3765 | 3779 | HP5-AU |
| 3781 | 3783 | HP4-AU |
| 3785 | 3799 | HP5-AU |
| 3802 | 3815 | HP4-AU |
| 3816 | 3824 | HP5-AU |
| 3825 | 3825 | HP4-AU |
| 3831 | 3835 | HP5-AU |
| 3840 | 3892 | HP4-AU |
| 3893 | 3900 | HP5-AU |
| 3902 | 3996 | HP4-AU |
| 4000 | 4419 | HP3-AU |
| 4420 | 4420 | HP1-AU |
| 4421 | 4428 | HP3-AU |
| 4454 | 4454 | HP1-AU |
| 4455 | 4465 | HP3-AU |
| 4467 | 4468 | HP1-AU |
| 4470 | 4474 | HP2-AU |
| 4477 | 4477 | HP1-AU |
| 4478 | 4482 | HP2-AU |
| 4486 | 4488 | HP3-AU |
| 4489 | 4493 | HP2-AU |
| 4494 | 4615 | HP3-AU |
| 4620 | 4724 | HP1-AU |
| 4725 | 4725 | HP2-AU |
| 4726 | 4726 | HP1-AU |
| 4727 | 4731 | HP2-AU |
| 4732 | 4735 | HP1-AU |
| 4736 | 4736 | HP2-AU |
| 4737 | 4824 | HP1-AU |
| 4825 | 4830 | HP2-AU |
| 4849 | 4895 | HP1-AU |
| 5000 | 5214 | HP3-AU |
| 5220 | 5223 | HP4-AU |
| 5231 | 5261 | HP3-AU |
| 5262 | 5263 | HP4-AU |
| 5264 | 5270 | HP3-AU |
| 5271 | 5291 | HP4-AU |
| 5301 | 6256 | HP3-AU |
| 6258 | 6262 | HP4-AU |
| 6271 | 6317 | HP3-AU |
| 6318 | 6338 | HP4-AU |
| 6341 | 6341 | HP3-AU |
| 6343 | 6348 | HP4-AU |
| 6350 | 6353 | HP3-AU |
| 6355 | 6357 | HP4-AU |
| 6358 | 6395 | HP3-AU |
| 6396 | 6398 | HP4-AU |
| 6401 | 6438 | HP3-AU |
| 6440 | 6440 | HP2-AU |
| 6442 | 6443 | HP3-AU |
| 6445 | 6452 | HP4-AU |
| 6460 | 6640 | HP3-AU |
| 6642 | 6725 | HP2-AU |
| 6726 | 6743 | HP1-AU |
| 6751 | 6799 | HP2-AU |
| 7000 | 7470 | HP5-AU |

Table note: For heat pump systems, climate zones for heat pumps are called HP1-AU to HP5-AU in AS/NZS4234.

Table 24: Water heater zone for all other water heater technologies by postcode

| **Postcode** | | **Zone** |
| --- | --- | --- |
| **From** | **To** |
| 800 | 854 | 1 |
| 860 | 860 | 2 |
| 862 | 862 | 1 |
| 870 | 875 | 2 |
| 880 | 886 | 1 |
| 2000 | 2914 | 3 |
| 3000 | 3381 | 4 |
| 3384 | 3384 | 3 |
| 3385 | 3387 | 4 |
| 3388 | 3396 | 3 |
| 3400 | 3413 | 4 |
| 3414 | 3424 | 3 |
| 3427 | 3451 | 4 |
| 3453 | 3465 | 3 |
| 3467 | 3469 | 4 |
| 3472 | 3520 | 3 |
| 3521 | 3522 | 4 |
| 3523 | 3649 | 3 |
| 3658 | 3658 | 4 |
| 3659 | 3709 | 3 |
| 3711 | 3723 | 4 |
| 3725 | 3749 | 3 |
| 3750 | 3898 | 4 |
| 3900 | 3900 | 3 |
| 3902 | 3996 | 4 |
| 4000 | 4419 | 3 |
| 4420 | 4420 | 1 |
| 4421 | 4428 | 3 |
| 4454 | 4454 | 1 |
| 4455 | 4465 | 3 |
| 4467 | 4468 | 1 |
| 4470 | 4474 | 2 |
| 4477 | 4477 | 1 |
| 4478 | 4482 | 2 |
| 4486 | 4488 | 3 |
| 4489 | 4493 | 2 |
| 4494 | 4615 | 3 |
| 4620 | 4724 | 1 |
| 4725 | 4725 | 2 |
| 4726 | 4726 | 1 |
| 4727 | 4731 | 2 |
| 4732 | 4735 | 1 |
| 4736 | 4736 | 2 |
| 4737 | 4824 | 1 |
| 4825 | 4830 | 2 |
| 4849 | 4895 | 1 |
| 5000 | 5214 | 3 |
| 5220 | 5223 | 4 |
| 5231 | 5261 | 3 |
| 5262 | 5263 | 4 |
| 5264 | 5270 | 3 |
| 5271 | 5291 | 4 |
| 5301 | 6256 | 3 |
| 6258 | 6262 | 4 |
| 6271 | 6317 | 3 |
| 6318 | 6338 | 4 |
| 6341 | 6341 | 3 |
| 6343 | 6348 | 4 |
| 6350 | 6353 | 3 |
| 6355 | 6357 | 4 |
| 6358 | 6395 | 3 |
| 6396 | 6398 | 4 |
| 6401 | 6438 | 3 |
| 6440 | 6440 | 2 |
| 6442 | 6443 | 3 |
| 6445 | 6452 | 4 |
| 6460 | 6640 | 3 |
| 6642 | 6725 | 2 |
| 6726 | 6743 | 1 |
| 6751 | 6799 | 2 |
| 7000 | 7470 | 4 |

For the purposes of simulation under AS/NZS 4234, the assumed conditions for heat pumps in zones HP1-AU to HP4-AU are the same as for Zones 1 to 4 for all other types of water heaters.

### Hot water systems

Research by Energy Efficient Strategies[[10]](#footnote-11) determined performance characteristics for a set of generic conventional water heaters in accordance with AS/NZS4234. In addition, analysis and TRNSYS simulations by the water heater industry for solar thermal and heat pump systems has provided a firm quantitative basis for modelling a much wider range of solar water heater types and different performance levels for these types of water heaters. The water heaters that are currently covered are:

* Solid fuel
* Off-peak electric (assumes ‘large’ MEPS compliant storage unit)
* Continuous electric (assumes ‘small’ MEPS compliant storage unit)
* Instantaneous electric
* Electric boosted solar thermal – a range of sizes and performance levels
* Gas boosted solar thermal – a range of sizes and performance levels
* Heat pump – a range of sizes and performance levels
* Gas storage (4.0, 4.5 or 5.0 stars)
* Gas instantaneous (4.0 to 7.0 stars in 0.5 star increments)

Other types of water heaters may be added as suitable data becomes available, as well as consideration of peak and off-peak electricity tariffs for heat pump and electric boosted solar water heaters.

Note: Characteristics for central hot water systems are under consideration.

### Water heater energy calculations

#### Water heater annual energy use

The approach taken to modelling the energy consumption of water heaters is as follows:

1. Define the household size (persons) based on the floor area of the building
2. Determine the winter peak hot water demand in MJ/day based on the household size and climate zone (also commonly called the thermal load on the water heater) – note that the daily hot water demand varies by month and the monthly variation is defined in AS/NZS 4234
3. Determine the annual hot water demand (thermal load = energy output) from the winter peak daily hot water demand
4. Estimate the annual purchased energy (energy input) from the annual hot water demand (energy output) based on a third order polynomial equation
5. Split the purchased annual energy (energy input) by month of the year based on the operating characteristics of the water heater (this takes into account changes in water heater performance throughout the year and changes in operating conditions and system performance throughout the year)
6. Split the monthly energy into an average input energy daily profile (hourly energy consumption) based on the assumed drawoff pattern of hot water and/or the energisation profile of the system.

All modelling assumptions in this specification are in line with AS/NZS4234, except for the hot water demand, which is varied according to the estimated number of occupants in the dwelling (which is based on the floor area of the dwelling). A nominal hot water demand of 40 litres per person per day is used to generate the winter peak daily hot water demand. The standard assumes an identical hot water demand profile for every day of each month (at this stage there is no adjustment for weekday versus weekends or weather related effects). The hot water seasonal demand profile is varied by month throughout the year as defined in AS/NZS4234. Parameters such as cold water inlet temperature are also varied by month for each climate zone in AS/NZS4234. Parameters such as air temperature and solar radiation (for solar thermal systems) are contained in representative mean year climate files, which contain hourly data used for TRNSYS simulations.

The first step is to define the number of occupants, as defined in Equation 2 and repeated here for convenience:

Where:

NOcc = Number of occupants in the home

AD = Area of Dwelling

Area of Dwelling is defined as the sum of the floor area of all zones, excluding the garage.

NOcc is to be rounded the nearest 2nd decimal place – i.e. #.xx (i.e. the number of occupants is not an integer)

The second step is to estimate the winter peak hot water demand in MJ/day (*Kwp*) based on the household size (number of occupants) and climate zone as per AS/NZ4234 and defined in Equation 19:

Equation 19: Determination of winter peak hot water demand

**

Where *y* is the average Litres of water per MJ for a 1MJ peak load in Winter by climate zone, shown in Table 25 and “40” is the assumed nominal average winter peak hot water demand of 40 litres per person per day.

Table 25: Average water volume per MJ winter peak hot water demand by climate zone

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Climate | **Zone 1 and HP1-AU** | **Zone 2 and HP2-AU** | **Zone 3 and HP3-AU** | **Zone 4 and HP4-AU** | **HP5-AU** |
| L/MJ (y) | 6.144 | 5.482 | 5.107 | 4.746 | 4.514 |

Table notes: For the purposes of simulation under AS/NZS 4234, the assumed conditions for heat pumps in zones HP1-AU to HP4-AU are the same as for Zones 1 to 4 for other types of water heaters.

The third step is to convert the winter peak hot water demand (MJ/day) into the annual hot water demand (energy output) as defined in Equation 20

Equation 20: Determination of annual water demand



Where:

*EAnnual-output* is the annual energy output (hot water demand) for the water heater in GJ/year

*Kwp* is the winter peak hot water demand in MJ/day from Equation 19

365 is days in a standard year

0.904521 is a factor to convert a winter peak demand MJ/day into an average annual daily demand, taking into account days per month and the seasonal hot water demand profile in AS/NZS4234

1000 is a factor to convert MJ to GJ.

The fourth step is to estimate the annual purchased energy *EAnnual-input* (energy input) from the annual hot water demand energy *EAnnual-output* (energy output) based on a third order polynomial, with coefficients for each specific water heater type in each climate zone to determine annual energy input in MJ/year. This is defined in Equation 21.

Equation 21: Determination of annual purchase energy from annual hot water demand



Where *EAnnual-output* is the annual hot water load (energy output) in GJ/year from Equation 20 and *EAnnual-input* is the annual hot water energy purchased (energy input) in MJ/year.

Note: An earlier version of the water heater module used *Kwp* in Equation 21 to estimate *EAnnual-input*. The same general form of equation is used in this update, but *EAnnual-output* is now used instead as the input to this equation. This means that all coefficients a, b, c and d have been changed in this updated specification.

The following restrictions apply to solar thermal electric boost water heaters and solar thermal gas boost water heaters:

* Where the number of occupants in accordance with Equation 2 is greater than or equal to 6, then a solar thermal electric boost system or solar thermal gas boost system must be classified as large by the Clean Energy Regulator;
* Where the number of occupants in accordance with Equation 2 is greater than or equal to 4 but less than 6, then a solar thermal electric boost system or solar thermal gas boost system must be classified as medium or large by the Clean Energy Regulator.

To provide guidance, Table 26 sets out the minimum STC levels for larger households.

Table 26: Minimum STC levels for solar thermal water heaters by household size and climate

| **Climate Zone** | **Minimum STC – solar thermal electric boost 4 ≤ NOcc < 6 (medium)** | **Minimum STC – solar thermal electric boost NOcc > 6 (large)** | **Minimum STC – solar thermal gas boost 4 ≤ NOcc < 6 (medium)** | **Minimum STC – solar thermal gas boost NOcc > 6(large)** |
| --- | --- | --- | --- | --- |
| 1 | 21 | 28 | 18 | 25 |
| 2 | 21 | 28 | 18 | 25 |
| 3 | 25 | 35 | 22 | 32 |
| 4 | 27 | 38 | 25 | 35 |

There may be additional requirements to confirm the water heater has the capacity to deliver the required hot water.

The coefficients for each water heater type and climate zone are defined in tables in rating. The codes used in Appendix B are set out on more detail below. These are also included in a separate spreadsheet provided for users.

Codes used to identify each water heater type and climate zone are in the following general format:

XXX-Y-ZZ

Where:

XXX is a three letter code to identify the water heater type

Y is an integer to identify the climate zone (1 to 5 for heat pump systems in Zones HP1-AU to HP5-AU and 1 to 4 in Zones 1 to 4 for all other water heater types)

ZZ is a specific 2 digit code that is specific performance level for the water heater type.

More detail for each of these code elements are set out Table 27.

Table 27: Codes for different water heater types

| **Water heater code** | **Water heater type** | **Suffix details** | **Notes** |
| --- | --- | --- | --- |
| SOF | Solid fuel | 00 for all systems |  |
| ESS | Electric storage small | 00 for all systems | Assumes 80 litre continuous energisation |
| ESL | Electric storage large | 00 for all systems | Assumes 315 litre off peak energisation |
| EIN | Electric storage instantaneous | 00 for all systems |  |
| GST | Gas storage | XX is star rating(a) × 10 | Several star ratings |
| GIN | Gas instantaneous | XX is star rating(a) × 10 | Several star ratings, separate gas and electric |
| STE | Solar thermal electric boost | STCs earned(b) | Remote of close coupled, range of STC levels |
| STG (STX) | Solar thermal gas boost | STCs earned(c) | In line boosting, range of STC levels, electric+gas |
| SHP | Heat pump | STCs earned(d) | Range of STC levels |

Table notes: (a) Gas star rating in half star increments ×10 e.g. 55 = star rating of 5.5 stars and these coefficients used in Equation 21 give the gas energy consumption. Code 99 for GIN is the auxiliary electricity energy consumption for gas instantaneous water heaters.  
(b) STC range is based on modelling during 2021 and allocates full deemed 10 year energy savings for small, medium and large systems. STC values range from 12 to 45, but this varies by climate. Not all STC levels are available in all climates.   
(c) STC range is based on modelling during 2021 and allocates full deemed 10 year energy savings for small, medium and large systems. STC values range from 12 to 45, but this varies by climate. Not all STC levels are available in all climates. For solar thermal with gas boost, the estimated energy is for gas and electric combined. This is separated by fuel when monthly values are estimated in the following section. Code STG estimates monthly gas consumption and code STX estimates monthly electricity consumption.  
(d) STC range is based on modelling during 2021 and allocates full deemed 10 year energy savings for small and medium systems only. STC values range from 12 to 35, but this varies by climate. Not all STC levels are available in all climates. Heat pump covers 5 separate climate zones.

#### Water heater monthly energy use

Once annual energy input (purchased energy) has been determined, this is split into energy input by month. In terms of splitting annual energy into monthly components, there are three main cases. Firstly, the energy input for instantaneous systems will be largely in direct proportion to changes in monthly hot water energy demand as essentially there are no fixed losses for these types (there may be some ongoing auxiliary electrical energy consumption = standby power (electrical) and some start-up losses, but these are assumed to scale with hot water consumption). For conventional storage systems (mainly electric and gas) the input energy will slightly vary by month in accordance with the hot water load and the changes in heat loss through the year, so the monthly split will be slightly different for these products and this will depend on the relative size of the heat losses. In terms of modelling, it has been found that heat pumps water heaters behave like conventional storage water heaters in terms of their monthly breakdown share of energy.

For solar thermal systems (electric and gas boost), the monthly breakdown is quite complex as the overall solar contribution and the monthly breakdown of input energy are both dependent on the hot water demand. In general terms, lower hot water demand results in higher solar contributions overall with very low input energy in summer and a higher share of annual input energy in winter (even though the total energy input is smaller). As hot water demand increases, the overall solar contribution decreases and the seasonal share of energy becomes more evenly distributed across the months. Monthly parameters for all water heater types are also affected by climate zone.

The share of hot water demand from the water heater by month (taking into account the monthly energy profile and the days per month in a standard year) is defined in the standard and is set out in Table 28. This table is also used to allocate annual energy into month for instantaneous water heaters. The monthly share of input energy is set out in the following tables and equations for each of the hot water systems covered by the NatHERS Whole of Home scheme. A full list of monthly share of annual energy input (purchased energy) for all water heater types and climates are listed in Appendix C – Water Heater Performance Coefficients for monthly share of energy by climate zone for Whole of Home rating.

Table 28: Share of hot water demand by month, all climate zones

| **Month** | **Hot water Demand by month** |
| --- | --- |
| Jan | 6.5728% |
| Feb | 6.7848% |
| Mar | 7.9812% |
| Apr | 8.1781% |
| May | 8.9202% |
| Jun | 9.0868% |
| Jul | 9.3897% |
| Aug | 9.3897% |
| Sep | 9.0868% |
| Oct | 8.9202% |
| Nov | 8.1781% |
| Dec | 7.5117% |
| Total | 100.0000% |

Table notes: Derived from the monthly seasonal multiplier defined in AS/NZS4234 Table A5 and the number of days per month in a standard year. This table is also used to break down annual energy input (*Fm,z*) for instantaneous electric and gas systems for all zones.

Table 29: Share purchased energy by month and climate zone, small electric storage hot water systems (Fm,z)

| **Month** | **Zone 1** | **Zone 2** | **Zone 3** | **Zone 4** |
| --- | --- | --- | --- | --- |
| Jan | 6.7260% | 6.6291% | 6.7444% | 6.8500% |
| Feb | 6.8112% | 6.7257% | 6.8012% | 6.7213% |
| Mar | 7.9116% | 7.9446% | 7.9017% | 7.9760% |
| Apr | 8.1341% | 8.1744% | 8.1422% | 8.1207% |
| May | 8.9275% | 8.9981% | 8.9667% | 8.9133% |
| Jun | 9.1331% | 9.2057% | 9.1182% | 9.0702% |
| Jul | 9.4580% | 9.6551% | 9.4737% | 9.4094% |
| Aug | 9.3801% | 9.5126% | 9.3803% | 9.3308% |
| Sep | 9.0378% | 9.0638% | 8.9597% | 8.9879% |
| Oct | 8.8496% | 8.6926% | 8.8773% | 8.8624% |
| Nov | 8.1063% | 8.0089% | 8.1050% | 8.1401% |
| Dec | 7.5246% | 7.3893% | 7.5297% | 7.6177% |
| **Total** | **100.0000%** | **100.0000%** | **100.0000%** | **100.0000%** |

Table 30: Share purchased energy by month and climate zone, large electric storage hot water systems (Fm,z)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Month** | **Zone 1** | **Zone 2** | **Zone 3** | **Zone 4** |
| Jan | 6.8464% | 6.7171% | 6.8749% | 7.0196% |
| Feb | 6.8555% | 6.7434% | 6.8445% | 6.7396% |
| Mar | 7.9118% | 7.9580% | 7.9009% | 7.9996% |
| Apr | 8.1250% | 8.1799% | 8.1363% | 8.1080% |
| May | 8.9145% | 9.0075% | 8.9640% | 8.8931% |
| Jun | 9.1102% | 9.2043% | 9.0877% | 9.0234% |
| Jul | 9.4403% | 9.6947% | 9.4569% | 9.3713% |
| Aug | 9.3397% | 9.5111% | 9.3370% | 9.2709% |
| Sep | 8.9872% | 9.0215% | 8.8844% | 8.9183% |
| Oct | 8.8130% | 8.6103% | 8.8481% | 8.8274% |
| Nov | 8.0884% | 7.9625% | 8.0877% | 8.1332% |
| Dec | 7.5680% | 7.3896% | 7.5776% | 7.6957% |
| **Total** | **100.0000%** | **100.0000%** | **100.0000%** | **100.0000%** |

Table 31: Share purchased energy by month and climate zone, gas storage hot water systems (Fm,z) (all star ratings)

| **Month** | **Zone 1** | **Zone 2** | **Zone 3** | **Zone 4** |
| --- | --- | --- | --- | --- |
| Jan | 6.8949% | 6.7004% | 6.9262% | 7.1274% |
| Feb | 6.8458% | 6.6762% | 6.8256% | 6.6707% |
| Mar | 7.8475% | 7.9144% | 7.8310% | 7.9769% |
| Apr | 8.0914% | 8.1723% | 8.1091% | 8.0684% |
| May | 8.9313% | 9.0709% | 9.0074% | 8.9029% |
| Jun | 9.1704% | 9.3133% | 9.1390% | 9.0453% |
| Jul | 9.5169% | 9.9050% | 9.5443% | 9.4178% |
| Aug | 9.3620% | 9.6237% | 9.3621% | 9.2666% |
| Sep | 8.9811% | 9.0333% | 8.8298% | 8.8869% |
| Oct | 8.7761% | 8.4673% | 8.8326% | 8.8046% |
| Nov | 8.0360% | 7.8447% | 8.0363% | 8.1058% |
| Dec | 7.5465% | 7.2784% | 7.5566% | 7.7267% |
| **Total** | **100.0000%** | **100.0000%** | **100.0000%** | **100.0000%** |

Table 32: Share purchased energy by month and climate zone, heat pump water heaters (Fm,z) (all STC levels)

| **Month** | **Zone HP1-AU** | **Zone HP2-AU** | **Zone HP3-AU** | **Zone HP4-AU** | **Zone HP5-AU** |
| --- | --- | --- | --- | --- | --- |
| Jan | 5.8703% | 5.5245% | 5.7955% | 6.3054% | 5.4751% |
| Feb | 6.2888% | 5.7195% | 6.1267% | 5.7225% | 5.2918% |
| Mar | 7.1813% | 6.9196% | 7.0289% | 7.4892% | 7.1121% |
| Apr | 7.8434% | 7.9791% | 7.8875% | 7.7164% | 7.4856% |
| May | 9.2218% | 9.4957% | 9.4748% | 9.2536% | 9.3851% |
| Jun | 10.1730% | 10.0638% | 9.9447% | 9.6631% | 11.5143% |
| Jul | 10.5260% | 12.9193% | 10.8934% | 10.6023% | 11.9732% |
| Aug | 10.0873% | 10.6036% | 10.0740% | 9.9239% | 10.6750% |
| Sep | 9.5082% | 9.5443% | 9.1853% | 9.2708% | 9.6299% |
| Oct | 8.7002% | 7.9810% | 9.0796% | 9.0284% | 8.3309% |
| Nov | 7.7042% | 6.9322% | 7.7545% | 7.7997% | 6.8849% |
| Dec | 6.8956% | 6.3175% | 6.7551% | 7.2247% | 6.2420% |
| Total | 100.0000% | 100.0000% | 100.0000% | 100.0000% | 100.0000% |

For solar thermal electric boost systems and solar thermal gas boost systems, the monthly share of energy is given by a third order polynomial equation for each month in the following general form:

Equation 22: Monthly share of energy for solar thermal systems



Where *EAnnual-output* (hot water demand) is defined in Equation 20. Separate coefficients are supplied for solar thermal electric boost water heaters for each month and in each climate zone. The sum of values for the 12 months from Equation 22 for solar thermal electric should be equal to 1.0000.

For solar thermal gas boost systems, two sets of coefficients are provided to separately estimate the share of gas (STG) (main boost fuel) and electricity (STX) (auxiliary energy) in each month (noting that the total annual purchased energy estimated from Equation 21 is gas plus electrical energy). The sum of values for each of the 12 months from Equation 22 for gas (STG) plus the 12 months for electricity (STX) for solar thermal electric should be equal to 1.0000.

To assist users, the coefficients in Equation 22 are provided in a table in Appendix C – Water Heater Performance Coefficients for monthly share of energy by climate zone for Whole of Home rating for all water heater types and climate zones. For the most accurate results, the source spreadsheet should be used to extract the exact values for each coefficient as more significant figures than shown in this report are available.

#### Water heater hourly energy use

As the whole-of-home schema aims to provide hour-by-hour energy demand, the monthly average data determined previously is then used to estimate daily and then hourly energy input into the water heater. Energy input will differ by hot water system for a given hot water demand. Conventional instantaneous systems and storage systems with continuous energisation will have an hourly energy profile that largely mirrors the hot water demand profile. Where the energisation profile has restricted times (e.g. off peak electric water heaters) the daily energy input is assumed to be consumed according to the applicable energisation profile.

Daily energy demand is calculated using Equation 23:

Equation 23: Daily energy inut for water heaters

Where:

Fm,z = Factor for relevant month and climate zone as specified in Appendix C – Water Heater Performance Coefficients for monthly share of energy by climate zone for Whole of Home rating determined from Equation 22.

*EAnnual-input* is the annual hot water energy purchased (energy input) in MJ/year determined from Equation 21.

Daysm = Days in the specified month (for a standard year = 365 days)

Hourly loads will depend on the type of water heater and the energisation profile. For example, a large electric storage unit traditionally heats up overnight, but a smaller unit with continuous energisation is more likely to respond immediately, or with a slight delay, to hot water drawoffs. Storage systems with some fixed and variable components have an hourly breakdown that is dependent on the hot water load when operated with continuous energisation. Note that the hourly loads relate to when the water heater is assumed to deliver hot water in accordance with the usage profile defined in standard AS/NZS4234. This may be different to when hot water would be used by the occupants in real life.

Some initial broad assumptions regarding time of energy input into the water heater (as opposed to time of hot water delivery) are provided in Table 33.

Table 33: Water heater schedules

| **Water Heater** | **Energy Input (energisation) Schedule in** Table 34 |
| --- | --- |
| Solid fuel (f) | Additional research required (assume time of hot water use as the default) |
| Off-peak electric (e) | Overnight or Daytime limited energisation |
| Continuous electric (e) | Energisation dependent on hot water load |
| Solar thermal std eff (e) | Time of hot water use (or overnight/daytime if on limited energisation) |
| Solar thermal instant gas (g) | Time of hot water use |
| Heat pump (e) | Energisation dependent on hot water load (or overnight/daytime if on limited energisation) |
| Gas storage (g) | Energisation dependent on hot water load |
| Gas Instant (g) (All types) | Time of hot water use for gas, electricity dependent on hot water load |

Schedules are defined in Table 34. Time of hot water use pattern is initially suggested to operate on the same basis as the AS/NZ4234 Table A4.

Table 34: Daily hot water demand and energisation profiles (F Hourly)

| **Nominal hour number** | **Clock Hour beginning** | **Clock Hour ending** | **Time of Hot Water use by hour** | **Daytime energisation by hour** | **Overnight energisation by hour** | **Energisation dependent on hot water load storage systems** | **Share auxiliary electricity energy for solar thermal gas systems** |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | 00:00 | 01:00 | 0 | 0 | 0.25 | Component A | 1.1% |
| 2 | 01:00 | 02:00 | 0 | 0 | 0.25 | Component A | 1.1% |
| 3 | 02:00 | 03:00 | 0 | 0 | 0.25 | Component A | 1.1% |
| 4 | 03:00 | 04:00 | 0 | 0 | 0.25 | Component A | 1.1% |
| 5 | 04:00 | 05:00 | 0 | 0 | 0 | Component A | 1.1% |
| 6 | 05:00 | 06:00 | 0 | 0 | 0 | Component A | 1.1% |
| 7 | 06:00 | 07:00 | 0 | 0 | 0 | Component A | 1.1% |
| 8 | 07:00 | 08:00 | 0.15 | 0 | 0 | Component D | 1.7% |
| 9 | 08:00 | 09:00 | 0.15 | 0.125 | 0 | Component D | 1.7% |
| 10 | 09:00 | 10:00 | 0 | 0.125 | 0 | Component A | 4.6% |
| 11 | 10:00 | 11:00 | 0 | 0.125 | 0 | Component A | 8.1% |
| 12 | 11:00 | 12:00 | 0.1 | 0.125 | 0 | Component B | 12.0% |
| 13 | 12:00 | 13:00 | 0 | 0.125 | 0 | Component A | 15.1% |
| 14 | 13:00 | 14:00 | 0.1 | 0.125 | 0 | Component B | 15.5% |
| 15 | 14:00 | 15:00 | 0 | 0.125 | 0 | Component A | 11.6% |
| 16 | 15:00 | 16:00 | 0.125 | 0.125 | 0 | Component C | 8.6% |
| 17 | 16:00 | 17:00 | 0.125 | 0 | 0 | Component C | 5.1% |
| 18 | 17:00 | 18:00 | 0.125 | 0 | 0 | Component C | 1.6% |
| 19 | 18:00 | 19:00 | 0.125 | 0 | 0 | Component C | 1.6% |
| 20 | 19:00 | 20:00 | 0 | 0 | 0 | Component A | 1.1% |
| 21 | 20:00 | 21:00 | 0 | 0 | 0 | Component A | 1.1% |
| 22 | 21:00 | 22:00 | 0 | 0 | 0 | Component A | 1.1% |
| 23 | 22:00 | 23:00 | 0 | 0 | 0 | Component A | 1.1% |
| 24 | 23:00 | 24:00 | 0 | 0 | 0 | Component A | 1.1% |

Table notes: Nominal hour number is hour ending the specified hour number as clock time (refer to Section 3.1 regarding hour notation). Time of hot water use is as defined in AS/NZS4234 Table A4. Hour 24:00 on the current day is equal to hour 0:00 on the next day. Hourly breakdown for storage systems with continuous energisation is dependent on the hot water demand. Daytime and overnight energisation profiles can be adjusted by the user.

The assumption of allocating the hourly share of average daily energy input for solar thermal electric and solar thermal gas boost systems to the hot water demand profile is known to be an approximation. In reality, overall solar thermal performance will vary from day to day, depending on the sequence of weather experienced at the site. This means that the boost energy required on any particular day may be lower or higher than the average value for the month, as estimated by the simulation. While it is possible to track daily variations in solar contribution for solar thermal simulations, this is very onerous and complex, with little overall improvement in the overall energy estimates for the whole year, which is the main focus of this work. Simulations use a representative mean year weather file, so while this provides a good overall basis for examining performance, actual weather sequences may differ.

Solar thermal electric boost water heaters are sometimes configured to be suitable for operation on controlled tariffs (e.g. off peak). These configuration changes are reflected in the STCs earned, so no additional modelling requirements need to be included. However, solar thermal water heaters with electric boost should only be operated on controlled tariffs when the supplier confirms that they are correctly configured for this mode of operation.

The hourly breakdown of energy (*EHourly*) is defined in Equation 24 using the hourly share (*FHourly*) from Table 34 for the relevant water heater type, configuration and energisation profile and the daily energy defined in Equation 23

Equation 24: Hourly energy input for water heaters

As set out in Table 34, the hourly breakdown of energy (*FHourly*) for the following water heaters is dependent on the hot water load as heat losses (or fixed energy components) are spread throughout the day for storage systems. As the hot water load increases, the increased hot water energy reduces the relative share of the heat losses. The distribution of electrical auxiliary energy for gas instantaneous systems throughout the day is similar as at no hot water load there is only standby, and electrical energy consumption increases with hot water load for those hours with hot water demand. The following water heaters use four separate equations to apportion the daily energy into different hours of the day (Components A, B, C and D) when they are operating with continuous energisation:

* Electric storage
* Heat pump
* Gas storage (gas energy input)
* Gas Instantaneous (electrical auxiliary energy)
* Solar thermal gas boost (electrical auxiliary energy) – assumed to be the same as gas instantaneous.

For these water heater system types and fuels, the hourly breakdown of energy (*FHourly*) is given by the following four equations:

Equation 25: Hourly breakdown of energy for storage type water heaters – Component A



Where coefficients *aA*, *bA*, *cA* and *dA* are defined in Appendix D – Water Heater Performance Coefficients for hourly share of energy by climate zone for Whole of Home rating.

Similarly, Components B, C and D are determined using similar equations with different coefficients as follows:

Equation 26: Hourly breakdown of energy for storage type water heaters – Component B



Equation 27: Hourly breakdown of energy for storage type water heaters – Component C



Equation 28: Hourly breakdown of energy for storage type water heaters – Component D



In summary:

* Component A applies to Hours 0% hot water demand = hours 0-6,9,10,14,20-23
* Component B applies to Hours 10% hot water demand = hours 11,13
* Component C applies to Hours 12.5% hot water demand = hours 15,16,17,18
* Component D applies to Hours 15% hot water demand = hours 7,8.

As a check, the following equation should be used to validate the values for the four components:

Equation 29: Validation of hourly Components A, B, C and D for storage systems



An illustration of how the hourly share of daily energy changes with hot water load is provided in Figure 1. At zero hot water load, the heat loss is evenly distributed across the 24 hours. As the hot water load increases, the share of heat loss reduces and the hours with hot water consumption are scaled up in proportion to the demand in those hours.

Figure 2: Illustration of changes in hourly share of daily with hot water load for a small electric storage system in Zone 3

Figure 1: Illustration of changes in hourly share of daily with hot water load for a small electric storage system in Zone 3

Figure notes: The four hot water demands shown are 0 MJ/day, 20 MJ/day, 40 MJ/day and 60 MJ/day (winter peak).

#### Water heater worked examples

The following worked examples are provided to illustrate the calculations for water heaters and to provide results for the validation of calculations.

**Example 1**: A solar thermal electric boosted water heater is being installed in a 200 m2 new home in Zone 3.

In accordance with Equation 2, the number of occupants is given by:

= 3.546934

The number of occupants becomes 3.55 when rounded to two decimal places, as specified.

From Table 25, the value of *y* for Zone 3 is equal to 5.107.

From Equation 19, the winter peak hot water demand *Kwp* is defined as follows:

**= 27.805 MJ/day winter peak hot water demand.

From Equation 20, the annual hot water demand (energy output) *EAnnual-output* is defined as follows:

 = 9.1782 GJ/year

Several possible water heaters have been investigated for the site. The first is a solar thermal electric boost that earns 27 STCs in Zone 3. The relevant code for this water heater is therefore STE-3-27. From Appendix B, the relevant parameters for Equation 21 are obtained from the lookup table as follows:

| **a** | **b** | **c** | **d** |
| --- | --- | --- | --- |
| -0.27887 | 28.75026 | 87.96217 | 337.4859 |

This is a valid selection as the STCs earned is not restricted for *NOcc* of less than 4 people (see Table 26).

The annual purchased energy (energy input) can then be determined from Equation 21 as follows:



*EAnnual-input* = 3351.996 MJ/year of electricity.

The monthly breakdown of energy is determined from Equation 22 using coefficients from Appendix C – Water Heater Performance Coefficients for monthly share of energy by climate zone for Whole of Home rating as shown in the following table.

| **Month** | **Daysm** | **Month Code** | **a-month** | **b-month** | **c-month** | **d-month** | **Monthly share *Fm.z*** | **Monthly energy MJ** | **Daily energy MJ *EDaily.m*** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| JAN | 31 | STE-3-JAN | -7E-06 | 0.000278 | -0.00285 | 0.034901 | 0.026773 | 89.7 | 2.89 |
| FEB | 28 | STE-3-FEB | 1.56E-06 | -7.8E-05 | 0.002106 | 0.018935 | 0.032885 | 110.2 | 3.94 |
| MAR | 31 | STE-3-MAR | -1.1E-05 | 0.000553 | -0.00783 | 0.086503 | 0.052781 | 176.9 | 5.71 |
| APR | 30 | STE-3-APR | 2.93E-06 | -0.00024 | 0.006759 | 0.023464 | 0.067403 | 225.9 | 7.53 |
| MAY | 31 | STE-3-MAY | 1.83E-05 | -0.00075 | 0.005705 | 0.184674 | 0.187803 | 629.5 | 20.31 |
| JUN | 30 | STE-3-JUN | -2.2E-06 | 0.000308 | -0.01234 | 0.287633 | 0.198519 | 665.4 | 22.18 |
| JUL | 31 | STE-3-JUL | 2.01E-05 | -0.00085 | 0.008645 | 0.143214 | 0.166113 | 556.8 | 17.96 |
| AUG | 31 | STE-3-AUG | 4.4E-06 | -0.00035 | 0.00774 | 0.064724 | 0.109486 | 367.0 | 11.84 |
| SEP | 30 | STE-3-SEP | -1.2E-05 | 0.000414 | -0.00102 | 0.04258 | 0.058472 | 196.0 | 6.53 |
| OCT | 31 | STE-3-OCT | -5.1E-06 | 0.000251 | -0.00206 | 0.05056 | 0.048816 | 163.6 | 5.28 |
| NOV | 30 | STE-3-NOV | 1.41E-06 | -3.9E-05 | 0.001452 | 0.023815 | 0.03497 | 117.2 | 3.91 |
| DEC | 31 | STE-3-DEC | -1.1E-05 | 0.000514 | -0.0063 | 0.038998 | 0.015979 | 53.6 | 1.73 |
| Year | 365 |  |  |  |  |  | 1.00000 | 3352.00 |  |

Table notes: It is recommended that the parameters for a, b, c and d be extracted from the source spreadsheet provided as these usually include many more significant figures that are shown in the tables in this report.

For a solar thermal electric system on continuous energisation, the hourly energy use is assumed to be in line with the hourly hot water demand as set out in Table 34.

**Example 2**: A second alternative installation of a solar thermal gas water heater is examined at the same site. The system earns 38 STCs in Zone 3. The relevant code for this water heater is therefore STG-3-38. From Appendix B, the relevant parameters for Equation 21 are obtained from the lookup table as follows:

|  |  |  |  |
| --- | --- | --- | --- |
| a | b | c | d |
| 0.233107 | 13.17273 | 131.502 | 491.7095 |

This is a valid selection as the STCs earned is not restricted for *NOcc* of less than 4 people (see Table 26).

The annual purchased energy (energy input) can then be determined from Equation 21 as follows:



*EAnnual-input* = 2989.25 MJ/year of electricity and gas.

The monthly breakdown of energy is determined from Equation 22 using coefficients from Appendix C – Water Heater Performance Coefficients for monthly share of energy by climate zone for Whole of Home rating as shown in the following tables. Note that gas and electricity are separately determined.

Gas share

| **Month** | **Daysm** | **Month Code Gas** | **a-month** | **b-month** | **c-month** | **d-month** | **Monthly share *Fm.z*** | **Monthly energy MJ** | **Daily energy MJ *EDaily.m*** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| JAN | 31 | STG-3-JAN | -8E-06 | 0.0004 | -0.00575 | 0.051326 | 0.026061 | 77.9 | 2.51 |
| FEB | 28 | STG-3-FEB | -7.3E-06 | 0.000321 | -0.00337 | 0.04218 | 0.032632 | 97.5 | 3.48 |
| MAR | 31 | STG-3-MAR | -7.2E-06 | 0.000277 | -0.00181 | 0.049192 | 0.050308 | 150.4 | 4.85 |
| APR | 30 | STG-3-APR | -1.8E-06 | -3.9E-05 | 0.003465 | 0.046153 | 0.073318 | 219.2 | 7.31 |
| MAY | 31 | STG-3-MAY | 3.09E-05 | -0.00141 | 0.018412 | 0.078389 | 0.152409 | 455.6 | 14.70 |
| JUN | 30 | STG-3-JUN | 3.45E-05 | -0.00152 | 0.018599 | 0.094321 | 0.163372 | 488.4 | 16.28 |
| JUL | 31 | STG-3-JUL | 2.39E-05 | -0.0011 | 0.014615 | 0.081664 | 0.141675 | 423.5 | 13.66 |
| AUG | 31 | STG-3-AUG | 1.34E-05 | -0.00069 | 0.011043 | 0.055385 | 0.109328 | 326.8 | 10.54 |
| SEP | 30 | STG-3-SEP | -5.6E-06 | 0.000128 | 0.001777 | 0.046305 | 0.069 | 206.3 | 6.88 |
| OCT | 31 | STG-3-OCT | -1.2E-05 | 0.000517 | -0.00461 | 0.05281 | 0.044452 | 132.9 | 4.29 |
| NOV | 30 | STG-3-NOV | -1.3E-05 | 0.000577 | -0.00628 | 0.0508 | 0.031732 | 94.9 | 3.16 |
| DEC | 31 | STG-3-DEC | -1.1E-05 | 0.000546 | -0.00757 | 0.050007 | 0.018326 | 54.8 | 1.77 |
| Year | 365 |  |  |  |  |  | 0.91261 | 2728.03 |  |

Electricity share

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Month** | **Daysm** | **Month Code Electricity** | **a-month** | **b-month** | **c-month** | **d-month** | **Monthly share *Fm.z*** | **Monthly energy MJ** | **Daily energy MJ *EDaily.m*** |
| JAN | 31 | STX-3-JAN | -2.8E-06 | 0.00015 | -0.00287 | 0.02265 | 0.006811 | 20.4 | 0.66 |
| FEB | 28 | STX-3-FEB | -2.2E-06 | 0.000124 | -0.00251 | 0.020922 | 0.006648 | 19.9 | 0.71 |
| MAR | 31 | STX-3-MAR | -2.4E-06 | 0.000136 | -0.00279 | 0.023408 | 0.007414 | 22.2 | 0.71 |
| APR | 30 | STX-3-APR | -2.5E-06 | 0.000147 | -0.00304 | 0.025096 | 0.007574 | 22.6 | 0.75 |
| MAY | 31 | STX-3-MAY | -3.7E-06 | 0.000195 | -0.00358 | 0.025975 | 0.006663 | 19.9 | 0.64 |
| JUN | 30 | STX-3-JUN | -3.8E-06 | 0.0002 | -0.00371 | 0.027118 | 0.006979 | 20.9 | 0.70 |
| JUL | 31 | STX-3-JUL | -4.8E-06 | 0.00025 | -0.00451 | 0.031767 | 0.007675 | 22.9 | 0.74 |
| AUG | 31 | STX-3-AUG | -3.8E-06 | 0.000205 | -0.00391 | 0.029389 | 0.007878 | 23.5 | 0.76 |
| SEP | 30 | STX-3-SEP | -3E-06 | 0.000168 | -0.00334 | 0.026497 | 0.007666 | 22.9 | 0.76 |
| OCT | 31 | STX-3-OCT | -2.6E-06 | 0.000143 | -0.00283 | 0.023366 | 0.007448 | 22.3 | 0.72 |
| NOV | 30 | STX-3-NOV | -2.3E-06 | 0.000128 | -0.00263 | 0.022626 | 0.007501 | 22.4 | 0.75 |
| DEC | 31 | STX-3-DEC | -2.8E-06 | 0.000146 | -0.0028 | 0.022656 | 0.007129 | 21.3 | 0.69 |
| Year | 365 |  |  |  |  |  | 0.08739 | 261.22 |  |

Note that the sum of all monthly shares for gas (0.91261) PLUS the sum of all monthly shares for electricity (0.08739) add to 1.0000. Note also that the gas energy (2728.03) PLUS the electricity energy (261.22 MJ) add to give total energy input (2989.25 MJ).

For a solar thermal gas system on continuous energisation, the hourly energy gas use is assumed to be in line with the hourly hot water demand as set out in Table 34. The electrical auxiliary energy consumption by hour is as set out in the last column of Table 34.

**Example 3**: A third example is examined – this is a 6 star instantaneous gas water heater at the same site. The relevant code for this water heater is therefore GIN-3-60. From Appendix B, the relevant parameters for Equation 21 are obtained from the lookup table as follows:

| **a** | **b** | **c** | **d** |
| --- | --- | --- | --- |
| 0.209420838 | -8.2968348 | 1432.318768 | 0 |

The annual purchased energy (energy input) can then be determined from Equation 21 as follows:



*EAnnual-input* = 12611.26 MJ/year of gas.

The relevant code for the auxiliary electrical energy for this water heater is therefore GIN-3-99. From Appendix B, the relevant parameters for Equation 21 are obtained from the lookup table as follows:

| **a** | **b** | **c** | **d** |
| --- | --- | --- | --- |
| 0.000855679 | -0.0339003 | 4.686018207 | 100.9152 |

The annual purchased energy (energy input) can then be determined from Equation 21 by substituting the new coefficients, which gives *EAnnual-input* = 141.74 MJ/year of electricity.

The monthly breakdown of energy is determined from Equation 22 using coefficients from Appendix C – Water Heater Performance Coefficients for monthly share of energy by climate zone for Whole of Home rating as shown in the following tables. Note that gas and electricity are assumed to be the same monthly breakdown for instantaneous gas, which is in line with the hot water energy breakdown.

Gas energy

| **Month** | **Daysm** | **Month Code Gas** | **a-month** | **b-month** | **c-month** | **d-month** | **Monthly share *Fm.z*** | **Monthly energy MJ** | **Daily energy MJ *EDaily.m*** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| JAN | 31 | GIN-3-JAN | 0 | 0 | 0 | 0.065728 | 0.065728 | 828.9 | 26.74 |
| FEB | 28 | GIN-3-FEB | 0 | 0 | 0 | 0.067848 | 0.067848 | 855.6 | 30.56 |
| MAR | 31 | GIN-3-MAR | 0 | 0 | 0 | 0.079812 | 0.079812 | 1006.5 | 32.47 |
| APR | 30 | GIN-3-APR | 0 | 0 | 0 | 0.081781 | 0.081781 | 1031.4 | 34.38 |
| MAY | 31 | GIN-3-MAY | 0 | 0 | 0 | 0.089202 | 0.089202 | 1124.9 | 36.29 |
| JUN | 30 | GIN-3-JUN | 0 | 0 | 0 | 0.090868 | 0.090868 | 1146.0 | 38.20 |
| JUL | 31 | GIN-3-JUL | 0 | 0 | 0 | 0.093897 | 0.093897 | 1184.2 | 38.20 |
| AUG | 31 | GIN-3-AUG | 0 | 0 | 0 | 0.093897 | 0.093897 | 1184.2 | 38.20 |
| SEP | 30 | GIN-3-SEP | 0 | 0 | 0 | 0.090868 | 0.090868 | 1146.0 | 38.20 |
| OCT | 31 | GIN-3-OCT | 0 | 0 | 0 | 0.089202 | 0.089202 | 1124.9 | 36.29 |
| NOV | 30 | GIN-3-NOV | 0 | 0 | 0 | 0.081781 | 0.081781 | 1031.4 | 34.38 |
| DEC | 31 | GIN-3-DEC | 0 | 0 | 0 | 0.075117 | 0.075117 | 947.3 | 30.56 |
| Year | 365 |  |  |  |  |  | 1.00000 | 12611.26 |  |

Electrical energy

| **Month** | **Daysm** | **Month Code Electricity** | **a-month** | **b-month** | **c-month** | **d-month** | **Monthly share *Fm.z*** | **Monthly energy MJ** | **Daily energy MJ *EDaily.m*** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| JAN | 31 | GIN-3-JAN | 0 | 0 | 0 | 0.065728 | 0.065728 | 9.3 | 0.30 |
| FEB | 28 | GIN-3-FEB | 0 | 0 | 0 | 0.067848 | 0.067848 | 9.6 | 0.34 |
| MAR | 31 | GIN-3-MAR | 0 | 0 | 0 | 0.079812 | 0.079812 | 11.3 | 0.36 |
| APR | 30 | GIN-3-APR | 0 | 0 | 0 | 0.081781 | 0.081781 | 11.6 | 0.39 |
| MAY | 31 | GIN-3-MAY | 0 | 0 | 0 | 0.089202 | 0.089202 | 12.6 | 0.41 |
| JUN | 30 | GIN-3-JUN | 0 | 0 | 0 | 0.090868 | 0.090868 | 12.9 | 0.43 |
| JUL | 31 | GIN-3-JUL | 0 | 0 | 0 | 0.093897 | 0.093897 | 13.3 | 0.43 |
| AUG | 31 | GIN-3-AUG | 0 | 0 | 0 | 0.093897 | 0.093897 | 13.3 | 0.43 |
| SEP | 30 | GIN-3-SEP | 0 | 0 | 0 | 0.090868 | 0.090868 | 12.9 | 0.43 |
| OCT | 31 | GIN-3-OCT | 0 | 0 | 0 | 0.089202 | 0.089202 | 12.6 | 0.41 |
| NOV | 30 | GIN-3-NOV | 0 | 0 | 0 | 0.081781 | 0.081781 | 11.6 | 0.39 |
| DEC | 31 | GIN-3-DEC | 0 | 0 | 0 | 0.075117 | 0.075117 | 10.6 | 0.34 |
| Year | 365 |  |  |  |  |  | 1.00000 | 141.74 |  |

For an instantaneous gas system, the hourly energy gas use is assumed to be in line with the hourly hot water demand as set out in Table 34. The electrical auxiliary energy consumption by hour is dependent on the hot water load, so this is defined as the four Components in Equation 25 to Equation 28. The four Components and the relevant coefficients from Appendix D – Water Heater Performance Coefficients for hourly share of energy by climate zone for Whole of Home rating are set out below:

| **Component** | **Code** | **a-x** | **b-x** | **c-x** | **d-x** | **Share at HW load** |
| --- | --- | --- | --- | --- | --- | --- |
| A | GIN-A | -8.50148E-06 | 0.000376 | -0.00582 | 0.041667 | 0.013356942 |
| B | GIN-B | 1.19021E-05 | -0.00053 | 0.00815 | 0.041667 | 0.081300281 |
| C | GIN-C | 1.7003E-05 | -0.00075 | 0.011642 | 0.041667 | 0.098286116 |
| D | GIN-D | 2.21039E-05 | -0.00098 | 0.015135 | 0.041667 | 0.11527195 |

As a check, confirm that 16×A + 2×B + 4×C + 2×D = 1.0000 (Equation 29). Using this data, the hourly breakdown for electrical energy for an instantaneous gas water heater in January (0.30 MJ/day) is:

| **Nominal Hour** | **Component** | **Fhourly** | **Ehourly** |
| --- | --- | --- | --- |
| 1 | Component A | 0.013357 | 0.004014 |
| 2 | Component A | 0.013357 | 0.004014 |
| 3 | Component A | 0.013357 | 0.004014 |
| 4 | Component A | 0.013357 | 0.004014 |
| 5 | Component A | 0.013357 | 0.004014 |
| 6 | Component A | 0.013357 | 0.004014 |
| 7 | Component A | 0.013357 | 0.004014 |
| 8 | Component D | 0.115272 | 0.034641 |
| 9 | Component D | 0.115272 | 0.034641 |
| 10 | Component A | 0.013357 | 0.004014 |
| 11 | Component A | 0.013357 | 0.004014 |
| 12 | Component B | 0.081300 | 0.024432 |
| 13 | Component A | 0.013357 | 0.004014 |
| 14 | Component B | 0.081300 | 0.024432 |
| 15 | Component A | 0.013357 | 0.004014 |
| 16 | Component C | 0.098286 | 0.029537 |
| 17 | Component C | 0.098286 | 0.029537 |
| 18 | Component C | 0.098286 | 0.029537 |
| 19 | Component C | 0.098286 | 0.029537 |
| 20 | Component A | 0.013357 | 0.004014 |
| 21 | Component A | 0.013357 | 0.004014 |
| 22 | Component A | 0.013357 | 0.004014 |
| 23 | Component A | 0.013357 | 0.004014 |
| 24 | Component A | 0.013357 | 0.004014 |
|  | Total day | 1.000000 | 0.300518 |

**Example 4**: A fourth example is examined at the same site – this is a small electric storage water heater. The relevant code for this water heater is therefore ESS-3-00. From Appendix B, the relevant parameters for Equation 21 are obtained from the lookup table as follows:

|  |  |  |  |
| --- | --- | --- | --- |
| **a** | **b** | **c** | **d** |
| 0 | 0 | 1020.408163 | 1681.753 |

The annual purchased energy (energy input) can then be determined from Equation 21 as follows:



*EAnnual-input* = 11048.91 MJ/year of electricity.

The monthly breakdown of energy is determined from Equation 22 using coefficients from Appendix C – Water Heater Performance Coefficients for monthly share of energy by climate zone for Whole of Home rating as shown in the following table.

| **Month** | **Daysm** | **Month Code** | **a-month** | **b-month** | **c-month** | **d-month** | **Monthly share *Fm.z*** | **Monthly energy MJ** | **Daily energy MJ *EDaily.m*** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| JAN | 31 | ESS-3-JAN | 0 | 0 | 0 | 0.067444 | 0.067444 | 745.2 | 24.04 |
| FEB | 28 | ESS-3-FEB | 0 | 0 | 0 | 0.068012 | 0.068012 | 751.5 | 26.84 |
| MAR | 31 | ESS-3-MAR | 0 | 0 | 0 | 0.079017 | 0.079017 | 873.0 | 28.16 |
| APR | 30 | ESS-3-APR | 0 | 0 | 0 | 0.081422 | 0.081422 | 899.6 | 29.99 |
| MAY | 31 | ESS-3-MAY | 0 | 0 | 0 | 0.089667 | 0.089667 | 990.7 | 31.96 |
| JUN | 30 | ESS-3-JUN | 0 | 0 | 0 | 0.091182 | 0.091182 | 1007.5 | 33.58 |
| JUL | 31 | ESS-3-JUL | 0 | 0 | 0 | 0.094737 | 0.094737 | 1046.7 | 33.77 |
| AUG | 31 | ESS-3-AUG | 0 | 0 | 0 | 0.093803 | 0.093803 | 1036.4 | 33.43 |
| SEP | 30 | ESS-3-SEP | 0 | 0 | 0 | 0.089597 | 0.089597 | 989.9 | 33.00 |
| OCT | 31 | ESS-3-OCT | 0 | 0 | 0 | 0.088773 | 0.088773 | 980.8 | 31.64 |
| NOV | 30 | ESS-3-NOV | 0 | 0 | 0 | 0.08105 | 0.08105 | 895.5 | 29.85 |
| DEC | 31 | ESS-3-DEC | 0 | 0 | 0 | 0.075297 | 0.075297 | 832.0 | 26.84 |
| Year | 365 |  |  |  |  |  | 1.00000 | 11048.91 |  |

For a small electric storage water heater with continuous energisation, the hourly energy use dependent on the hot water load, so this is defined as the four Components in Equation 25 to Equation 28. The four Components and the relevant coefficients from Appendix D – Water Heater Performance Coefficients for hourly share of energy by climate zone for Whole of Home rating are set out below:

| **Component** | **Code** | **a-x** | **b-x** | **c-x** | **d-x** | **Share at HW load** |
| --- | --- | --- | --- | --- | --- | --- |
| A | ESS-A | -1.58437E-05 | 0.000654 | -0.00868 | 0.041667 | 0.004860844 |
| B | ESS-B | 2.21812E-05 | -0.00092 | 0.012147 | 0.041667 | 0.093194818 |
| C | ESS-C | 3.16875E-05 | -0.00131 | 0.017352 | 0.041667 | 0.115278311 |
| D | ESS-D | 4.11937E-05 | -0.0017 | 0.022558 | 0.041667 | 0.137361805 |
|  |  |  |  |  | Check | 1.000000 |

As a check, it is confirmed that 16×A + 2×B + 4×C + 2×D = 1.0000 (Equation 29).

Using this data, the hourly breakdown for electrical energy for a small electric storage water heater in July (33.77 MJ/day) is as follows:

| **Nominal Hour** | **Component** | **Fhourly** | **Ehourly** |
| --- | --- | --- | --- |
| 1 | Component A | 0.004861 | 0.16413 |
| 2 | Component A | 0.004861 | 0.16413 |
| 3 | Component A | 0.004861 | 0.16413 |
| 4 | Component A | 0.004861 | 0.16413 |
| 5 | Component A | 0.004861 | 0.16413 |
| 6 | Component A | 0.004861 | 0.16413 |
| 7 | Component A | 0.004861 | 0.16413 |
| 8 | Component D | 0.137362 | 4.638121 |
| 9 | Component D | 0.137362 | 4.638121 |
| 10 | Component A | 0.004861 | 0.16413 |
| 11 | Component A | 0.004861 | 0.16413 |
| 12 | Component B | 0.093195 | 3.146791 |
| 13 | Component A | 0.004861 | 0.16413 |
| 14 | Component B | 0.093195 | 3.146791 |
| 15 | Component A | 0.004861 | 0.16413 |
| 16 | Component C | 0.115278 | 3.892456 |
| 17 | Component C | 0.115278 | 3.892456 |
| 18 | Component C | 0.115278 | 3.892456 |
| 19 | Component C | 0.115278 | 3.892456 |
| 20 | Component A | 0.004861 | 0.16413 |
| 21 | Component A | 0.004861 | 0.16413 |
| 22 | Component A | 0.004861 | 0.16413 |
| 23 | Component A | 0.004861 | 0.16413 |
| 24 | Component A | 0.004861 | 0.16413 |
|  | Total | 1.000000 | 33.77 |

### PV Solar Diverters

#### Introduction and background

Rheem Australia have prepared a model for PV solar diverter systems that correlates well with a detailed TRNSYS model of a PV solar diverter for a water heater which is based on the modelling requirements of AS/NZS4234:2020.

This detailed specification for the NatHERS Whole of Home National Calculation Method will allow the reference tool and other providers to prepare a compatible simplified software model that will generate reasonably accurate results for simple PV solar diverters. This documentation has relied heavily on the Rheem documentation and their input to the process is gratefully acknowledged.

Some products are available that divert excess on-site PV generation into a hot water storage device, such as an electric storage water heater, in preference to exporting electricity to the grid. In general terms, this is financially attractive where feed-in tariffs are low or where specific sites are unable to export to the grid (or where export capacity is limited). In this document, this type of product is called a PV solar diverter.

This section sets out the design and operation of a PV solar diverter module in the NatHERS Whole of Home Calculation Methodologies. The operation of this module is conceptually based on a battery storage module but with altered settings to reflect the overall operation of a PV solar diverter moving energy into an electric storage water heater as well as the associated hot water drawoff and heat losses. Thermodynamic principles were used to mimic the behaviour of hot water tanks during use.

An electric storage water heater is used to store energy for later use. The amount of energy that can be stored depends on the volume of heated water and the temperature of the stored hot water (usually dictated by the thermostat setting). Usually the hot water energy stored in a water heater is calculated relative to the incoming cold water temperature, which is defined in the standard. The cold water temperature (and hence the heat storage volume) changes each month. PV solar diverters are likely to only work well with larger storage volumes (say 250 litres or more).

This module design only covers so called “dumb PV solar diverters” that assess the situation on an hour by hour basis. These systems cannot anticipate future changes in PV generation or whole of home load and cannot respond to external calls from the grid to increase or decrease load. Nor can it modify current PV diversion decisions based on future anticipated spot electricity prices. However, pre-set energisation windows can be defined.

With any simplified model, there are some shortcomings, but in general terms these do not appear to generate significant inaccuracies. However, technical limitations are noted in red text where applicable in the documentation below.

#### Overview of systems covered

This model specification covers three types of PC solar diverter systems. These are described in general terms below.

**Type 1: Simple time clock**

With a hot water storage system, the energisation profile can be controlled so that input energy and hot water demand (output) are not correlated in time. This is typically done by operating larger electric storage water heaters on off peak tariffs, which are often controlled by electricity utilities (using timeclocks or ripple control switching). A Type 1 PV solar diverter has the element energisation period during the day (nominally 10am to 3pm) to maximise the chance that the tank input energy will occur during periods when there is excess PV generation. For this type of product the element power in NOT modulated (it is ON or OFF at rated power only) and there is no monitoring of when there may be excess PV available on site. The energisation profile is selected by the user and the water heater only recharges during those hours, irrespective of whether there is excess local PV generation. This type of approach would be very favourable for the new SA Power Networks “solar sponge” tariff, which has the lowest energy rate during hours 10am to 3pm each day. The SA solar sponge tariff does not require any local PV generation so would not strictly be classified as a PV solar diverter.

**Type 2: Modulated input into an existing tank – add on product**

This type of system has a retrofitted external control added to an existing standard electric storage water heater. The controller is able to monitor the house load and local PV generation and diverts any excess local PV generation to the water heater where possible. The controller is able to modulate the power input into the water heater to match the excess power on site, within the temperature constraints in the tank and the power rating of the boost element. The control system allows the system to be topped up overnight (on off peak grid energy) to a lower thermostat set point and then during the day it diverts as much excess PV energy to the water heater as it can with a higher temperature set point. This system assumes that there is only a single element, but it can be operated at different thermostat settings, depending on whether the boost power is excess PV or grid. An example of this type of product is Catchpower – see <https://www.catchpower.com.au/>

**Type 3: Bespoke PV solar diverter - dedicated product**

This is a specially designed PV solar diverter water heater. The controller is able to monitor the house load and local PV generation and diverts excess solar energy to the water heater. The water heater has two elements (one lower and one upper), but they are electrically interlocked so that only one can operate at any one time. The control logic heats the upper tank segment to a defined primary temperature and then heats the lower tank segment to the same defined primary temperature using excess PV energy. Where there is additional excess PV energy, the upper tank segment is heated to a defined higher (super) temperature. Where there is still additional excess PV energy available, the lower tank segment is heated to the same defined super temperature. Grid energy is only ever used to heat the upper tank segment to a minimum storage temperature (47°C) to ensure the adequate hot water is always available to the user. An example of this product is the Solahart Powerstore – see <https://www.solahart.com.au/products/battery-storage/solahart-powerstore/>

Limitation Note: As the tank for a Type 3 system can operate for extended periods with a water temperature of less than 60°C, these systems have a sanitisation cycle that heats the whole tank to at least 60°C after a defined period where the temperature is below 60°C in order to control Legionella growth (refer to AS3498). This sanitisation cycle can be infrequent and usually only consumes a small amount energy, so it is ignored in this modelling approach.

#### Modelling approach

For all three system types, the tank is split into two segments – an upper and a lower segment. This is illustrated in Figure 2. The two segments are used to represent the stratification of a storage tank where hot water is drawn off during use, but that top up energy is not necessarily applied until a later time.

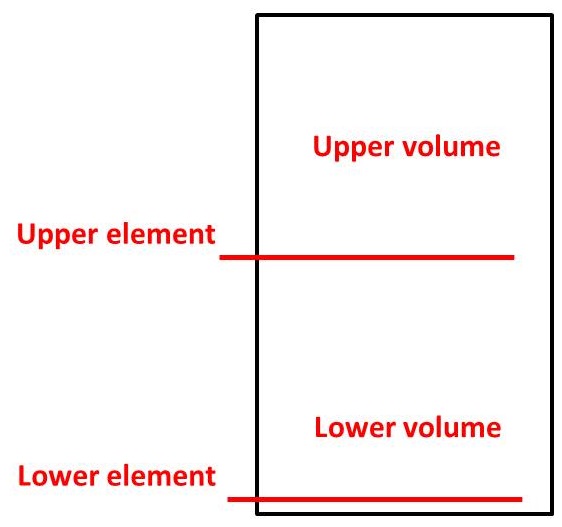


Figure 2: Key elements of a storage water heater in a PV solar diverter model

For all three system types, it is assumed that hot water is drawn from the lower segment (lower volume) until that segment is empty (when the tank temperature = the cold water temperature). Then hot water is drawn from the upper segment (upper volume) until it is empty. It is assumed that hot water demand in any particular hour occurs at the start of the hour. This mimics the drawoff in a conventional storage water heater as hot water is removed from the top of the tank and the lower part of the tank gradually fills with cold inlet water. Ideally stratification is maintained (with minimal mixing).

Limitation Note: Heat loss for all three systems is calculated every hour and is based on the tank temperature at the start of the hour. This is a simplification as the tank temperature varies with hot water drawoff and input energy over the hour, but the error will be relative small over a year. An average of the start and end temperature for the hour would be more accurate, but this will give the same result as the start temperature (as the temperature at the start of each hour is equal to the temperature at the end of the previous hour).

It is assumed that hot water energy and heat loss are drawn from the tank at the start of the hour. Input energy is then added where required within the defined control parameters. Input power to the tank is limited by the power rating of heating element(s). For Type 2 and Type 3 systems, this approach will be quite accurate as the element can modulate to follow the available PV excess energy on a minute by minute basis. For a Type 1 system, the simplified hourly model will tend to overestimate the PV utilisation, as the model assumes that all PV excess in an hour where the element is energised will go to the water heater, whereas in practice, only the PV excess during the element ON time will be diverted to the water heater (which may be 10 minutes in the hour, for example). As data is only available at an hourly level, there is not information on the variation in excess PV energy within the hour or how that aligns with the element ON time.

Limitation Note: For a Type 1 system (without power modulation), a PV utilisation correction factor is calculated based on the total element on time within each hour, assuming that excess PV energy is spread evenly across the hour. This may be refined once more detailed modelling data is reviewed.

#### Initial PV solar diverter modelling calculations

This section sets out the calculations that are required before modelling can be undertaken.

*Volume(L)* = 315 litres (this is a default value but can be changed) – this is the rated hot water delivery of the tank as per AS/NZS4692.1.

*Volume(m3)* = 

*Vlwr* = lower tank volume in litres

*Vupp* = upper tank volume in litres

Note: *Vlwr* + *Vupp* = *Volume(L)*

Equation 30: Calculation of upper tank volume fraction

*Fractionupp* = 

Default values for *Fractionupp* are as follows:

| **System type** | **Type 1** | **Type 2** | **Type 3** |
| --- | --- | --- | --- |
| *Fractionupp* | 0.75 | 0.75 | 0.50 |

Calculation of the tank dimensions and internal surface area is as follows:

For modelling purposes, it is assumed that the aspect ratio (*AR*) (height to diameter) is 2.6. The tank diameter is calculated as follows:

Equation 31: Calculation of tank diameter

*Dtank* =  where diameter is in metres

The tank height is calculated as follows:

Equation 32: Calculation of tank height

*Htank* = *AR* × *Dtank where* height is in metres

Internal surface area of the lower segment is as follows:

Equation 33: Calculation of inner surface are of lower tank segment

*Alwr* = 

Internal surface area of the upper segment (*Volume2*) is as follows:

Equation 34: Calculation of inner surface are of upper tank segment

*Aupp* = 

The nominal tank heat loss in accordance with AS/NZS4692.2 Table A1 is calculated from a 4th order polynomial that is fitted to the data as follows (see sample spreadsheet for a more accurate values for each coefficient):

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Coefficient | B4 | B3 | B2 | B1 | B0 | R2 |
| Value | -9.7853 | 22.0738 | -19.7292 | 10.43019 | 0.97237 | 0.999452 |

Equation 35: Calculation of tank heat loss

*Heatloss* = B4×*Volume(m3)*4 + B3×*Volume(m3)*3 + B2×*Volume(m3)*2 + B1×*Volume(m3)* + B0

Where *Heatloss* is in kWh/day and is equal to the MEPS level for electric storage water heaters.

Note: These heat loss values assume only a single element and a single hot side temperature/pressure relief valve, so the values in Table A1 have been increased by 0.2.

The calculated heat loss for a 315 litre tank using this equation is 2.89384789 kWh/day.

The overall tank thermal transmittance U is then calculated for this heat loss:

*UA* = 

Where UA is in MJ/hour/K

3.6 is a factor to convert kWh to MJ

24 is hours in a day

55 is the nominal temperature difference in K for heat loss measurements under AS/NZS4692.1.

Equation 36: Calculation of tank thermal transmittance

*U* = 

Where *Alwr* and *Aupp* are in m2 and U is in MJ/hour/K/m2

The heat storage volume in each segment of the tank is calculated as follows:

Equation 37: Heat storage capacity of the upper tank volume for specified temperatures

*Qupp* = 

Where:

*Qupp* is the heat storage capacity of the upper segment in MJ

*Vupp* is the upper storage volume in litres

*Cp* is the specific heat of water at constant pressure - average value of 4.185 at 15°C and 60°C in kJ/kg/K

*Thot* is the stored hot water heater in °C

*Tcold* is the cold water inlet temperature in °C

1000 is a factor to convert kJ to MJ.

The same equation is used to calculate *Qlwr* by substituting *Vupp* with *Vlwr*.

Equation 38: Heat storage capacity of the lower tank volume for specified temperatures

*Qlwr* = 

These equations are used continuously to calculate the heat storage volume in each part of the tank at different times in each hour. Note that the cold water inlet temperature changes each month. There are a number of hot water temperature conditions in these equations (*Thot*) that are defined for modelling as follows, with default values shown for each system type:

| **Parameter** | **Description** | **Type 1** | **Type 2** | **Type 3** |
| --- | --- | --- | --- | --- |
| *Tgrid* | Cutout temperature using grid power | 70°C | 60°C | 47°C |
| *TPV* | Cutout temperature using diverted PV power | 70°C | 70°C | 75°C |
| *Tprimary* | Intermediate temp using diverted PV power | N/A | N/A | 65°C |

Table notes: Documentation for Type 3 systems refers to a boost temperature of *Tsuper*, but this is assumed to be equal to *TPV* for modelling purposes. Type 1 (external time clock) cannot affect the thermostat temperature.

The initial condition and heat storage of the upper and lower segments is assumed to be equal to *Tgrid* at the start of the first hour of the year.

The temperature of each segment can be calculated at any moment from the heat storage value Q as follows:

Equation 39: Temperature of the upper tank volume for a specified heat capacity

*Tupp* = 

Equation 40: Temperature of the lower tank volume for a specified heat capacity

*Tlwr* = 

Where *Q* is in MJ and volume is in litres.

The power input into the water heater in any time period is limited by the rating of the element. The default values for each type of system are set out below.

| **Parameter** | **Description** | **Type 1** | **Type 2** | **Type 3** |
| --- | --- | --- | --- | --- |
| *Emax-lwr(kW)* | Power rating for lower element | 3.6 kW | 3.6 kW | 3.6 kW |
| *Emax-upp(kW)* | Power rating for upper element | N/A | N/A | 3.6 kW |
| *Emax-lwr* | Power rating for lower element | 12.96 MJ/h | 12.96 MJ/h | 12.96 MJ/h |
| *Emax-upp* | Power rating for upper element | N/A | N/A | 12.96 MJ/h |

Table notes: Element rating in kW × 3.6 = rating in MJ/hour. For Type 3 systems, an interlock prevents the upper and lower element operating simultaneously (i.e. maximum power input for the default case is 3.6 kW).

The power consumption for the controller and the capability for each system is set out below when PV power is being used.

| **Parameter** | **Description** | **Type 1** | **Type 2** | **Type 3** |
| --- | --- | --- | --- | --- |
| *ParasiticPV* | Net heater system controller parasitic load (MJ/hr) | 0 | 0.007 × *Emax-lwr(kW)* | 0.007 × *Emax-lwr(kW)* |
| *Modulation* | Heater load fraction that is modulated | 0 | 1 | 1 |
| *ModEff-PV* | Efficiency of the heater modulating control | 1 | 0.90 | 0.95 |

Table notes: For a default element rating of 3.6 kW, the parasitic load is 0.0252 MJ/hour for Type 2 & 3. For Type 3, there is only a single parasitic load for the 2 elements. Type 1 system is a time clock so there is no parasitic load, modulation or modulation losses. Type 3 modulation efficiency is complex and varies by load using a proprietary system design – the default efficiency of 0.95 when modulating power is an average efficiency for both elements across a range of loads.

The power consumption for the controller and the capability for each system is set out below when GRID power is being used.

| **Parameter** | **Description** | **Type 1** | **Type 2** | **Type 3** |
| --- | --- | --- | --- | --- |
| *ParasiticGrid* | Net heater system controller parasitic load (MJ/hr) | 0 | 0 | 0 |
| *Modulation* | Heater load fraction that is modulated | 0 | 0 | 0 |
| *ModEff-Grid* | Efficiency of the heater modulating control | 1 | 1 | 1 |

Table notes: It is assumed that for grid boosting, that there is no power modulation for all system types and no parasitic losses.

#### Setting up PV solar diverter modelling for the year prior to calculations

The following input parameters need to be mapped for each hour over the year to be modelled. The source of these parameters are noted. In terms of hourly notation, hour 1 means the hour ending at 01:00 (i.e. starting at 00:00 and ending at 01:00). Refer to the sample spreadsheet for detailed annotation for each hour of the year.

**Hourly house electricity load**: this should be a realistic profile for the house – in the reference tool, this will be based on the Whole of Home National Calculation engine for the selected dwelling. Sample house loads have been included in the sample spreadsheet to enable validation of data. Units: MJ (in each hour)

**Hourly local PV generation**: this should be hourly PV generation for the house – in the reference tool, this will be based on the Whole of Home National Calculation engine for the selected dwelling and PV system and orientation selected. Sample PV generation profiles have been included in the sample spreadsheet to enable validation of data. Units: MJ (in each hour)

Limitation note: House electricity loads and PV generation will vary minute by minute throughout any particular hour. However, only hourly data is available for these parameters for most models. Type 2 and Type 3 systems can modulate their power input to track the excess PV minute by minute, so in practice there is no need to assume any particular temporal distribution of PV power and house electricity load across the hour when using a 1 hour time step – the average excess PV energy for the hour will be the same as the integrated minute by minute excess PV energy. However, for Type 1 systems, excess PV input into the water heater will only occur when the element happens to be ON in that particular hour (as there is no element modulation and no system to track excess PV energy). A secondary correction that limits excess PV input into the tank to be in proportion to the element ON time in each hour is proposed later in this specification. For this correction, the only reasonable assumption about any power variation within an hour is to assume that the house load and the PV generation are constant across the hour. This assumption is only used to estimate the share of excess PV energy that is used by the water heater for a Type 1 control system.

**Hot water demand**: this should be hourly hot water demand as defined in the Whole of Home National Calculation Methodologies. Hot water demand uses house floor area to determine the number of occupants. A further equation then generates the annual hot water demand. Note that the monthly breakdown for the PV solar diverter model is as per an instantaneous system. The daily breakdown is as per the time of hot water demand. The normal third order polynomial equations are NOT used to estimate hot water energy input as this is being calculated hour by hour using (an approximation of) first principles. For a selected house floor area, the sample spreadsheet generates the monthly and hourly hot water demand. Units: MJ (in each hour)

**Cold water inlet temperature**: This is defined in AS/NZS4234 Table A6 and is included in the sample spreadsheet. The cold water temperature changes once per month, so this affects all heat storage calculations through the year. Units: °C (changes once per month)

**Ambient air temperature**: This is the hourly ambient temperature for each hour of the year. This normally comes from a climate file (dry bulb temperature in °C). For the NatHERS Whole of Home National Calculation Methodology this would be the hourly data from the relevant climate zone being analysed (1 of the 69 possible climates). For the sample spreadsheet, hourly data from the five AS/NZS4234 climate files have been included for validation and checking. Units: °C (in each hour)

Limitation note: Heat loss calculations assume that the water heater is located outside. If located inside, an indoor temperature profile would need to be used. The NatHERS reference tool may be able to generate a suitable profile for the specific building and climate being modelled.

**Grid energisation profile**: This is a flag to indicate whether grid power is available for the hour of the day. Typically the same 24 hour profile is applied all year. Default energisation profiles for each type of system are as follows:

* Type 1: time clock has been set as ON at 10:00 and OFF at 15:00 but this can be adjusted as required. No grid or PV boosting is assumed to occur outside of these hours.
* Type 2: overnight grid boost window of ON at 01:00 and OFF at 05:00 has been selected as the default. No grid boosting is assumed to occur outside of these hours but PV boosting occurs at any hour during the day when there is excess PV energy.
* Type 3: grid is assumed to be available for 24 hours. Grid boosting only occurs when the top segment falls below 47°C. PV boosting occurs at any hour during the day when there is excess PV energy.

The following heat storage volumes (*Qupp* and *Qlwr*) need to be calculated for each hour of the year (noting that these volumes will be constant within each month):

* For a hot water temperature of *TPV* – this is the maximum heat storage capacity of the unit – Q*uppTpv* and *QlwrTpv*
* For a hot water temperature of *Tgrid* – this is the heat storage capacity of the unit when boosted by grid power (for Type 1 this is the same as for *TPV*) – Q*uppTgrid* and *QlwrTgrid*
* For a hot water temperature of *Tprimary* – this is the heat storage capacity of the unit when boosted by PV – it is an intermediate temperature step for Type 3 systems only – Q*uppTprimary* and *QlwrTprimary*

The following table sets out the list of variables used in this specification:

Table 35: List of key variables

| **Variable** | **Description** |
| --- | --- |
| *Volume(L)* | Total tank hot water storage volume (litres) (*Volume(L)* = *Vupp* + *Vlwr*) |
| *Volume(m3)* | Total tank hot water storage volume (cubic metres) |
| *Vupp* | Storage volume of the upper segment (litres) |
| *Vlwr* | Storage volume of the lower segment (litres) |
| *Fractionupp* | Fraction of the upper volume to the total volume (no units) |
| *Aupp* | Inner surface area of the storage tank – upper segment (m2) |
| *Alwr* | Inner surface area of the storage tank – lower segment (m2) |
| *Cp* | Specific heat of water at constant pressure - value of 4.185 at 15°C and 60°C (kJ/kg/K) |
| *U* | Thermal transmittance of the tank (MJ/hour/K/m2) |
| *Tpv* | Control cutout storage maximum temperature for PV boosting (°C) |
| *Tprimary* | Control cutout storage intermediate temperature for PV boosting (°C) (Type 3 only) |
| *Tgrid* | Control cutout storage temperature for grid boosting (°C) |
| *QuppTpv* | Maximum energy stored in the upper segment at temperature *TPV* (MJ) |
| *QuppTprimary* | Maximum energy stored in the upper segment at temperature *Tprimary* (MJ) (Type 3 only) |
| *QuppTgrid* | Maximum energy stored in the upper segment at temperature *Tgrid* (MJ) |
| *QlwrTpv* | Maximum energy stored in the upper segment at temperature *TPV* (MJ) |
| *QlwrTprimary* | Maximum energy stored in the upper segment at temperature *Tprimary* (MJ) (Type 3 only) |
| *QlwrTgrid* | Maximum energy stored in the upper segment at temperature *Tgrid* (MJ) (not Type 3) |
| *Qupp0* | Energy stored in the upper segment at the start of the time period (MJ) |
| *Qupp1* | Energy stored in the upper segment after heat loss and hot water use (MJ) (time step 1) |
| *Qupp4* | Energy stored in the upper segment at the end of the time period (MJ) (= start next period) |
| *Qlwr0* | Energy stored in the lower segment at the start of the time period (MJ) |
| *Qlwr1* | Energy stored in the lower segment after heat loss and hot water use (MJ) (time step 1) |
| *Qlwr4* | Energy stored in the lower segment at the end of the time period (MJ) (= start next period) |
| *Tupp0* | Temperature in the upper segment at the start of the hour (°C) |
| *Tupp1* | Temperature in the upper segment after heat loss and hot water use (°C) |
| *Tupp4* | Temperature in the upper segment at the end of the hour (°C) |
| *Tlwr0* | Temperature in the lower segment at the start of the hour (°C) |
| *Tlwr1* | Temperature in the lower segment after heat loss and hot water use (°C) |
| *Tlwr4* | Temperature in the lower segment at the end of the hour (°C) (= start next hour) |
| *Tamb* | Ambient outdoor temperature for the hour (°C) (from climate file) |
| *Tcold* | Cold water inlet temperature for the month and climate (°C) (from AS/NZS4234) |
| *HWtotal* | Total hot water energy drawn from the water heater in the time period (MJ) (*HWlwr* + *HWupp*) |
| *HWlwr* | Hot water energy drawn from the lower segment in the time period (MJ) |
| *HWupp* | Hot water energy drawn from the upper segment in the time period (MJ) |
| *Qlwr2-PV* | Energy flow from excess PV into the lower segment of the water heater (MJ) (time step 2) |
| *Qupp2-PV* | Energy flow from excess PV into the upper segment of the water heater (MJ) (time step 2) |
| *Qlwr3-PV* | Energy flow from excess PV into the lower segment of the water heater (MJ) (time step 3) |
| *Qupp3-PV* | Energy flow from excess PV into the upper segment of the water heater (MJ) (time step 3) |
| *Qlwr2-grid* | Energy flow from the grid into the lower segment of the water heater (MJ) (time step 2a) |
| *Qlwr3-grid* | Energy flow from the grid into the lower segment of the water heater (MJ) (time step 3a) |
| *Qupp3-grid* | Energy flow from the grid into the upper segment of the water heater (MJ) (time step 3a) |
| *PVusable* | Excess energy available from PV generation in the time period after losses (MJ) |

Table notes: All calculated energy capacity values Q depend on the hot water temperature and the cold water temperature, which changes once per month in AS/NZS4234. Energy stored in each segment is calculated in accordance with Equation 37 and Equation 38. Water temperatures in each segment are calculated in accordance with Equation 39 and Equation 40.

#### Hourly calculations for PV solar diverter modelling

In each hour, a cycle of calculations are undertaken as set out below.

Initial heat storage (*Qupp0* and *Qlwr0*) and temperature (*Tupp0* and *Tlwr0*) of each segment is defined as an initial condition at internal time step 0 within the hour (at the start of hour 1 for the year) or as a value from the end of the previous hour.

First calculate the heat loss of the tank based on the initial temperature in each segment as follows.

*Heatlossupp* = U × *Aupp* × (*Tupp0* – *Tamb*) (IF *Qupp0* = 0, then 0)

*Heatlosslwr* = U × *Alwr* × (*Tlwr0* – *Tamb*) (IF *Qlwr0* = 0, then 0)

Where *Tamb* is the ambient temperature for the hour from the climate file in °C and *Tupp0* and *Tlwr0* and the temperatures of the upper and lower segments at the start of the hour calculated using Equation 39 and Equation 40 respectively.

Note: this condition of Q > 0 ignores any heat losses that can theoretically occur when the cold water temperature is warmer than the air temperature.

Any hot water demand energy is initially subtracted from the lower segment (*Vollwr*) while the storage temperature is above the cold water temperature (i.e. when *Qlwr* > 0). Once the storage temperature of the lower segment reaches the cold water inlet temperature, any additional hot water demand is subtracted from the upper segment.

A discharge signal (flag) is calculated as follows:

*Dischargesignal* = IF(*Tupp0*>*Tcold*,1,0) + IF(*Tlwr0*>*Tcold*,1,0)

This equation generates a discharge signal for the hour with the following possible values:

* Discharge signal = 2 – both upper and lower segments are above *Tcold* so start discharging from the lower segment
* Discharge signal = 1 – the lower segment is empty (equal to or less than *Tcold* so start discharging from the upper segment
* Discharge signal = 0 – both upper and lower segments are empty (no hot water available)

The way the charge and discharge equations are configured means then *Tlwr* should always be less than or equal to *Tupp*.

If *Dischargesignal* = 2, then hot water is initially drawn from the lower segment, but this cannot exceed the heat capacity in the lower segment. If the hot water demand in the hour exceeds the heat capacity in the lower segment, then the balance is drawn from the upper segment. If *Dischargesignal* = 1, then hot water is drawn from the upper segment only, but cannot exceed the heat capacity stored in the upper segment.

*HWlwr* = MIN(*Qlwr0*, *HWtotal*) where *Dischargesignal* = 2 (otherwise 0)

Where *HWlwr* is the energy drawn from the lower segment of the tank and *HWtotal* is the total water demand for the hour in MJ. The MIN function ensures that the hot water drawn from the lower segment does not exceed the remaining heat storage capacity. The hot water drawn from the upper segment is then calculated.

*HWupp* = MIN (*Qupp0*, *HWtotal - HWlwr*)

Where *HWupp* is the energy drawn from the upper segment of the tank and *HWtotal* is the total water demand for the hour in MJ. Where *Dischargesignal* < 2, then *HWlwr* will be 0.

Hot water energy and heat losses are assumed to be taken out at the start of the hour at the end of internal time step 1.

*Qupp1* = *Qupp0 - HWupp* - *Heatlossupp*

*Qlwr1* = *Qlwr0 – HWlwr* – *Heatlosslwr*

Note: Taking hot water and losses out at the start of the hour is a simplification of the thermal interactions that will occur over the hour. But discharging first and then recharging later means that the tank will end up at the relevant thermostat set point at the end of the hour (if there is sufficient boost energy available), which is realistic and easy to check.

Using Equation 39 and Equation 40, calculate the corresponding temperature in each segment *Tupp1* and *Tlwr1* after the hot water energy and heat losses have been subtracted.

The next calculations in the hour are about how available energy (PV and/or grid energy) is put into the upper and lower segments of the tank. There are three signals (flags) that need to be determined in order to allocate energy flows into the tank according to the relevant control logic.

*Chargelower* is a signal indicates that the lower segment is a lower temperature than the upper segment and if this value is 1 (or TRUE) then initially any available charge energy should be added to the lower segment. This signal is only used for Type 1 and Type 2 (ignored for Type 3).

*Chargelower* = IF ( *Tlwr1* < *Tupp1* THEN 1 (TRUE) ELSE 0 (FALSE))

*Gridsignal* is a flag that indicates whether grid power is available for heating the water heating. The conditions for this flag by system type are as follows:

* Type 1: power is made available to the water heater based on a time clock (typically during the middle of the day when excess PV generation is likely to be available). The parameter *Gridsignal* is set to 1 during these periods of energisation (nominally ON at 10am and OFF at 3pm) and is set to 0 at all other times.
* Type 2: the default setting is that power is available to the water heater for grid boosting overnight. The parameter *Gridsignal* is set to 1 during these periods of energisation (nominally ON at 1am and OFF at 5am) and is set to 0 at all other times.
* Type 3: the default setting is that power is available to the water heater for grid boosting on a continuous basis (24 hours a day). The Type 3 system boosts the upper section of the tank to a lower temperature (*Tgrid* = 47°C) whenever the upper section falls below that temperature set point.

*PVsignal* is a flag that indicates whether there is excess power available to divert to the water heater. The conditions for this flag by system type are as follows:

* Type 1: this type of system has no control to monitor the available PV, so *PVsignal* is set to 1 when *Gridsignal* = 1. Any excess PV that happens to be available when the unit charges with grid power will be utilised.
* Type 2 and Type 3: For these types of systems, the controller monitors the house load and the local PV generation and when there is excess PV available for diversion to the water heater (PV generation > internal house load), then this flag is set to 1.

For each hour the *PVavailable* is calculated as the net of total PV generation minus total internal house load (all in MJ). Where total PV generation is less than the total house load, then *PVavailable* is set to 0.

The *PVusable* is calculated after taking into account any system losses:

*PVusable* = MAX (*Emax-lwr* × *ModEff-PV* – *ParasiticPV*, 0)

Limitation Note: This function limits the usable PV to the net energy available after taking into account the modulation efficiency and the parasitic load. However, when there is no excess PV available, it sets *PVusable* to zero, which may not be strictly true in practice as some parasitic load is always likely to always be present. This is a point under discussion.

Charge logic and sequence for each of the three system types is set out below.

**Type 1 and Type 2 charging**

For Type 1 products, *Gridsignal* and *PVsignal* always have the flag set the same. The element operates when *Gridsignal* is equal to 1 and if there happens to be available PV present, then this is consumed (see limitations noted below). The element is only energised during the day.

For Type 2 products, *Gridsignal* flag is set to one only when grid boost is available (nominally limited hours overnight. *PVsignal* is set to 1 when there is excess PV available on site. As the system can modulate power, all available PV can be diverted to the water heater (with temperature constraints).

The overall strategy if *Chargelower* flag is 1, then to charge the lower segment up to the same temperature as the upper segment. If there is additional energy available, then both segments are charged at a rate that is proportional to the total volume of each segment so they both finish at the same temperature (to a maximum temperature of *TPV*)(which is the same as *Tgrid* for Type 1, these are different for Type 2). Charging rate is limited by the power input of the electrical element *Emax-lwr*. The energy input into the lower segment *Qlwr2-PV* from the PV system is minimum of the following three terms where *Chargelower* flag is 1 and *PVsignal* = 1:

Term 1: 

Term 2: *PVusable*

Term 3: *Emax-lwr* × *ModEff-PV* – *ParasiticPV*

The first terms brings the temperature of the lower segment to be equal to the upper segment, the second term is limited by the available PV, the third term sets a limit on the energy input equal to the element rating (after control losses are taken into account).

Limitation Note: For a Type 1 system (without element modulation or tracking of excess PV energy), the assumption that all PV energy in any hour is directed to the water heater is not likely to be very accurate. For example, if the element is ON for 10 min in the hour (for Type 1 this can be only at the element rating as there is no modulation), then only the PV that is present for that 10 min ON period should be counted as being diverted to the water heater. This is partly a limitation of a 1 hour time step as this problem largely disappears say at a 1 min or even a 10 min time step. A correction for Type 1 systems is therefore warranted for systems that cannot modulate. In these initial calculations in this section, all PV energy available in hour is assumed to be diverted to water heater in a method that is consistent for Type 1 and Type 2 with modulation. This PV contribution is then corrected for Type 1 systems (or other systems where there is no modulation) in the last section of this documentation because this correction cannot be easily estimated until all energy added by the end of the time step from PV and grid is calculated. Omitting the correction may overstate the PV energy that is diverter to the water heater for systems without modulation.

The next step is to take any remaining excess PV energy that may be available and to divert this into both segments at a rate that is proportional to their volume (so the temperature increase is the same). *Qlwr3-PV* is the minimum of the following three terms when *PVsignal* = 1:

Term 1: *QlwrTpv* – *Qlwr1* – *Qlwr2-PV*

Term 2: (*PVusable* – *Qlwr2-PV*) × (1 – *Fractionupp*)

Term 3: (*Emax-lwr* × *ModEff-PV* – *ParasiticPV* – *Qlwr2-PV*) × (1 – *Fractionupp*)

*Qupp3-PV* is the minimum of the following three terms:

Term 1: *QuppTpv* – *Qupp1* – *Qlwr2-PV*

Term 2: (*PVusable* – *Qlwr2-PV*) × ( *Fractionupp*)

Term 3: (*Emax-lwr* × *ModEff-PV* – *ParasiticPV* – *Qlwr2-PV*) × (*Fractionupp*)

The first term tops up the segment to its potential capacity, the second term shares any remaining *PVusable* (after allocation of *Qlwr2-PV*) to each segment, the third term sets a limit on the energy input equal to the element rating (after control losses are taken into account).

Note: There is no term *Qupp2-PV* for Type 1 and Type 2 systems (i.e. this parameter is set to 0).

Grid energy allocation follows the same pattern: the bottom segment is topped up to be the same temperature as the top segment, then both segments are allocated energy in proportion to their respective volumes, within the limits of the available energy and storage temperatures.

Where *Gridsignal* and *Chargelower* flags are both 1 then *Qlwr2-grid* is the minimum of the following three terms:

Term 1: 

Term 2: *QlwrTgrid* – *Qlwr1* – *Qlwr2-PV* (if this term if less than zero, then it is set to 0)

Term 3: *Emax-lwr* × *ModEff-Grid* – *ParasiticGrid* – *Qlwr2-PV*

The first terms brings the temperature of the lower segment to be equal to the upper segment (less PV energy into the lower segment), the second term is the available heat storage capacity to a temperature of *Tgrid* (less PV energy into the lower segment), the third term sets a limit on the energy input equal to the element rating (after control losses are taken into account).

Note: For grid boosting, the default assumption is that *ModEff-Grid* is 100% and *ParasiticGrid* is 0 for all three system types.

After the bottom segment is topped up, both segments are charged with the remaining grid capacity for the hour where the *Gridsignal* flag is 1:

*Qlwr3-grid* is the minimum of the following two terms:

Term 1: *QlwrTgrid* – *Qlwr1* – *Qlwr2-PV*  – *Qlwr3-PV*  – *Qupp3-PV*  – *Qlwr2-grid* (if this term if less than zero, then it is set to 0)

Term 2: (*Emax-lwr* × *ModEff-Grid* – *ParasiticGrid* – *Qlwr2-PV*  – *Qlwr3-PV*  – *Qupp3-PV*  – *Qlwr2-grid* ) × (1 – *Fractionupp*)

*Qupp3-grid* is the minimum of the following two terms:

Term 1: *QuppTpv* – *Qupp1* – *Qlwr2-PV*  – *Qlwr3-PV*  – *Qupp3-PV*  – *Qlwr2-grid*

Term 2: (*Emax-lwr* × *ModEff-Grid* – *ParasiticGrid* – *Qlwr2-PV*  – *Qlwr3-PV*  – *Qupp3-PV*  – *Qlwr2-grid* ) × (*Fractionupp*)

The first term tops up the segment to it potential heat storage capacity, the second term shares any remaining electrical element capacity *Emax-lwr* (after allocation of all solar inputs and the lower tank grid boost) to each segment.

Note: There is no term *Qupp2-grid* for Type 1 and Type 2 systems (i.e. this parameter is set to 0).

Notes: Type 1 only charges during the day so is typically a mix of any available PV energy when it happens to charge plus grid top up energy. Type 2 modulates all available PV energy to the water heater during the day (within temperature limits) and tops up from the grid overnight (when there is no PV present).

**Type 3 charging**

The charging approach for Type 3 is completely different to Type 1/Type 2. There are two elements, so in practical terms there is a lot more flexibility of operation and several different set point temperatures. When there is any available excess PV energy, this is all diverted to the water heater. Firstly the top segment is charged to temperature *Tprimary* then to bottom segment is charged to *Tprimary*. Once these segments are both to temperature, the top segment is charged to *TPV* and then the bottom segment is charged to *TPV*. These segments are only charged in this sequence with excess PV energy. The unit can top up with grid energy wherever required. This only occurs where the top segment has a temperature of less than *Tgrid* (nominally 47°C). While the system is assumed to be energised 24 hours a day, grid energy is only used when *Tupp* < *Tgrid* – under this condition the *Gridsignal* flag is set to 1. As this logic and sequence is completely different to Type 1 and Type 2 systems, a different set of algorithms is required.

The energy input into the upper segment *Qupp2-PV* from the PV system to temperature *Tprimary* is minimum of the following three terms where *PVsignal* = 1:

Term 1: *Qupp-Tprimary* – *Qupp1*

Term 2: *PVusable*

Term 3: *Emax-lwr* × *ModEff-PV* – *ParasiticPV*

The first terms brings the upper segment to be equal to the heat capacity to *Tprimary*, the second term is limited by the available PV, the third term sets a limit on the energy input equal to the element rating (after control losses are taken into account).

The energy input into the lower segment *Qlwr2-PV* from the PV system to temperature *Tprimary* is minimum of the following three terms where *PVsignal* = 1:

Term 1: *Qlwr-Tprimary* – *Qlwr1*

Term 2: *PVusable – Qupp2-PV*

Term 3: *Emax-lwr* × *ModEff-PV* – *ParasiticPV*

The first terms brings the lower segment to be equal to the heat capacity to *Tprimary*, the second term is limited by the available PV less energy already put into the lower segment, the third term sets a limit on the energy input equal to the element rating (after control losses are taken into account).

The energy input into the upper segment *Qupp3-PV* from the PV system to temperature *TPV* is minimum of the following three terms where *PVsignal* = 1:

Term 1: *Qupp-Tpv* – *Qupp1 – Qupp2-PV*

Term 2: *PVusable – Qupp2PV – Qlwr2-PV*

Term 3: *Emax-lwr* × *ModEff-PV* – *ParasiticPV*

The first terms brings the upper segment to be equal to the heat capacity to *TPV*, the second term is limited by the available PV (taking into account heating of other segments), the third term sets a limit on the energy input equal to the element rating (after control losses are taken into account).

The energy input into the lower segment *Qlwr3-PV* from the PV system to temperature *TPV* is minimum of the following three terms where *PVsignal* = 1:

Term 1: *Qlwr-Tpv* – *Qlwr1 – Qlwr2-PV*

Term 2: *PVusable – Qupp2-PV – Qlwr2-PV – Qupp3-PV*

Term 3: *Emax-lwr* × *ModEff-PV* – *ParasiticPV*

The first terms brings the lower segment to be equal to the heat capacity to *TPV*, the second term is limited by the available PV (taking into account heating of other segments), the third term sets a limit on the energy input equal to the element rating (after control losses are taken into account).

For grid boosting for Type 3 systems, the flag *Gridsignal* = 1 when the *Tupp1* is less than *Tgrid* (nominally 47°C). Grid boosting never flows into the lower segment for Type 3.

*Qupp3-grid* is the minimum of the following two terms:

Term 1: *QuppTgrid* – *Qupp1* – *Qupp2-PV* – *Qlwr2-PV*  – *Qupp3-PV*  – *Qlwr3-PV*  (if this term is <0 THEN 0)

Term 2: (*Emax-upp* × *ModEff-Grid* – *ParasiticGrid* – *Qupp2-PV* – *Qlwr2-PV*  – *Qupp3-PV*  – *Qlwr3-PV* )

The first term tops up the segment to the heat storage capacity at *Tgrid*, the second term shares any remaining electrical element capacity *Emax-upp* (after allocation of all solar inputs). For Type 3 systems the terms *Qlwr2-grid* and *Qlwr3-grid* are set to zero.

Note: For grid boosting, the default assumption is that *ModEff-Grid* is 100% and *ParasiticGrid* is 0 for all three system types. The term *Qupp2-grid* is not used for any system type.

Note: As there is an interlock that prevents both elements from operating simultaneously, the total energy input in an hour is limited by the rating of one element. If these upper and lower elements were different power ratings, additional checks not included may need to be undertaken to ensure that energy inputs are balanced.

**Determining the temperature at the end of the hour**

The energy flows are summed to determine the heat storage capacity in each segment at the end of the hour. All terms are included in the following equations – terms that are not relevant should be set to zero.

Heat capacity in the upper segment at the end of the hour is:

*Qupp4* = *Qupp1* + *Qupp2-PV* + *Qupp3-PV* + *Qupp3-grid*

Heat capacity in the lower segment at the end of the hour is:

*Qlwr4* = *Qlwr1* + *Qlwr2-PV* + *Qlwr3-PV* + *Qlwr2-grid* + *Qlwr3-grid*

The temperature of the upper and lower segments are calculated using Equation 39 and Equation 40. As a check, the temperature at the end of the hour should never exceed the defined thermostat set points and the temperature of the lower segment should always be less than or equal to the upper segment.

The heat storage and temperatures at the end of the hour become the new values at the start of the next hour (i.e. *Qlwr4* = *Qlwr0*, *Qupp4* = *Qupp0*).

**PV input correction for Type 1 systems (or other systems that do not modulate power)**

As noted previously, for Type 1 systems the excess PV input into the water heater will only occur when the element happens to be ON in that particular hour (as there is no element modulation and no system to track excess PV energy). The methodology documented above for Type 1 system allocates all excess PV energy into the water heater first and then tops up any remaining heat requirement for the tank with grid energy when grid is available as if the element is able to modulate to track PV excess energy. This will overestimate the amount of excess PV energy flowing into the tank for those hours where the element is not operating for the whole hour.

This section sets out a correction that limits the excess PV input into the tank for Type 1 systems to be in proportion to the element ON time in each hour. This correction should be applied to any system where the element cannot modulate its power to track excess PV energy in real time (i.e. where the variable *Modulation* is not equal to 1). For this correction, the only reasonable assumption about any power variation within an hour (assuming 1 hourly data) is to assume that the house load and the PV generation are constant across a given hour. This assumption is only used to estimate the share of excess PV energy that is used by the water heater for a Type 1 control system.

At the end of each hour, examine that total energy input into the tank from both excess PV and the grid (noting that for Type 1 systems, *Gridsignal* and *PVsignal* always have the flag set the same). Calculate a correction factor, which is the total energy input for the hour divided by the rated capacity of the element, to estimate a percentage run time during the hour (noting that where the energy input is equal to the element rating then the correction factor is 1.0 = the element is running for the whole time period). For example, if the Type 1 water heater had an energy input (PV+Grid) of 8.5 MJ in a particular hour, then the estimated ON time correction for the element would be 8.5/12.96 = 0.6559. This calculation is true if the modulation efficient is 100% and there are no parasitic losses for both PV charging and Grid charging (which are the default settings for a Type 1 system). If there was a conversion efficiency and a parasitic loss applied to both PV and Grid energy, then the element percent on time would then be calculated as:

Equation 41: Calculation of element on time (%) with modulation and parasitic control losses

Element ON % = 

When the modulating efficiency is 100% and the parasitic power is zero, then this simplifies to:

Equation 42: Calculation of element on time (%) without modulation and parasitic control losses

Element ON % = 

Limitation Note: This calculation assumes that an upper element (where present) is the same power rating as the lower element. This equation would need adjustment if the upper and lower element had different power ratings.

The corrected total PV input energy into the water heater in the example above would then be estimated as 0.6559 × excess PV energy in that hour. For this example, if the excess PV energy assumed to flow into the tank was 3.9 MJ, then the corrected PV input into the water heater would be 0.6559 × 3.9 = 2.5579 MJ (3.9 – 2.5579 is a reduction of 1.3421 MJ of PV energy). The reduced energy into the tank supplied by PV is then assumed to be supplied by the grid (in this case 1.3421 MJ of energy is taken off the PV input and 1.3421 MJ of energy is added to the grid energy for Type 1 systems only or where *Modulation* = 0). The 1.3421 MJ of excess PV energy not put into the hot water system is then assumed to be exported to the grid.

## Lighting Module

Energy used for lighting calculates the annual energy consumption, and the assigns proportions of this across each evening for the year.

### Annual Load

The total annual energy consumption for lighting is defined by Equation 43:

Equation 43: Total lighting energy consumption



Where:

*Etot*= total annual energy load in MJ

*PL* = Light Power density (W/m2)

*Havg* = Average hours use per day (hours)

*Atot* = Total floor area (m2)

365 is days per year, 3.5 converts kWh to MJ, 1000 converts Wh to kWh

Note that this equation provides the estimated annual energy – it does not indicate that all the lights are only on for 1.6 hours per day, or that all lights are on at the same time. The variables for Equation 43 are defined in Table 36.

Table 36: Lighting constants

| **Variable** | **Value** |
| --- | --- |
| PL | 5 W/m2 (default, lower value selectable) |
| Havg | 1.6 hours[[11]](#footnote-12) |
| Atot | Total floor area of all conditioned, unconditioned and garage zones. |

The value for PL is set to the default minimum performance level as specified in NCC 2019. If a user wants to install a lighting system that has lower energy consumption than the maximum value permitted under the NCC then they should be able to override the default value of 5 W/m2 with a lower value and this lower value should then be used in the calculation.

### Hourly Load

Not all lights are on at the same time, and therefore the lighting load should be distributed across the day. An average hourly use is therefore calculated, based on the number of hours per day that any lights are assumed to be on. All outputs are to be broken down by hour. This is important as it will allow tools to be able to reflect demand, feed-in, and occupancy time cycles, and allow the greatest flexibility to verify any requirements that may be established for the National Construction Code 2022.

Table 37 shows the factors for each hour of the day across the months of the year based on selected end use metering data for lighting.

Table 37: Lighting hourly factor (FL.hr)

| **Hour** | **Jan %** | **Feb %** | **Mar %** | **Apr %** | **May %** | **Jun %** | **Jul %** | **Aug %** | **Sep %** | **Oct %** | **Nov %** | **Dec %** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | 0.010833 | 0.011894 | 0.011069 | 0.010417 | 0.010369 | 0.011002 | 0.010470 | 0.010804 | 0.011012 | 0.010867 | 0.011101 | 0.011026 |
| 2 | 0.005417 | 0.005947 | 0.005534 | 0.005208 | 0.005184 | 0.005501 | 0.005235 | 0.005402 | 0.005506 | 0.005433 | 0.005551 | 0.005513 |
| 3 | 0.002167 | 0.002379 | 0.002214 | 0.002083 | 0.002074 | 0.002200 | 0.002094 | 0.002161 | 0.002202 | 0.002173 | 0.002220 | 0.002205 |
| 4 | 0.002167 | 0.002379 | 0.002214 | 0.002083 | 0.002074 | 0.002200 | 0.002094 | 0.002161 | 0.002202 | 0.002173 | 0.002220 | 0.002205 |
| 5 | 0.002167 | 0.002379 | 0.002214 | 0.002083 | 0.002074 | 0.002200 | 0.002094 | 0.002161 | 0.002202 | 0.002173 | 0.002220 | 0.002205 |
| 6 | 0.002167 | 0.002379 | 0.002214 | 0.002083 | 0.002074 | 0.002200 | 0.002094 | 0.002161 | 0.002202 | 0.002173 | 0.002220 | 0.002205 |
| 7 | 0.002600 | 0.003390 | 0.003597 | 0.004427 | 0.005184 | 0.006326 | 0.006282 | 0.005402 | 0.005066 | 0.003984 | 0.003164 | 0.002812 |
| 8 | 0.003900 | 0.005531 | 0.006088 | 0.007813 | 0.009332 | 0.010727 | 0.010470 | 0.009724 | 0.009030 | 0.006882 | 0.005162 | 0.004355 |
| 9 | 0.004117 | 0.005590 | 0.006088 | 0.007813 | 0.009332 | 0.011552 | 0.011517 | 0.009724 | 0.009030 | 0.006882 | 0.005218 | 0.004521 |
| 10 | 0.003900 | 0.005174 | 0.005479 | 0.006406 | 0.006843 | 0.008086 | 0.007957 | 0.007131 | 0.007004 | 0.006013 | 0.004829 | 0.004245 |
| 11 | 0.003467 | 0.004520 | 0.004538 | 0.004740 | 0.005184 | 0.005996 | 0.005863 | 0.005402 | 0.005242 | 0.004636 | 0.004219 | 0.003749 |
| 12 | 0.003250 | 0.004104 | 0.003985 | 0.003750 | 0.003733 | 0.004621 | 0.004607 | 0.003889 | 0.003964 | 0.003912 | 0.003830 | 0.003473 |
| 13 | 0.003250 | 0.003568 | 0.003321 | 0.003125 | 0.003111 | 0.003301 | 0.003141 | 0.003241 | 0.003304 | 0.003260 | 0.003330 | 0.003308 |
| 14 | 0.003250 | 0.003568 | 0.003321 | 0.003125 | 0.003111 | 0.003301 | 0.003141 | 0.003241 | 0.003304 | 0.003260 | 0.003330 | 0.003308 |
| 15 | 0.003250 | 0.003568 | 0.003321 | 0.003125 | 0.003111 | 0.003301 | 0.003141 | 0.003241 | 0.003304 | 0.003260 | 0.003330 | 0.003308 |
| 16 | 0.003250 | 0.003568 | 0.003431 | 0.003646 | 0.003940 | 0.004676 | 0.004607 | 0.004106 | 0.004008 | 0.003550 | 0.003330 | 0.003308 |
| 17 | 0.003467 | 0.003985 | 0.003929 | 0.004323 | 0.004770 | 0.006711 | 0.006910 | 0.004970 | 0.004801 | 0.004129 | 0.003719 | 0.003584 |
| 18 | 0.004550 | 0.005709 | 0.006641 | 0.010417 | 0.013480 | 0.018428 | 0.018846 | 0.014045 | 0.012554 | 0.008331 | 0.005329 | 0.004852 |
| 19 | 0.007583 | 0.011002 | 0.013836 | 0.023438 | 0.031107 | 0.047033 | 0.049208 | 0.032412 | 0.028632 | 0.018111 | 0.010269 | 0.008545 |
| 20 | 0.015167 | 0.022005 | 0.025459 | 0.036459 | 0.045623 | 0.050058 | 0.048161 | 0.047537 | 0.043168 | 0.030427 | 0.020538 | 0.017091 |
| 21 | 0.023834 | 0.031877 | 0.033428 | 0.039011 | 0.044586 | 0.048133 | 0.046067 | 0.046457 | 0.044093 | 0.036077 | 0.029752 | 0.026022 |
| 22 | 0.031417 | 0.038062 | 0.037081 | 0.036980 | 0.038365 | 0.040707 | 0.038738 | 0.039975 | 0.039864 | 0.037309 | 0.035525 | 0.033079 |
| 23 | 0.032500 | 0.035683 | 0.033207 | 0.031251 | 0.031107 | 0.033005 | 0.031410 | 0.032412 | 0.033037 | 0.032600 | 0.033304 | 0.033079 |
| 24 | 0.021667 | 0.023789 | 0.022138 | 0.020834 | 0.020738 | 0.022004 | 0.020940 | 0.021608 | 0.022024 | 0.021733 | 0.022203 | 0.022053 |

Table notes: Nominal hour number is hour ending the specified hour number as clock time (refer to Section 3.1 regarding hour notation).The values in Table 37 are used to allocate the share of annual lighting energy into each hour of the day and month of the year. These factors have been weighted to take into account the number of days in the month for a standard year. When these factors are multiplied by the number of days in each month, they sum to 1.0000 over a 12 month period.

Hourly loads for lighting are calculated using Equation 44:

Equation 44: Hourly lighting energy consumption

*Em.hr*=*Etot* × *FL.hr*

Where:

Em.hr = Hourly energy consumption for an hour of the day in a month in MJ

Etot = total annual energy load, defined by Equation 43 (MJ)

FL.hr = Hourly load factor for hour of day in month, defined by Table 37.

## Pool and Spa Equipment Module

**NOTE: Pool equipment has not been reviewed as part of the 2021 enhancement projects. This module is intended to be reviewed in early 2022, with additional information for pool heating as well as expanding to account for spa equipment (pumps and heating).**

Pool pump energy use is assumed to be primarily driven by the size of the pool and the type of pump used. Additional information regarding the cleaning technology and efficiency rating provides a more detailed calculation.

### Pool Volume

If pool volume (in L) is known, pool volume is directly entered by the user.

If pool volume is not known, the user should estimate pool volume based on pool surface area using Equation 45:

Equation 45: Pool volume

Where:

VP = Pool Volume, L

AP = Pool Area, m2

Note that Equation 45 shall form part of the NatHERS tech notes and does not necessarily need to be implemented into software tools directly.

### Base Pump Size

Base Pump sizes are assumed to correlate with pool size. Base size, in kW, is defined by Equation 46:

Equation 46: Pool pump base size

### Pump Energy

Pump energy is based on the pump size and the efficiency of the system.

Pump efficiency is based on the 2019 GEMS determination. **Until the 2019 GEMS determination is implemented and ratings are available to consumers, the selection will be limited to Single Speed, 2-star pumps.**

*Pump Type*

Pool pumps are designated as either:

* Single speed
* Dual Speed
* Multi speed

For the purposes of this calculation Variable speed pumps are assumed to be the same as Multi speed pumps.

*Operating Power*

Pump operating power reflects the average power of the pool pump across its operating cycle. This is based on the Base pump size and the pump type, and calculated using Equation 47:

Equation 47: Pool pump operating power

Base Size is defined using Equation 46.

Power adjustment factor is defined using Table 38.

Table 38: Power Adjustment Factor

| **Type** | **Power adjustment factor** |
| --- | --- |
| Single Speed | 1 |
| Dual Speed | 0.336 |
| Multi Speed | 0.113 |

*Star Rating*

If the star rating under the 2019 GEMS determination is known, this can be entered by the user.

If the star rating is not known, it is estimated based on pump technology. This is defined in Table 39.

Table 39: Assumed Pump Star Ratings

| **Pump type** | **Star Rating** |
| --- | --- |
| Single Speed | 2 |
| Dual Speed | 5 |
| Multi-Speed | 8 |

*Energy Factor*

Having determined the star rating, a weighted energy factor (WEF) in L/wh is required to calibrate star rating against the pump size using Equation 48 and Equation 49:

Equation 48: Pool pump weighted energy factor

Equation 49: Pool pump baseline efficiency

Where:

SR = Star Rating

Base Size is defined from Equation 22

*Flow Rate*

Average flow rate in L/hr is calculated using Equation 50:

Equation 50: Pool pump flow rate

*Run Time*

The time, in hours, required to cycle the pool once is calculated using Equation 51:

Equation 51: Pool pump turnover time

T shall be rounded up to the nearest whole integer (i.e 5.99 = 6, 6.01 = 7)

*Hourly Energy*

Hourly energy, in kWh, is equal to Operating Power.

### Hours of Operation

Pool pumps are assumed to run for longer during swimming seasons than non-swimming seasons. Pumps are assumed to be turned on a set time, and run until the required number of cycles is achieved

The pump schedule is defined in Table 40.

Table 40: Pool Pump operating schedule

| **Cycles per day** | **On Time** |
| --- | --- |
| 1 | 8am |

Pump off time is defined by Equation 52:

Equation 52: Pool pump off time

### Pool Cleaning

Cleaning energy is different depending on filter and pump type in Table 41.

If pool cleaning system is unknown, Booster Pump shall be assumed as the worst-case (highest energy use) option.

Table 41: Pool cleaning matrix

| **Pump** | **Pressure cleaner operated by Main Filtration Pump with Flow Rate > 6600L/hr** | **Pressure cleaner operated by Main Filtration Pump with Flow Rate < 6600L/hr** | **Pressure Cleaner operated by Booster Pump** | **Robotic Cleaner** |
| --- | --- | --- | --- | --- |
| Single Speed | No additional energy | No additional energy | PowerClean = 1kW | PowerClean = 0.07kW |
| Dual Speed | No additional energy | Use affinity law and Equation 53 to calculate Cleaning Power required for flow rate of 6600L/hr | PowerClean = 1kW | PowerClean = 0.07kW |
| Multi Speed | No additional energy | Use affinity law and Equation 53 to calculate Filter Power required for flow rate of 6600L/hr | PowerClean = 1kW | PowerClean = 0.07kW |

*Affinity Law*

Cleaning Power uses the Pump Affinity Law to calculate the power required to meet the minimum cleaning flow rate for mains filter pressure cleaners.

Cleaning power is defined using Equation 53:

Equation 53: Pool pump cleaning power

Operating power is defined in Equation 47.

FlowClean = 6600 L/hr

FlowOperating is Flow Rate defined in Equation 50.

*Filter Time*

Filter is assumed to run for 3 hours.

### Cleaning Energy

Cleaning energy is defined using Equation 54:

Equation 54: Pool pump cleaning energy

Cleaning on time is the same as Pump on time, defined in Table 40.

Cleaner off time is defined by Equation 55:

Equation 55: Pool cleaner off time

## On-site Energy Generation

### Overview

On-site generation is currently limited to Solar PV systems. This may be expanded to cover other forms of generation in the future.

Calculation of the hourly available electrical supply from a PV installation is undertaken in a number of steps as follows:

1. Calculate the theoretical hourly output from the PV panels (see Section 3.6.2) taking into account:
   1. Location/climatic conditions (derived from the applicable climate file)
   2. The slope and orientation of the array
   3. The rated output of the array
2. Account for shading losses (if any) (see Section 3.6.3)
3. Account for various expected system losses (see Section 3.6.4) including:
   1. Ambient Temperature Related Losses
   2. Soiling Related Losses
   3. DC Wiring Related Losses
   4. Conversion Losses
4. Account for limitations imposed by the rated capacity of the installed inverter (see Section 3.6.5) and its connection to the grid.

From these four steps the available PV generated electricity is derived for each hour of the year for each separate array of PV panels. This electricity may be used to offset on-site consumption from any electrical end use, including any plug loads (but generally excluding usage by any equipment connected as a controlled load e.g. “off peak” water heating, unless the energisation period is activated during PV generation). Any PV generation that is surplus to on-site requirements is then assumed to be delivered to an on-site battery, up to the limit of its storage capacity, where one is installed (see Section 3.7 for details for how this aspect is accounted for in the calculations) and/or a PV diverter in a water heater, where present. Where there is no on-site battery and/or PV diverter in a water heater, or if the surplus generation exceeds the capacity of the on-site battery’s or PV diverter in a given hour, then the remaining surplus generation is assumed to be exported to the grid, subject to any export limits.

Export to the grid, where it does occur, is subject to any power capacity limit that may be defined by the network utility in that particular location or for that particular system – see Section 3.6.6.

A residential PV system may be divided into two or more arrays (for example, one array may be located on the east side of a gable roof running north south and one on the west side). Each PV array may have different orientations and different slopes and be subject to different overshadowing effects. Consequently, where a residential PV system is installed across several locations on a roof then each array must be treated separately for the purposes of calculating PV output. The hourly results for each array must then be aggregated together to give a total hourly electrical production. Note however, if two arrays have the same orientation and slope and are not subject to any overshadowing, then they may be treated as a single system for the purposes of calculating PV electrical output.

The following sub-sections detail the calculation methods for each of the calculation steps noted above.

### Solar PV Panel Output Calculation

Solar PV panel output calculations rely on the geographic location of the dwelling, the amount of solar radiation present in the climate file and the angle and orientation of the panels.

Solar PV calculations are based on the Hay, Davies, Klucher, Reindl model (HDKR) laid out in *Solar Engineering of Thermal Processes, 4th Ed.* Additional corrections for ensuring valid estimates are made based on information provided by CSIRO.

Note that unless otherwise specified, all angles use Radians. It is recommended that relevant user inputs are made in Degrees and then converted to Radians. This may be done using Equation 56, or similar in-built function of the mathematical library used.

Equation 56: Conversion factor from degrees to radians

**Constants and System Defined Variables**

The solar PV module utilises a number of constant factors, or information taken from user inputs from the Thermal Shell.

Tzn - GMT Time Zone – Derived from Postcode using the postcode list (part of existing NatHERS Thermal documentation). Refer to Appendix E (under development).

Φ – Latitude of dwelling, derived from Postcode using the postcode list (part of existing NatHERS Thermal documentation)

LLoc – Longitude of dwelling, derived from Postcode using the postcode list (part of existing NatHERS Thermal documentation)

GSC – Solar Constant, 1367

ρg – Ground reflectance, 0.6

Fd ­Derating Factor, 1.0 (note: This de-rating factor was used in an earlier version of the calculation method but has been replaced with specific de-rating calculations for losses and impacts of shading etc. The factor is retained but is now simply set to 1).

**User Defined Variables**

The solar PV module uses the following inputs from the user to describe the specifics of the solar PV system.

β – Slope of Solar Panel from horizontal

γ – Azimuth of Solar Panel from North

Ps – Size of the solar array in kW

NP – The number of phases across which the PV array is to be connected. (options = 1 (default), 2 or 3)

Ci – total capacity of all installed inverters (kW) (default = 0.75 \* Ps , rounded up to the nearest whole number, however this can be overridden) – see also Note 1 below

ELpv – The PV export limit of the electrical network (kW) (default = NP \* 5, however this can be overridden with a lesser value if required) - see also Note 2 below.

Note 1: The software should offer a picklist of commonly available Inverter capacities including 3, 4, and 5 kW as well as the facility for free input by the user. If the nominated Ci  value is less than 0.75 \* Ps then issue a warning that “The inverter should be at least 75% of the capacity of the solar array – please check”.

Note 2: If ELpv  is greater than NP \* 5 and NP = 1, disallow this value with the error “single phase installation cannot be greater than 5kW”. If ELpv  is greater than NP \* 5 and NP = 2 or 3, then issue a warning that “The PV export limit typically does not exceed 5kW per phase – please check”.

**Solar Time**

Adjustments are made to correct for the distance between the dwelling and the weather station. Solar time is calculated for each hour.

Solar Time, TSol, is defined using Equation 57. Note that Tsol should remain as a decimal, not converted to hours and minutes.

Equation 57: Solar time

Where:

TLoc = Local Time

Lst is defined by Equation 58.

Lcol is defined by Equation 59.

E is defined by Equation 60.

Equation 58: Calculation of Lst

Where:

Tzn is GMT time zone.

Equation 59: Calculation of Lcol

Where:

LLoc is Longitude of the dwelling location.

Equation 60: Calculation of E

Where:

B is defined by Equation 61.

Equation 61: Earth to sun distance factor

Where:

B = earth-to-sun distance factor in Radians

n = Day of year (1st Jan = 1, 2nd Jan = 2 … 31 Dec = 365. 1 ≤ n ≤ 365).

**Declination**

Declination is the angular position of the Sun at Solar Noon compared to the Equator. This varies across the year due to the tilt of the earth’s rotational axis. The declination angle is calculated for each day using Equation 62:

Equation 62: Sun declination

Where:

δ = Declination angle in Radians

n = Day of year (1st Jan = 1, 2nd Jan = 2 … 31 Dec = 365. 1 ≤ n ≤ 365)

**Sunrise and Sunset**

Solar PV generation may be inaccurately calculated during the hours of sunrise and sunset if not handled correctly. Note that times for sunrise and sunset should remain as a decimal, and not converted to hours and minutes. Time of sunrise is calculated for each day using Equation 63

Equation 63: Sunrise time

Where:

Trise = Time of Sunrise in Hours

δ = Declination angle in Radians

Φ – Latitude of dwelling in Radians

Time of sunset is calculated for each day using Equation 64:

Equation 64: Sunset time

Where:

Tset = Time of Sunset in Hours

δ = Declination angle in Radians

Φ – Latitude of dwelling in Radians

**Hour Angle**

The hour angle represents the position of the sun, East-West, compared to the local meridian. Morning values are Negative, afternoon values are Positive. Hour angle is calculated for each hour of the day.

For some purposes, it is more appropriate to use the hour angle for the mid-point of the hour, rather than the start.

Hour angle at the start of the hour is calculated using Equation 65:

Equation 65: Sun hour angle – start of hour

Where:

ω = Hour angle in Radians

Tsol = Solar time

Hour angle for the mid-point of the hour is calculated using Equation 66:

Equation 66: Sun hour angle – mid point of hour

Where:

ωmid = Hour angle for middle of the hour, in Radians

Tsol = Solar time

**Ratio of Beam Radiation**

Solar radiation in the weather files is for horizontal surfaces. Rb is a geometric factor relating the ratio of beam radiation on the horizontal surface to that on the tilted surface of the solar PV panel. Care must be taken to ensure accurate values of Rb are used. Rb is calculated using Equation 67 and Equation 68.

Equation 67: Permitted range for ratio of beam radiation

Equation 68: Ratio of beam radiation

Where:

Rb = Ratio of Beam radiation from horizontal to tilted plane

cos θ = equation relating angle incidence of beam radiation on the tilted surface to the other angles in the system

cos θz = equation relating Zenith angle of the Sun to the other angles in the system

*‘Real’ angle incidences*

The cosines for angles θ and θz may be calculated regardless of the position of the sun, however are only relevant when the sun is above the horizon. Equation 69 defines cos θ. cos θ is calculated for each hour of the day.

Equation 69: Angle of the sun above the horizon

Where:

δ = declination angle in Radians

Φ = Latitude of dwelling in Radians

β = Slope of Solar Panel in Radians

γ = Azimuth of Solar Panel in Radians

ωmid = Hour angle for middle of the hour, in Radians

Tsol = Solar time

Trise = Time of Sunrise in Hours

Tset = Time of Sunset in Hours

θz is the angle between a vertical line, and the line to the sun. When θz = 0 (in Degrees), the sun is directly above the panels, and θz = 90 (in Degrees) the sun is level with the panels on the horizontal plane. θz must be between 00 and 900. This is tested by calculating cos θz.i using Equation 70, and then rearranging to solve for θz using Equation 71. The value of cos θz to be used in Equation 68 is then defined using Equation 72.

Equation 70: Calculation of cosθz.i

Where:

Cos θz.i = Initial estimate of cos θz

δ = declination angle in Radians

Φ = Latitude of dwelling in Radians

ωmid = Hour angle for middle of the hour, in Radians

Equation 71: Sun zenith angle

Where:

θz = Zenith angle in Degrees

Equation 72: Cos of the sun zenith angle

Where:

θz = Zenith angle in Degrees

**Extra-terrestrial Radiation**

Extra-terrestrial radiation on a horizontal surface is calculated using Equation 73 and Equation 74.

Equation 73: Extra-terrestrial radiation on a horizontal surface

Equation 74: Calculation of IO

Where:

Io = Extraterrestrial radiation for 1 hour in kWh

Gsc = Global solar constant

n = Day of year number

Φ = Latitude of dwelling in Radians

δ = declination angle in Radians

ω1 = Hour angle in Radians at start of hour

ω2 = Hour angle in Radians at end of hour

**Available Solar Radiation**

The weather file used by the Chenath engine contains the required solar data for calculating the amount of solar radiation available at the location. Total Radiation on the horizontal surface, IH is made up from Diffuse, Idif, and Beam, Ib, components. IH and Idif are included in the weather file. Ib is calculated using Equation 75. Note that by definition Beam radiation requires line-of-sight from the Sun to the panel, thus Ib may only be greater than 0 between sunrise and sunset.

Equation 75: Beam portion of solar radiation

Where:

Ib = Beam portion of solar radiation

IH = Total solar radiation measured on the horizontal plane

Idif = Diffuse portion of solar radiation

Tsol = Solar time

Trise = Time of Sunrise in Hours

Tset = Time of Sunset in Hours

**Important Note**: The beam portion of the solar radiation is assumed to be equal to zero if an obstruction is shading the PV array in that hour. The method for determining if a PV panel is in fact shaded in a given hour is described in Section 3.6.3.

**Anisotropy Index**

The Anisotropy index, Ai, makes adjustments to account for diffuse elements of extraterrestrial solar radiation on the tilted surface. It determines part of the extraterrestrial diffuse radiation which should be treated as beam radiation. Ai is calculated using Equation 76:

Equation 76: Anisotropy index

Where:

Ai = Anisotropy index

Ib = Beam portion of solar radiation

Io = Extraterrestrial radiation

**Total available solar radiation**

Total available solar radiation on the solar PV panel is defined using Equation 77 and corrected using Equation 79.Total available solar radiation cannot be greater than Gsc. Values greater than Gsc are only likely to occur where the hour angle is very small, ultimately inflating Rb and Ai and should be ignored.

Equation 77: Total available solar radiation

Where:

IT,i = Initial estimate of total solar radiation on the solar PV panel

Ib = Beam portion of solar radiation

Idif = Diffuse portion of solar radiation

IH = Total solar radiation measured on the horizontal plane

Ai = Anisotropy index

Rb = Ratio of Beam radiation from horizontal to tilted plane

β = Slope of Solar Panel in Radians

ρg = Ground reflectance

f = Modulating factor, calculated using Equation 78

Equation 78: Modulating factor

Equation 79: Realistic solar radiation on the solar PV panel

Where:

IT = Realistic solar radiation on the solar PV panel

IT,i = Initial estimate of total solar radiation on the solar PV panel

Gsc = Global solar constant

**Electricity generated from Solar PV**

Conversion of available solar on the panel to electricity relies on the efficiency of the panel and the array size. Hourly electricity generation is calculated by Equation 80 and Equation 81.

Equation 80: Valid range for electricity generated by the solar panel

Equation 81: Electricity generated by the solar panel

Where:

Esol = Electricity generated by the solar panel for 1 hour in kWh

IT = Realistic solar radiation on the solar PV panel

Fd = Derating Factor

Ps – Size of the solar array in kW

### Shading Losses

Note: this section is under development.

The calculations in Section 3.6.2 determine the PV panel hourly output. Part of that calculation requires determination of whether or not the PV array is overshadowed in a given hour of operation. If it is overshadowed, then that impacts upon the direct component of the solar radiation (referred to as the beam portion of the solar radiation[[12]](#footnote-13) (Ib) in Equation 75 ). Effectively, when overshadowing occurs the direct beam portion of the solar radiation is assumed to be set to zero and only the indirect (diffuse) radiation then contributes to the PV panel output.

To determine for each hour of the year if a PV array is or is not overshadowed an assessment needs to be undertaken for each hour, that takes into account the position of the sun and the position of any potential overshadowing objects relative to the position of the PV array.

For each hour of the year the NatHERS climate files provide details of the sun’s azimuth and elevation. Overshadowing objects can be defined relative to the centre of the PV array, by the azimuth angles to the left and right edges of the object, and the elevation angle to the top of the object.

For each potential overshadowing object the assessor needs to collect and input the following three data points, relative to the centre of the PV array:

* Elevation angle of the top of the object (AltO)
* Azimuth of the left-hand edge of the object (AzO1)
* Azimuth of the right-hand edge of the object (AzO2).

In addition, the existing climate files already contain the following required shading calculation input data for each hour of the year:

* Elevation angle of the sun – at start of the hour (AltS1)
* Elevation angle of the sun – at end of the hour (AltS2)
* Azimuth angle of the sun – at start of the hour (AzS1)
* Azimuth angle of the sun – at end of the hour (AzS2).

Note: The end of a specific hour under analysis is the start of the next hour.

For each hour of the year, the range of azimuth angles as subtended by the left hand side (LHS) of the object and the right hand side (RHS) of the object must be compared to the hourly range of azimuth angles covered by the sun (as per the climate file). If the azimuth angles subtended by the object is within the range subtended by the sun in that hour then the object will overshadow the PV array in that hour provided the minimum elevation angle of the sun in that hour (i.e. minimum of AltS1 andAltS2) is also less than the elevation angle of the object.

In the example shown in Figure 3 below, the azimuth range subtended by the LHS and RHS of the object (green lines) overlaps the sun’s azimuth range (yellow lines) in that hour. If during that hour the sun’s elevation is lower than the object height, then shading occurs[[13]](#footnote-14).

Where it is determined that overshadowing will occur in a particular hour then the ‘Beam portion of solar radiation’ (Ib) as calculated in Equation 75, is instead set to zero. That is, the electrical output of the PV system is calculated using a direct solar radiation (or beam portion) value of zero and any generation will only be from diffuse radiation.

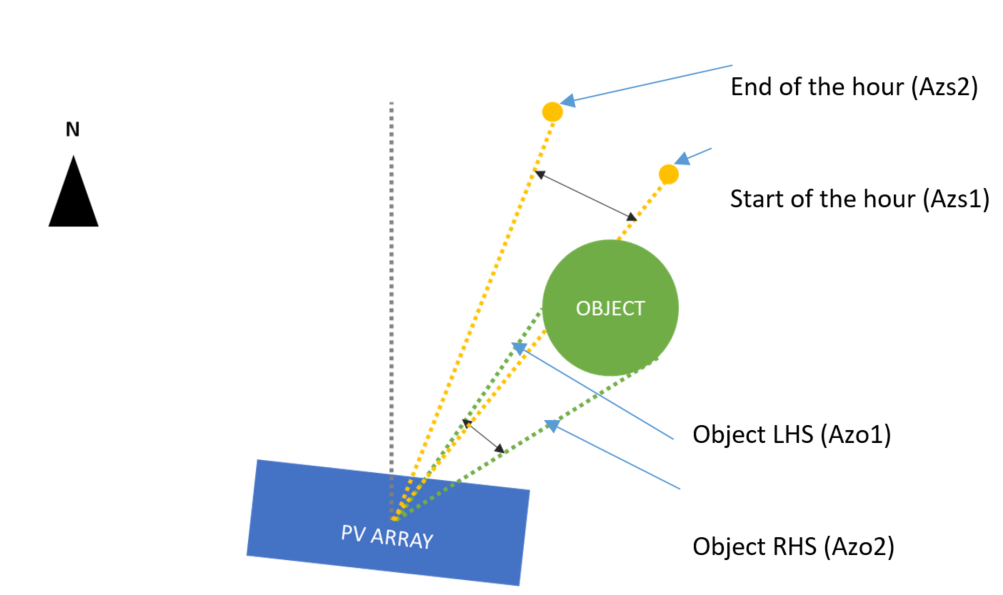


Figure 3: Example of the sun azimuth range covered over one hour with obstructing object (plan view)

It is noted that this method will provide a slightly conservative result regarding the PV generation, as any partial shading obstruction in a single hour is calculated with the same result as full shading for that hour.

**Example Calculation:**

Assume for the obstruction:

AltO = 60°

AzO1 = 30°

AzO2 = 45°

Looking at a single hour from the climate file with the following parameters:

AltS1 = 55° (Start of hour)

AltS2 = 50° (End of hour)

AzS1 = 35° (Start of hour)

AzS2 = 20° (End of hour).

Since AzO1 < AzS1 < AzO2 AND

AltS2 < AltO\*

THEN: shading is deemed to occur.

Therefore, set Ib (‘Beam portion of solar radiation’) to 0. (see Equation 75)

\* In this case both AltS2 and AltS1 are less than AltO. However only one of these two conditions needs to be true for the PV array to be deemed to be overshadowed in that hour.

Where PV arrays are located on various sections of the roof then each section will need to be assessed for overshadowing separately.

In cases where micro inverters or DC optimisers are proposed to be used then the array could be divided into as many sections as there are microinverters or DC optimisers, at the assessor’s discretion. Such an approach could only be taken where the location of such devices is known at the design stage (not often) and the assessor is of the view that it is worth the additional effort to divide the array up as suggested.

### PV System Losses

As noted previously, system losses include for:

* Ambient Temperature Related Losses
* Soiling Related Losses
* DC Wiring Related Losses
* Conversion Losses

Total system losses are calculated by Equation 82:

Equation 82: Total PV system losses

LTOT = (1-LA) × (1-LS) × (1-LW) × (1-LC)

Where:

LTOT = Total PV System Loss Factor

LA = Ambient Temperature Related Losses

LS = Soiling Related Losses

LW = DC Wiring Related Losses

LC = Conversion Losses

Ambient temperature related losses are calculated for each hour by Equation 83:

Equation 83: Ambient temperature related PV losses

LA = ((Tamb + 0.03125 xGinc)– 25)) × 0.4 (%)

Where:

LA = the ambient temperature related losses (%)

Tamb = the ambient air temperature (oC) –the dry bulb temperature in the climate file for that hour

Ginc = the incident radiation (W) ) – derived from the climate file for that hour

**Soiling losses (LS)** will vary depending on the site and washing practices, but can be estimated using a default value of 5%, in line with Clean Energy Council Guidelines (a user override of this default value can be provided, although it is unlikely that many would use such a facility).

**DC wiring losses (LW)** will vary based on circuit length and conductor thickness, but can be estimated using a default value of 3%, in line with Clean Energy Council Guidelines (a user override of this default value can be provided, although it is unlikely that many would use such a facility).

**Conversion losses (LC)** will vary slightly based on the inverter and its loading, but can be estimated using a default value of 3% (a user override of this default value can be provided, although it is unlikely that many would use such a facility).

The system loss calculation should be applied to the hourly PV panel generation calculation (Equation 81) to derive the de-rated hourly PV panel generation by Equation 84.

Equation 84: Electricity generated by the solar PV system with losses

EsolD =Esol x LTOT

Where:

EsolD = Electricity generated by the solar PV system for 1 hour in kWh

Esol = Electricity generated by the solar panel before system losses for 1 hour in kWh – see Equation 81

LTOT = Total PV System Loss Factor – see Equation 82

### Inverter limitations on available PV generated electricity

Whilst Equation 84 above calculates the de-rated output of the Solar PV array for each hour of the year, this output must then be limited according to the capacity of the associated inverter i.e.

Equation 85: Electricity generated by the solar PV system with external constraints

EsolD ≤ Ci

Where:

Esol = Electricity generated by the solar panel for 1 hour in kWh

Ci – total capacity of all installed inverters (kW)

### Network limitations on export of PV generated electricity

For each hour of the year, any solar PV generation which is surplus to total electrical load of the home in that hour (including any battery loads) should be accounted for as electricity exported to the electricity network (En). However, any export to the network must be capped at the user specified value for the “generator export limit of the electrical network” (ELpv) i.e.

Equation 86:Maximum electricity that can be exported to the network

En ≤ ELpv

Where:

En = The maximum amount of electricity that can be exported to the network in a given hour (kWh)

ELpv = The generator export limit of the electrical network (kW)

## Battery Storage

### Overview

Where the output from Solar PV exceeds the hourly demand for electricity in any given hour, then a battery may be used to store that excess generation for use at a later time (e.g. at night time).

The complexity of modelling the performance of batteries depends significantly on the technology. Lithium-ion batteries can be modelled simply as energy storage tanks with power input/output constraints and round-trip losses. However, lead-acid batteries have greater limitations on charge acceptance, and greater capacity losses with increasing discharge rates.

Moreover, battery control can be simple and based on prevailing conditions, or can utilise highly sophisticated forecasting of demand, weather and price signals.

For this iteration of the model, batteries are modelled as simple energy storage tanks (as applicable to Lithium-ion batteries) and the battery control system is assumed to be a basic system not responsive to either the expected future load profile or current or future network price signals. Whenever excess generation is available, it is stored and whenever on-site demand exceeds available supply from a PV system, then the battery is used to make up any shortfall in any particular hour (all subject to the charge, discharge and capacity limitations of the battery).

### Required Inputs and Default Values

The following 6 user inputs are required for the battery storage and discharge calculations:

1. Battery Technology Type – see Table 42 for various options
2. BNC = Battery Nominal Storage Capacity (kWh)
3. BDD = Maximum Depth of Discharge – as a percentage of the nominal capacity of the battery. This means that if the battery is rated at 10 kWh and BDD = 90% then the useable capacity would be 9.0 kWh
4. BCE = Charge Efficiency (%) - This means that when charging only that percentage of the input energy is actually stored in the battery, the remainder is lost from the system.
5. BDE = Discharge Efficiency (%) - This means that when discharging, only that percentage of the energy discharged is in the form of available electrical power, the remaining percentage is lost from the system
6. BCR = Battery C-rate. This is the maximum proportion of the battery’s rated capacity that can be charged or discharged within one hour. This effectively limits the capacity of the battery to accept a charge or meet high hourly loads, in which case any shortfall is made up with imports from the grid. The charge and discharge C-rate are assumed to be the same.

Default values (to be capable of user override) are as follows:

Table 42: Default Battery Assumptions by Technology Type

| **Technology** | **Max. Depth of Discharge** | **Battery C rate** | **Charge Efficiency** | **Discharge**  **Efficiency** | **Round-Trip Efficiency**  **(charge + discharge)** | **Assumed initial charge**  **(Hour 1)** |
| --- | --- | --- | --- | --- | --- | --- |
| Lithium-Ion | 90% | 0.5 | 92% | 92% | 85% | 50% |
| Lead Acid1 | 50% | 0.2 | 89.5% | 89.5% | 80% | 50% |
| Zinc Bromine1 | 100% | 0.25 | 87% | 87% | 75% | 50% |

Table notes: It should be noted that the behaviour of lead-acid, zinc bromine and vanadium redox batteries are not identical to lithium-ion.

### Calculation Method

Where a battery is present, then hourly energy accounting for the following is required:

* Any charge delivered to the battery (i.e. excess from the PV system that the battery has the capacity to accept)
* Any discharge from the battery (to meet or partly meet on-site electrical equipment loads in that hour)
* Any PV generation exported to the grid (i.e. in excess of any battery’s charge acceptance capacity in a particular hour)
* The State of charge (SOC) of the battery at the start of each hour

This accounting is undertaken using the following logic:

* **A surplus of PV generation:** If in a given hour the output from the PV system (*EsolD*) exceeds the dwellings electrical load in that hour (*Etot*) then the excess generation is stored in the battery (less losses) until its capacity is reached, after which any excess is exported to the grid (at the feed-in tariff rate). Note: The capacity for a battery to accept charge in any given hour is limited by the Battery’s SOC at that time and its C- rate (see limitations noted below).
* **A deficit of electricity:** If in a given hour the output from the PV module is less than the dwellings electrical load in that hour, then stored electricity in the battery (less losses) is used to offset the shortfall. The offset amount is limited by the available energy within the battery for that hour (down to its maximum available depth of discharge) and also by the maximum discharge rate for the battery (limited by the C-rate). Any shortfall in the battery’s capacity to meet the load for that hour is made up from electricity imported from the grid.

**Rules for Battery Operation (Limitations)**

Equation 87: Rules for battery operation

BCHARGE-EXT must be ≤ (BNC - BSTART) / BCE

BCHARGE-EXT must be ≤ BNC x BCR / BCE

BCHARGE-EXT must be ≤ BPV (any excess is assumed to be delivered to the grid)

BCHARGE-BATT must be ≤ (BNC  - BSTART)

B CHARGE-BATT must be ≤ BNC x BCR

B CHARGE-BATT must be ≤ BPV x BCE (any excess is assumed to be delivered to the grid)

BDISCHARGE-BATT must be ≤ BSTART - BNC x (1 - BDD) (any shortfall in demand from appliances is assumed to be delivered from the grid and not from the battery)

BDISCHARGE-BATT must be ≤ BNC x BCR

BDISCHARGE-EXT must be ≤ (BSTART - BNC x (1 - BDD)) x BDE (any shortfall in demand from appliances is assumed to be delivered from the grid and not from the battery)

BDISCHARGE-EXT must be ≤ BNC x BCR x BDE

**CHARGING ACCOUNTING**

Equation 88: Rules for battery charge accounting

IF (BNC - BSTART) / BCE > BNC x BCR / BCE THEN

BCHARGE-EXTMAX = BNC x BCR / BCE OTHERWISE BCHARGE-EXTMAX = (BNC - BSTART) / BCE

IF BPV > BCHARGE-EXTMAX THEN

BCHARGE-BATT = BCHARGE-EXTMAX x BCE AND PVEXPORT = BPV - BCHARGE-EXTMAX (If <0 Then = 0)

OTHERWISE

BCHARGE-BATT = BPV x BCE

**DISCHARGING ACCOUNTING**

Equation 89: Rules for battery discharge accounting

IF (BSTART - BNC x (1 - BDD)) > BNC x BCR THEN

BDISCHARGE-EXTMAX = BNC x BCR x BDE OTHERWISE BDISCHARGE-EXTMAX = (BSTART - BNC x (1 - BDD)) x BDE

IF BED < BDISCHARGE-EXTMAX THEN

BED2 = 0 ANDBDISCHARGE-EXT =BED

OTHERWISE

BED2 = BED - BDISCHARGE-EXTMAX ANDBDISCHARGE-EXT = BDISCHARGE-EXTMAX

**TIMESTEP ACCOUNTING**

Equation 90: Rules for battery timestep accounting

IF BCHARGE BATT > 0 THEN BEND = BSTART + BCHARGE BATT

IF BDISCHARGE BATT > 0 THEN BEND = BSTART - BDISHARGE BATT

OTHERWISE BEND = BSTART

At timestep N, BSTART (N) = BEND (N-1)

**Where:**

BSTART = The total energy in the battery at the commencement of a given hour (kWh)

BCHARGE-EXT = Additional energy delivered to the battery in any given hour, before charging losses (kWh)

BCHARGE-BATT = Additional energy delivered to the battery in any given hour, after charging losses (kWh)

BDISCHARGE-BATT = Energy discharged from the battery in any given hour, before discharging losses (kWh)

BDISCHARGE-EXT = Energy discharged from the battery in any given hour, after discharging losses (kWh)

BPV = The amount of excess PV generation available to charge the battery in a given hour (kWh)

BNC = Battery Nominal Storage Capacity (kWh)

BDD = Maximum Depth of Discharge (%)

BCR = Battery C-rate

BCE = Charge Efficiency (%)

BDE = Discharge Efficiency (%)

BCHARGE-EXTMAX = Maximum additional energy that can be delivered to the battery from excess PV generation in any given hour, before charging losses

PVEXPORT = The PV energy delivered to the grid (note network limits must be applied i.e. IF PVEXPORT > Ci THEN PVEXPORT = Ci)

BDISCHARGE-EXTMAX = Maximum energy that can be discharged from the battery in any given hour, after discharging losses

BED = Net Electrical energy demand from appliances in any given hour (allowing for any reductions in demand due to supply to appliances from PVs but not from Batteries)

BED2 = As per BED but allowing for supply by any batteries

BEND = The total energy in the battery at the end of a given hour (kWh)

## Plug Loads

### Overview

This section covers electrical plug loads for all other equipment, apart from equipment already covered in the previous sections of this report, and includes items such as whitegoods, audio visual, small appliances, computers and peripherals, other electronics and standby power.

At this stage, performance and capacity data relating to these end uses do not form part of the user input requirements. Instead, a stock average load and load profile for plug loads (based on the number of occupants) is assumed. These loads are particularly important in relation to Solar PV generation (where installed) as they can consume a considerable amount of PV generation thereby reducing the need for grid supplied electricity to the home. Accounting for plug loads in the context of PV generation also has the effect of reducing the amount of solar PV generation that is exported to the grid.

### Annual Loads

The assumed annual plug loads have been based on work undertaken previously for Sustainability Victoria and the Australian Building Codes Board (ABCB). From this work annual average total plug loads per number of occupants were derived, these are shown in Table 43. Linear regression was then used to determine the relevant factors – see Figure 4.

Table 43: Annual Plug Loads by Number of Occupants

| **Number of Occupants** | **Annual Plug Load (MJ)** |
| --- | --- |
| 1 | 7441 |
| 2 | 7899 |
| 3 | 8353 |
| 4 | 8801 |
| 5 | 9245 |
| 6 | 9686 |
| 7 | 10123 |
| 8 | 10558 |
| 9 | 10990 |
| 10 | 11419 |

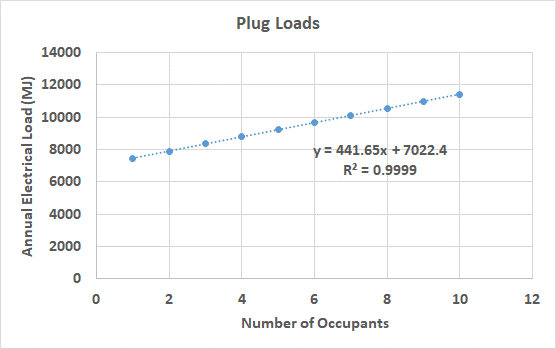


Figure 4: Annual Plug Loads by Number of Occupants

Annual plug loads are calculated using Equation 91.

Equation 91: Appliance annual plug loads as a function of occupants

EPLUG = 7022.4 + NOCC x 441.65

Where:

Eplug = total annual plug energy load in MJ/year

NOCC = Number of occupants in the home (refer Equation 2).

### Hourly Loads

Plug loads are not evenly distributed across the day or across the seasons (although seasonal variation tends to be less marked). The annual plug load value therefore needs to be broken down into hourly loads across the year based on the expected distribution of those loads through the year. This is important as it will allow tools to be able to reflect demand, feed-in, and occupancy time cycles, and allow the greatest flexibility to verify any requirements that may be established for the National Construction Code 2022.

Hourly loads for plug loads are calculated using Equation 92:

Equation 92: Appliance hourly plug loads

*EPLUG.hr* = *EPLUG*x *FPLUG.hr*

Where:

*EPLUG.hr* = Hourly energy load for hour of day in each month in MJ

*EPLUG*= total annual plug energy load defined in Equation 91 in MJ/year

*FPLUG.hr* = Hourly plug load factor for hour of day in month, defined by Table 44 for the All-day profile and Table 45 for the work-day profile (%).

Note: The values in Table 44 and Table 45 take into account the number of days in each month and the sum of values in each month times the days in each month should sum to 1.000 across the whole year.

Table 44: Plug Load hourly factor (%) – All day schedule

| **Hour** | **Jan %** | **Feb %** | **Mar %** | **Apr %** | **May %** | **Jun %** | **Jul %** | **Aug %** | **Sep %** | **Oct %** | **Nov %** | **Dec %** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **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 | 0.00739 | 0.00734 | 0.007668 | 0.007565 | 0.007475 | 0.007483 | 0.007251 | 0.007344 | 0.007206 |
| **3** | 0.007037 | 0.007463 | 0.007037 | 0.007208 | 0.00715 | 0.00744 | 0.007337 | 0.007262 | 0.007286 | 0.007075 | 0.00717 | 0.007037 |
| **4** | 0.00691 | 0.007322 | 0.00691 | 0.007069 | 0.007 | 0.007255 | 0.00715 | 0.00709 | 0.007131 | 0.00694 | 0.007038 | 0.00691 |
| **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** | 0.00838 | 0.009251 | 0.008884 | 0.009135 | 0.009227 | 0.010001 | 0.010002 | 0.00944 | 0.009485 | 0.008953 | 0.00905 | 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 | 0.01206 | 0.012444 | 0.012731 | 0.01393 | 0.014084 | 0.012993 | 0.012999 | 0.012195 | 0.012403 | 0.011648 |
| **10** | 0.010635 | 0.012162 | 0.011787 | 0.012157 | 0.012436 | 0.01363 | 0.013781 | 0.012698 | 0.012715 | 0.011913 | 0.012104 | 0.01138 |
| **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** | 0.01027 | 0.01169 | 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 | 0.01331 | 0.013388 | 0.012333 | 0.012413 | 0.011542 | 0.011702 | 0.011042 |
| **15** | 0.010349 | 0.011802 | 0.011471 | 0.011808 | 0.012043 | 0.01329 | 0.013389 | 0.012318 | 0.012382 | 0.011529 | 0.0117 | 0.011038 |
| **16** | 0.010467 | 0.011948 | 0.011612 | 0.011961 | 0.012199 | 0.013474 | 0.01356 | 0.012489 | 0.01255 | 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 | 0.01755 | 0.017864 | 0.020126 | 0.01985 | 0.018623 | 0.018667 | 0.01709 | 0.017392 | 0.016135 |
| **19** | 0.015324 | 0.017751 | 0.017124 | 0.017902 | 0.018206 | 0.020456 | 0.020138 | 0.019008 | 0.01899 | 0.017429 | 0.01775 | 0.016492 |
| **20** | 0.013396 | 0.01534 | 0.014745 | 0.015313 | 0.015576 | 0.017182 | 0.017087 | 0.016084 | 0.016001 | 0.014908 | 0.01522 | 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 | 0.01239 | 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 | 0.00976 | 0.009337 | 0.009501 | 0.009147 |

Table notes: Nominal hour number is hour ending the specified hour number as clock time (refer to Section 3.1 regarding hour notation). The values in Table 44 are used to allocate the share of annual plug load energy into each hour of the day and month of the year. These factors have been weighted to take into account the number of days in the month for a standard year. When these factors are multiplied by the number of days in each month, they sum to 1.0000 over a 12 month period.

Table 45: Plug Load hourly factor (%) – Work day schedule

| **Hour** | **Jan %** | **Feb %** | **Mar %** | **Apr %** | **May %** | **Jun %** | **Jul %** | **Aug %** | **Sep %** | **Oct %** | **Nov %** | **Dec %** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | 0.008231 | 0.00888 | 0.008372 | 0.00861 | 0.008616 | 0.009037 | 0.008959 | 0.008785 | 0.0087 | 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 | 0.00711 | 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 | 0.00711 | 0.007384 | 0.007278 | 0.007211 | 0.007245 | 0.007043 | 0.007141 | 0.007009 |
| 6 | 0.007212 | 0.00781 | 0.00749 | 0.007648 | 0.007672 | 0.008196 | 0.008207 | 0.007784 | 0.007869 | 0.0075 | 0.007566 | 0.007365 |
| 7 | 0.008902 | 0.009976 | 0.009652 | 0.009928 | 0.010086 | 0.011059 | 0.011126 | 0.010319 | 0.0104 | 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 | 0.00991 | 0.009904 | 0.009399 | 0.009525 | 0.009121 |
| 10 | 0.008744 | 0.00967 | 0.009254 | 0.009531 | 0.009644 | 0.010395 | 0.010417 | 0.009859 | 0.009858 | 0.009353 | 0.009474 | 0.009077 |
| 11 | 0.00859 | 0.009478 | 0.009072 | 0.009336 | 0.009437 | 0.010178 | 0.010194 | 0.009646 | 0.009662 | 0.00916 | 0.00927 | 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 | 0.00882 |
| 13 | 0.008446 | 0.009305 | 0.00892 | 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 | 0.00912 | 0.008763 |
| 16 | 0.008497 | 0.009378 | 0.008998 | 0.009248 | 0.00934 | 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 | 0.01928 | 0.017363 | 0.017556 | 0.015983 | 0.016204 | 0.015005 |
| 18 | 0.017339 | 0.020501 | 0.020011 | 0.020903 | 0.02138 | 0.024344 | 0.024104 | 0.022297 | 0.022413 | 0.020345 | 0.0207 | 0.019045 |
| 19 | 0.017782 | 0.020918 | 0.020315 | 0.02125 | 0.021701 | 0.024605 | 0.024299 | 0.022659 | 0.022698 | 0.020679 | 0.021064 | 0.019415 |
| 20 | 0.01536 | 0.017873 | 0.017294 | 0.017963 | 0.018358 | 0.020408 | 0.02038 | 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 | 0.01428 | 0.013764 | 0.014188 | 0.01448 | 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 | 0.01243 | 0.012514 | 0.011811 | 0.011684 | 0.011151 | 0.011407 | 0.01086 |
| 24 | 0.009472 | 0.010509 | 0.010032 | 0.010322 | 0.01047 | 0.011215 | 0.011274 | 0.010677 | 0.010563 | 0.01008 | 0.010278 | 0.009829 |

Table notes: Nominal hour number is hour ending the specified hour number as clock time (refer to Section 3.1 regarding hour notation). The values in Table 45 are used to allocate the share of annual plug load energy into each hour of the day and month of the year. These factors have been weighted to take into account the number of days in the month for a standard year. When these factors are multiplied by the number of days in each month, they sum to 1.0000 over a 12 month period.

# Appendix A - Cooling Thermostat settings by NatHERS climate zone for Whole of Home rating, ZERL Zones and Evaporative Cooler Applicability

| **NatHERS CZ** | **Location** | **NCC Climate Zone** | **NatHERS thermal simulation Cooling Set Point (oC)** | **WoH Cooling Set Point (oC)** | **Applicable GEMS ZERL Zone** | **Evaporative cooler Suitability[[14]](#footnote-15)** |
| --- | --- | --- | --- | --- | --- | --- |
| 1 | Darwin Airport | 1 | 26.5 | 25 | Hot/humid | Not recommended |
| 2 | Port Hedland Airport | 1 | 27 | 25 | Hot/humid | TBA |
| 3 | Longreach Aero | 3 | 27 | 25 | Hot/humid | Suitable |
| 4 | Carnarvon Airport | 3 | 26 | 25 | Hot/humid | TBA |
| 5 | Townsville Aero | 1 | 26.5 | 25 | Hot/humid | Not recommended |
| 6 | Alice Springs | 3 | 26.5 | 25 | Mixed | Suitable |
| 7 | Rockhampton Aero | 2 | 26 | 25 | Hot/humid | Not recommended |
| 8 | Moree MO | 4 | 26 | 25 | Mixed | Suitable |
| 9 | Amberley Aero | 2 | 26 | 25 | Mixed | Not recommended |
| 10 | Brisbane AMO | 2 | 25.5 | 25 | Hot/humid | Not recommended |
| 11 | Coffs Harbour MO | 2 | 25 | 24 | Mixed | Not recommended |
| 12 | Geraldton Airport | 5 | 25 | 24 | Mixed | TBA |
| 13 | Perth Airport | 5 | 25 | 24 | Mixed | Suitable |
| 14 | Armidale | 7 | 24 | 23 | Cold | TBA |
| 15 | Williamtown AMO | 5 | 25 | 24 | Mixed | TBA |
| 16 | Adelaide (Kent Town) | 5 | 25 | 24 | Mixed | Suitable |
| 17 | Sydney RO | 5 | 25.5 | 24 | Mixed | Not recommended |
| 18 | Nowra RAN | 6 | 24.5 | 24 | Cold | TBA |
| 19 | Charleville AMO | 3 | 27 | 25 | Mixed | TBA |
| 20 | Wagga AMO | 4 | 25 | 24 | Cold | Suitable |
| 21 | Melbourne RO | 6 | 24 | 23 | Cold | Suitable |
| 22 | East Sale AMO | 6 | 23 | 23 | Cold | TBA |
| 23 | Launceston (Ti Tree Bend) | 7 | 22.5 | 23 | Cold | TBA |
| 24 | Canberra Airport | 7 | 24 | 23 | Cold | Suitable |
| 25 | Cabramurra | 8 | 23 | 23 | Cold | TBA |
| 26 | Hobart RO | 7 | 23 | 23 | Cold | TBA |
| 27 | Mildura AMO | 4 | 25 | 24 | Mixed | Suitable |
| 28 | Richmond | 6 | 24.5 | 24 | Mixed | Not recommended |
| 29 | Weipa Aero | 1 | 26 | 25 | Hot/humid | Not recommended |
| 30 | Wyndham PO | 1 | 27.5 | 25 | Hot/humid | TBA |
| 31 | Willis Island | 1 | 26.5 | 25 | Hot/humid | TBA |
| 32 | Cairns AMO | 1 | 26.5 | 25 | Hot/humid | Not recommended |
| 33 | Broome Airport | 1 | 27 | 25 | Hot/humid | TBA |
| 34 | Learmouth Airport | 1 | 26.5 | 25 | Hot/humid | TBA |
| 35 | Mackay MO | 2 | 26 | 25 | Hot/humid | TBA |
| 36 | Gladstone Radar | 2 | 26 | 25 | Hot/humid | TBA |
| 37 | Halls Creek Airport | 3 | 27 | 25 | Hot/humid | TBA |
| 38 | Tennant Creek | 3 | 27 | 25 | Hot/humid | Suitable |
| 39 | Mount Isa AMO | 3 | 27 | 25 | Hot/humid | Suitable |
| 40 | Newman | 3 | 28 | 25 | Hot/humid | TBA |
| 41 | Giles MO | 4 | 27.5 | 25 | Mixed | Suitable |
| 42 | Meekatharra Airport | 4 | 28 | 25 | Mixed | TBA |
| 43 | Oodnadatta Airport | 4 | 27 | 25 | Mixed | Suitable |
| 44 | Kalgoorlie | 4 | 26 | 25 | Mixed | Suitable |
| 45 | Woomera Aerodrome | 4 | 26 | 25 | Mixed | Suitable |
| 46 | Cobar AMO | 4 | 26.5 | 25 | Mixed | Suitable |
| 47 | Bickley | 4 | 24.5 | 24 | Cold | TBA |
| 48 | Dubbo Airport | 4 | 25 | 24 | Cold | Suitable |
| 49 | Katanning | 4 | 24.5 | 24 | Cold | TBA |
| 50 | Oakey Aero | 5 | 25 | 24 | Mixed | TBA |
| 51 | Forrest AMO | 5 | 25.5 | 24 | Mixed | TBA |
| 52 | Swanbourne | 5 | 25 | 24 | Mixed | TBA |
| 53 | Ceduna | 5 | 24.5 | 24 | Mixed | Suitable |
| 54 | Mandurah | 5 | 25 | 24 | Mixed | TBA |
| 55 | Esperance | 5 | 24 | 23 | Cold | TBA |
| 56 | Mascot AMO | 5 | 24.5 | 24 | Mixed | Not recommended |
| 57 | Manjimup | 6 | 23.5 | 23 | Cold | TBA |
| 58 | Albany Airport | 6 | 23.5 | 23 | Cold | TBA |
| 59 | Mount Lofty | 6 | 23 | 23 | Cold | Suitable |
| 60 | Tullamarine | 6 | 24 | 23 | Cold | Suitable |
| 61 | Mount Gambier AMO | 6 | 23.5 | 23 | Cold | Suitable |
| 62 | Moorabbin Airport | 6 | 24 | 23 | Cold | Suitable |
| 63 | Warrnambool | 6 | 23 | 23 | Cold | TBA |
| 64 | Cape Otway | 6 | 23 | 23 | Cold | TBA |
| 65 | Orange AP | 7 | 23 | 23 | Cold | TBA |
| 66 | Ballarat Aerodrome | 7 | 23.5 | 23 | Cold | TBA |
| 67 | Low Head | 7 | 23 | 23 | Cold | TBA |
| 68 | Launceston AP | 7 | 23.5 | 23 | Cold | TBA |
| 69 | Thredbo Valley | 8 | 22.5 | 23 | Cold | TBA |

# Appendix B – Water Heater Performance Coefficients for annual energy by climate zone for Whole of Home rating

This Appendix sets out the coefficients for water heater modelling used to estimate the annual purchased energy *EAnnual-input* (energy input) from the annual hot water demand energy *EAnnual-output* (energy output) based on a third order polynomial with different coefficients for each type of system and each climate zone. The application of coefficients a, b, c and d is defined in Equation 21, which is repeated below for convenience:



The annual hot water demand energy *EAnnual-output* (energy output), which is the input parameter for this equation, is defined in Equation 20. Coefficients are set out in Table 46.

Codes used to identify each water heater type and climate are in the following general format:

XXX-Y-ZZ

Where:

XXX is a three letter code to identify the water heater type – see Table 27

Y is an integer to identify the climate zone (1 to 5 for heat pump systems and 1 to 4 for all other water heater types)

ZZ is a specific 2 digit code that is specific performance level for the water heater type – see Table 27.

A validation spreadsheet is available – this contains an electronic copy of all coefficients and worked examples for all climates, water heater types and selected household sizes. This can be used to validate software.

Table 46: Modelling coefficients for annual energy input for all water heaters, all climates (Equation 21)

| **System ID** | **Climate** | **STCs** | **CER Size** | **Description** | **Fuel** | **Energisation** | **Function** | **a** | **b** | **c** | **d** | **R2** | **Notes** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| SOF-1-00 | 1 | #N/A | #N/A | Solid fuel | Solid | Any | Main | 0 | -0.72615 | 1427.23 | 4743 | 1 | Equivalent to original curve |
| SOF-2-00 | 2 | #N/A | #N/A | Solid fuel | Solid | Any | Main | 0 | -0.54175 | 1423.292 | 4885 | 1 | Equivalent to original curve |
| SOF-3-00 | 3 | #N/A | #N/A | Solid fuel | Solid | Any | Main | 0 | -0.27092 | 1415.114 | 5152 | 1 | Equivalent to original curve |
| SOF-4-00 | 4 | #N/A | #N/A | Solid fuel | Solid | Any | Main | 0 | 0.161378 | 1404.513 | 5464 | 1 | Equivalent to original curve |
| ESS-1-00 | 1 | #N/A | #N/A | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 1020.408 | 1524.119 | 1 |  |
| ESS-2-00 | 2 | #N/A | #N/A | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 1020.408 | 1583.626 | 1 |  |
| ESS-3-00 | 3 | #N/A | #N/A | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 1020.408 | 1681.753 | 1 |  |
| ESS-4-00 | 4 | #N/A | #N/A | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 1020.408 | 1799.074 | 1 |  |
| ESL-1-00 | 1 | #N/A | #N/A | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 963.8672 | 2525.968 | 1 |  |
| ESL-2-00 | 2 | #N/A | #N/A | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 961.3917 | 2624.592 | 1 |  |
| ESL-3-00 | 3 | #N/A | #N/A | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 958.0354 | 2787.221 | 1 |  |
| ESL-4-00 | 4 | #N/A | #N/A | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 953.8245 | 2981.66 | 1 |  |
| EIN-1-00 | 1 | #N/A | #N/A | Electric instantaneous | Electricity | Continuous | Main | 0.130838 | -5.18353 | 1195.708 | 0 | 1 | Instant same parameters across climates |
| EIN-2-00 | 2 | #N/A | #N/A | Electric instantaneous | Electricity | Continuous | Main | 0.130838 | -5.18353 | 1195.708 | 0 | 1 |  |
| EIN-3-00 | 3 | #N/A | #N/A | Electric instantaneous | Electricity | Continuous | Main | 0.130838 | -5.18353 | 1195.708 | 0 | 1 |  |
| EIN-4-00 | 4 | #N/A | #N/A | Electric instantaneous | Electricity | Continuous | Main | 0.130838 | -5.18353 | 1195.708 | 0 | 1 |  |
| GST-1-40 | 1 | #N/A | #N/A | Gas storage 4.0 star | Gas | Continuous | Main | 0 | 0 | 1215.27 | 5856.144 | 1 | No change |
| GST-2-40 | 2 | #N/A | #N/A | Gas storage 4.0 star | Gas | Continuous | Main | 0 | 0 | 1214.224 | 6084.792 | 1 | No change |
| GST-3-40 | 3 | #N/A | #N/A | Gas storage 4.0 star | Gas | Continuous | Main | 0 | 0 | 1212.806 | 6461.826 | 1 | No change |
| GST-4-40 | 4 | #N/A | #N/A | Gas storage 4.0 star | Gas | Continuous | Main | 0 | 0 | 1211.027 | 6912.608 | 1 | No change |
| GST-1-45 | 1 | #N/A | #N/A | Gas storage 4.5 star | Gas | Continuous | Main | 0 | 0 | 1186.804 | 5263.561 | 1 | Updated 31 Oct 2021 |
| GST-2-45 | 2 | #N/A | #N/A | Gas storage 4.5 star | Gas | Continuous | Main | 0 | 0 | 1185.888 | 5469.072 | 1 | Updated 31 Oct 2021 |
| GST-3-45 | 3 | #N/A | #N/A | Gas storage 4.5 star | Gas | Continuous | Main | 0 | 0 | 1184.645 | 5807.953 | 1 | Updated 31 Oct 2021 |
| GST-4-45 | 4 | #N/A | #N/A | Gas storage 4.5 star | Gas | Continuous | Main | 0 | 0 | 1183.087 | 6213.119 | 1 | Updated 31 Oct 2021 |
| GST-1-50 | 1 | #N/A | #N/A | Gas storage 5.0 star | Gas | Continuous | Main | 0 | 0 | 1147.046 | 4810.404 | 1 | No change |
| GST-2-50 | 2 | #N/A | #N/A | Gas storage 5.0 star | Gas | Continuous | Main | 0 | 0 | 1146.238 | 4998.222 | 1 | No change |
| GST-3-50 | 3 | #N/A | #N/A | Gas storage 5.0 star | Gas | Continuous | Main | 0 | 0 | 1145.142 | 5307.929 | 1 | No change |
| GST-4-50 | 4 | #N/A | #N/A | Gas storage 5.0 star | Gas | Continuous | Main | 0 | 0 | 1143.768 | 5678.214 | 1 | No change |
| GIN-1-40 | 1 | #N/A | #N/A | Gas instantaneous 4.0 star | Gas | Continuous | Main | 0.43193 | -17.1122 | 1800.229 | 0 | 1 | Instant same parameters across climates |
| GIN-2-40 | 2 | #N/A | #N/A | Gas instantaneous 4.0 star | Gas | Continuous | Main | 0.43193 | -17.1122 | 1800.229 | 0 | 1 |  |
| GIN-3-40 | 3 | #N/A | #N/A | Gas instantaneous 4.0 star | Gas | Continuous | Main | 0.43193 | -17.1122 | 1800.229 | 0 | 1 |  |
| GIN-4-40 | 4 | #N/A | #N/A | Gas instantaneous 4.0 star | Gas | Continuous | Main | 0.43193 | -17.1122 | 1800.229 | 0 | 1 |  |
| GIN-1-45 | 1 | #N/A | #N/A | Gas instantaneous 4.5 star | Gas | Continuous | Main | 0.379575 | -15.038 | 1708.632 | 0 | 1 |  |
| GIN-2-45 | 2 | #N/A | #N/A | Gas instantaneous 4.5 star | Gas | Continuous | Main | 0.379575 | -15.038 | 1708.632 | 0 | 1 |  |
| GIN-3-45 | 3 | #N/A | #N/A | Gas instantaneous 4.5 star | Gas | Continuous | Main | 0.379575 | -15.038 | 1708.632 | 0 | 1 |  |
| GIN-4-45 | 4 | #N/A | #N/A | Gas instantaneous 4.5 star | Gas | Continuous | Main | 0.379575 | -15.038 | 1708.632 | 0 | 1 |  |
| GIN-1-50 | 1 | #N/A | #N/A | Gas instantaneous 5.0 star | Gas | Continuous | Main | 0.333764 | -13.2231 | 1621.169 | 0 | 1 |  |
| GIN-2-50 | 2 | #N/A | #N/A | Gas instantaneous 5.0 star | Gas | Continuous | Main | 0.333764 | -13.2231 | 1621.169 | 0 | 1 |  |
| GIN-3-50 | 3 | #N/A | #N/A | Gas instantaneous 5.0 star | Gas | Continuous | Main | 0.333764 | -13.2231 | 1621.169 | 0 | 1 |  |
| GIN-4-50 | 4 | #N/A | #N/A | Gas instantaneous 5.0 star | Gas | Continuous | Main | 0.333764 | -13.2231 | 1621.169 | 0 | 1 |  |
| GIN-1-55 | 1 | #N/A | #N/A | Gas instantaneous 5.5 star | Gas | Continuous | Main | 0.281409 | -11.1489 | 1530.145 | 0 | 1 |  |
| GIN-2-55 | 2 | #N/A | #N/A | Gas instantaneous 5.5 star | Gas | Continuous | Main | 0.281409 | -11.1489 | 1530.145 | 0 | 1 |  |
| GIN-3-55 | 3 | #N/A | #N/A | Gas instantaneous 5.5 star | Gas | Continuous | Main | 0.281409 | -11.1489 | 1530.145 | 0 | 1 |  |
| GIN-4-55 | 4 | #N/A | #N/A | Gas instantaneous 5.5 star | Gas | Continuous | Main | 0.281409 | -11.1489 | 1530.145 | 0 | 1 |  |
| GIN-1-60 | 1 | #N/A | #N/A | Gas instantaneous 6.0 star | Gas | Continuous | Main | 0.209421 | -8.29683 | 1432.319 | 0 | 1 |  |
| GIN-2-60 | 2 | #N/A | #N/A | Gas instantaneous 6.0 star | Gas | Continuous | Main | 0.209421 | -8.29683 | 1432.319 | 0 | 1 |  |
| GIN-3-60 | 3 | #N/A | #N/A | Gas instantaneous 6.0 star | Gas | Continuous | Main | 0.209421 | -8.29683 | 1432.319 | 0 | 1 |  |
| GIN-4-60 | 4 | #N/A | #N/A | Gas instantaneous 6.0 star | Gas | Continuous | Main | 0.209421 | -8.29683 | 1432.319 | 0 | 1 |  |
| GIN-1-65 | 1 | #N/A | #N/A | Gas instantaneous 6.5 star | Gas | Continuous | Main | 0.235598 | -9.33394 | 1368.679 | 0 | 1 |  |
| GIN-2-65 | 2 | #N/A | #N/A | Gas instantaneous 6.5 star | Gas | Continuous | Main | 0.235598 | -9.33394 | 1368.679 | 0 | 1 |  |
| GIN-3-65 | 3 | #N/A | #N/A | Gas instantaneous 6.5 star | Gas | Continuous | Main | 0.235598 | -9.33394 | 1368.679 | 0 | 1 |  |
| GIN-4-65 | 4 | #N/A | #N/A | Gas instantaneous 6.5 star | Gas | Continuous | Main | 0.235598 | -9.33394 | 1368.679 | 0 | 1 |  |
| GIN-1-70 | 1 | #N/A | #N/A | Gas instantaneous 7.0 star | Gas | Continuous | Main | 0.242143 | -9.59322 | 1297.781 | 0 | 1 |  |
| GIN-2-70 | 2 | #N/A | #N/A | Gas instantaneous 7.0 star | Gas | Continuous | Main | 0.242143 | -9.59322 | 1297.781 | 0 | 1 |  |
| GIN-3-70 | 3 | #N/A | #N/A | Gas instantaneous 7.0 star | Gas | Continuous | Main | 0.242143 | -9.59322 | 1297.781 | 0 | 1 |  |
| GIN-4-70 | 4 | #N/A | #N/A | Gas instantaneous 7.0 star | Gas | Continuous | Main | 0.242143 | -9.59322 | 1297.781 | 0 | 1 |  |
| GIN-1-99 | 1 | #N/A | #N/A | Gas instantaneous ALL | Electricity | Continuous | Auxiliary | 0.000856 | -0.0339 | 4.686018 | 100.9152 | 1 | Elec for gas same in all climates and stars |
| GIN-2-99 | 2 | #N/A | #N/A | Gas instantaneous ALL | Electricity | Continuous | Auxiliary | 0.000856 | -0.0339 | 4.686018 | 100.9152 | 1 | Elec for gas same in all climates and stars |
| GIN-3-99 | 3 | #N/A | #N/A | Gas instantaneous ALL | Electricity | Continuous | Auxiliary | 0.000856 | -0.0339 | 4.686018 | 100.9152 | 1 | Elec for gas same in all climates and stars |
| GIN-4-99 | 4 | #N/A | #N/A | Gas instantaneous ALL | Electricity | Continuous | Auxiliary | 0.000856 | -0.0339 | 4.686018 | 100.9152 | 1 | Elec for gas same in all climates and stars |
| STE-1-12 | 1 | 12 | Small | Solar-electric | Electricity | Any | Main | -2.30066 | 83.03858 | 33.56288 | 609.56 | 0.999958 |  |
| STE-1-13 | 1 | 13 | Small | Solar-electric | Electricity | Any | Main | -2.25265 | 83.11951 | -10.9864 | 485.4525 | 0.999962 |  |
| STE-1-14 | 1 | 14 | Small | Solar-electric | Electricity | Any | Main | -2.1433 | 82.4108 | -81.1466 | 524.0959 | 0.999972 |  |
| STE-1-15 | 1 | 15 | Small | Solar-electric | Electricity | Any | Main | -2.03396 | 81.70208 | -151.307 | 562.7393 | 0.999971 |  |
| STE-1-16 | 1 | 16 | Small | Solar-electric | Electricity | Any | Main | -1.92461 | 80.99337 | -221.467 | 601.3827 | 0.999957 |  |
| STE-1-17 | 1 | 17 | Small | Solar-electric | Electricity | Any | Main | -1.64842 | 74.98008 | -261.701 | 611.4312 | 0.999938 |  |
| STE-1-18 | 1 | 18 | Small | Solar-electric | Electricity | Any | Main | -0.98294 | 56.58946 | -232.109 | 554.7586 | 0.99992 |  |
| STE-1-19 | 1 | 19 | Small | Solar-electric | Electricity | Any | Main | -0.20697 | 31.1329 | -140.31 | 399.7752 | 0.999872 |  |
| STE-1-20 | 1 | 20 | Small | Solar-electric | Electricity | Any | Main | 0.11001 | 1.552352 | 19.0158 | 47.70643 | 0.999986 | Propose to exclude |
| STE-1-21 | 1 | 21 | Medium | Solar-electric | Electricity | Any | Main | -1.06598 | 62.32547 | -62.447 | 561.3133 | 0.999724 |  |
| STE-1-22 | 1 | 22 | Medium | Solar-electric | Electricity | Any | Main | -1.03301 | 62.28397 | -103.491 | 570.6061 | 0.999712 |  |
| STE-1-23 | 1 | 23 | Medium | Solar-electric | Electricity | Any | Main | -1.00005 | 62.24246 | -144.535 | 579.8989 | 0.999699 |  |
| STE-1-24 | 1 | 24 | Medium | Solar-electric | Electricity | Any | Main | -0.96709 | 62.20096 | -185.579 | 589.1917 | 0.999683 |  |
| STE-1-25 | 1 | 25 | Medium | Solar-electric | Electricity | Any | Main | -0.83764 | 58.75632 | -200.327 | 578.6838 | 0.999668 |  |
| STE-1-26 | 1 | 26 | Medium | Solar-electric | Electricity | Any | Main | -0.61172 | 51.90854 | -188.779 | 548.3753 | 0.999653 |  |
| STE-1-27 | 1 | 27 | Medium | Solar-electric | Electricity | Any | Main | -0.3858 | 45.06076 | -177.23 | 518.0668 | 0.999633 |  |
| STE-1-28 | 1 | 28 | Large | Solar-electric | Electricity | Any | Main | 0.448955 | 19.10699 | 99.03849 | 28.58955 | 0.999881 |  |
| STE-1-29 | 1 | 29 | Large | Solar-electric | Electricity | Any | Main | 0.516878 | 17.01246 | 89.09802 | 40.5195 | 0.999893 |  |
| STE-1-30 | 1 | 30 | Large | Solar-electric | Electricity | Any | Main | 0.5848 | 14.91793 | 79.15754 | 52.44944 | 0.999905 |  |
| STE-1-31 | 1 | 31 | Large | Solar-electric | Electricity | Any | Main | 0.652723 | 12.82341 | 69.21707 | 64.37939 | 0.999917 |  |
| STE-1-32 | 1 | 32 | Large | Solar-electric | Electricity | Any | Main | 0.720645 | 10.72888 | 59.27659 | 76.30934 | 0.999927 |  |
| STE-1-33 | 1 | 33 | Large | Solar-electric | Electricity | Any | Main | 0.787099 | 8.566705 | 50.81965 | 86.12824 | 0.999936 |  |
| STE-1-34 | 1 | 34 | Large | Solar-electric | Electricity | Any | Main | 0.840333 | 5.795667 | 55.71449 | 76.94772 | 0.999939 |  |
| STE-1-35 | 1 | 35 | Large | Solar-electric | Electricity | Any | Main | 0.893567 | 3.02463 | 60.60932 | 67.7672 | 0.999942 |  |
| STE-1-36 | 1 | 36 | Large | Solar-electric | Electricity | Any | Main | 0.946802 | 0.253593 | 65.50416 | 58.58669 | 0.999942 |  |
| STE-1-37 | 1 | 37 | Large | Solar-electric | Electricity | Any | Main | 0.996477 | -2.54946 | 71.82846 | 46.27163 | 0.999939 |  |
| STE-1-38 | 1 | 38 | Large | Solar-electric | Electricity | Any | Main | 1.031918 | -5.48055 | 83.87058 | 21.41842 | 0.999925 |  |
| STE-1-39 | 1 | 39 | Large | Solar-electric | Electricity | Any | Main | 1.06736 | -8.41165 | 95.91271 | -3.43479 | 0.999897 |  |
| STE-1-40 | 1 | 40 | Large | Solar-electric | Electricity | Any | Main | 1.058981 | -10.3863 | 103.7919 | -21.1084 | 0.999878 |  |
| STE-1-41 | 1 | 41 | Large | Solar-electric | Electricity | Any | Main | 1.031822 | -11.951 | 109.887 | -35.705 | 0.999862 |  |
| STE-1-42 | 1 | 42 | Large | Solar-electric | Electricity | Any | Main | 0.95478 | -12.6307 | 113.6694 | -54.769 | 0.999734 |  |
| STE-1-43 | 1 | 43 | Large | Solar-electric | Electricity | Any | Main | 0.80967 | -11.7351 | 106.8772 | -57.0934 | 0.999677 |  |
| STE-1-44 | 1 | 44 | Large | Solar-electric | Electricity | Any | Main | 0.569538 | -8.50683 | 84.50907 | -38.7977 | 0.999649 |  |
| STE-1-45 | 1 | 45 | Large | Solar-electric | Electricity | Any | Main | 0.301397 | -4.15191 | 52.68738 | -10.1156 | 0.999699 | Propose to exclude |
| STE-2-12 | 2 | 12 | Small | Solar-electric | Electricity | Any | Main | -2.27515 | 96.0848 | -161.381 | 1290.059 | 0.999924 |  |
| STE-2-13 | 2 | 13 | Small | Solar-electric | Electricity | Any | Main | -2.2501 | 96.84788 | -222.74 | 1253.303 | 0.999927 |  |
| STE-2-14 | 2 | 14 | Small | Solar-electric | Electricity | Any | Main | -2.22506 | 97.61096 | -284.099 | 1216.548 | 0.999931 |  |
| STE-2-15 | 2 | 15 | Small | Solar-electric | Electricity | Any | Main | -2.20002 | 98.37403 | -345.458 | 1179.792 | 0.999934 |  |
| STE-2-16 | 2 | 16 | Small | Solar-electric | Electricity | Any | Main | -1.94899 | 91.56507 | -380.43 | 1170.324 | 0.999942 |  |
| STE-2-17 | 2 | 17 | Small | Solar-electric | Electricity | Any | Main | -1.64147 | 82.86311 | -408.806 | 1167.679 | 0.999867 |  |
| STE-2-18 | 2 | 18 | Small | Solar-electric | Electricity | Any | Main | -1.29109 | 72.18634 | -418.799 | 1127.157 | 0.999683 |  |
| STE-2-19 | 2 | 19 | Small | Solar-electric | Electricity | Any | Main | -0.555 | 43.73638 | -263.342 | 745.7564 | 0.999803 |  |
| STE-2-20 | 2 | 20 | Small | Solar-electric | Electricity | Any | Main | 0.236292 | 1.115733 | 11.17285 | 143.8386 | 0.999829 | Propose to exclude |
| STE-2-21 | 2 | 21 | Medium | Solar-electric | Electricity | Any | Main | -2.09863 | 102.0643 | -446.045 | 1670.726 | 0.999765 |  |
| STE-2-22 | 2 | 22 | Medium | Solar-electric | Electricity | Any | Main | -2.06404 | 101.6233 | -476.61 | 1598.7 | 0.999779 |  |
| STE-2-23 | 2 | 23 | Medium | Solar-electric | Electricity | Any | Main | -1.93338 | 97.59179 | -482.742 | 1551.377 | 0.999739 |  |
| STE-2-24 | 2 | 24 | Medium | Solar-electric | Electricity | Any | Main | -1.77871 | 92.66263 | -482.765 | 1510.229 | 0.999672 |  |
| STE-2-25 | 2 | 25 | Medium | Solar-electric | Electricity | Any | Main | -1.62404 | 87.73346 | -482.788 | 1469.08 | 0.999586 |  |
| STE-2-26 | 2 | 26 | Medium | Solar-electric | Electricity | Any | Main | -1.46937 | 82.80429 | -482.811 | 1427.932 | 0.999476 |  |
| STE-2-27 | 2 | 27 | Medium | Solar-electric | Electricity | Any | Main | -1.3147 | 77.87513 | -482.834 | 1386.784 | 0.999338 |  |
| STE-2-28 | 2 | 28 | Large | Solar-electric | Electricity | Any | Main | 0.221797 | 26.48151 | 22.96278 | 455.6858 | 0.999508 |  |
| STE-2-29 | 2 | 29 | Large | Solar-electric | Electricity | Any | Main | 0.248215 | 25.6484 | 3.838764 | 462.6733 | 0.999486 |  |
| STE-2-30 | 2 | 30 | Large | Solar-electric | Electricity | Any | Main | 0.274632 | 24.81529 | -15.2852 | 469.6608 | 0.999459 |  |
| STE-2-31 | 2 | 31 | Large | Solar-electric | Electricity | Any | Main | 0.30105 | 23.98218 | -34.4093 | 476.6483 | 0.999427 |  |
| STE-2-32 | 2 | 32 | Large | Solar-electric | Electricity | Any | Main | 0.327467 | 23.14907 | -53.5333 | 483.6358 | 0.999388 |  |
| STE-2-33 | 2 | 33 | Large | Solar-electric | Electricity | Any | Main | 0.376839 | 20.90969 | -54.7706 | 459.1436 | 0.999382 |  |
| STE-2-34 | 2 | 34 | Large | Solar-electric | Electricity | Any | Main | 0.449166 | 17.26402 | -38.1211 | 403.1716 | 0.999413 |  |
| STE-2-35 | 2 | 35 | Large | Solar-electric | Electricity | Any | Main | 0.521493 | 13.61835 | -21.4717 | 347.1997 | 0.999444 |  |
| STE-2-36 | 2 | 36 | Large | Solar-electric | Electricity | Any | Main | 0.59382 | 9.972687 | -4.82222 | 291.2277 | 0.999473 |  |
| STE-2-37 | 2 | 37 | Large | Solar-electric | Electricity | Any | Main | 0.666147 | 6.327022 | 11.82722 | 235.2557 | 0.999498 |  |
| STE-2-38 | 2 | 38 | Large | Solar-electric | Electricity | Any | Main | 0.711125 | 3.402227 | 22.4529 | 196.3088 | 0.999526 |  |
| STE-2-39 | 2 | 39 | Large | Solar-electric | Electricity | Any | Main | 0.692288 | 2.159467 | 19.02311 | 197.087 | 0.999572 |  |
| STE-2-40 | 2 | 40 | Large | Solar-electric | Electricity | Any | Main | 0.673451 | 0.916706 | 15.59333 | 197.8652 | 0.999624 |  |
| STE-2-41 | 2 | 41 | Large | Solar-electric | Electricity | Any | Main | 0.673913 | -1.13344 | 21.13915 | 183.3136 | 0.999644 |  |
| STE-2-42 | 2 | 42 | Large | Solar-electric | Electricity | Any | Main | 0.693672 | -3.99097 | 35.66058 | 153.4323 | 0.999619 |  |
| STE-2-43 | 2 | 43 | Large | Solar-electric | Electricity | Any | Main | 0.714097 | -7.45047 | 62.08912 | 89.15036 | 0.999596 |  |
| STE-2-44 | 2 | 44 | Large | Solar-electric | Electricity | Any | Main | 0.70534 | -11.1039 | 97.46176 | -6.95007 | 0.999676 |  |
| STE-2-45 | 2 | 45 | Large | Solar-electric | Electricity | Any | Main | 0.526895 | -10.1168 | 98.18441 | -42.6623 | 0.999754 |  |
| STE-3-15 | 3 | 15 | Small | Solar-electric | Electricity | Any | Main | -0.32469 | 28.8115 | 257.2512 | 373.6616 | 0.999978 |  |
| STE-3-16 | 3 | 16 | Small | Solar-electric | Electricity | Any | Main | -0.3384 | 30.34192 | 198.4136 | 372.7606 | 0.999982 |  |
| STE-3-17 | 3 | 17 | Small | Solar-electric | Electricity | Any | Main | -0.33114 | 30.99594 | 145.8646 | 360.1895 | 0.999985 |  |
| STE-3-18 | 3 | 18 | Small | Solar-electric | Electricity | Any | Main | -0.24003 | 28.14433 | 118.4696 | 300.9382 | 0.99999 |  |
| STE-3-19 | 3 | 19 | Small | Solar-electric | Electricity | Any | Main | -0.14891 | 25.29271 | 91.07463 | 241.6869 | 0.999994 |  |
| STE-3-20 | 3 | 20 | Small | Solar-electric | Electricity | Any | Main | -0.07704 | 22.26917 | 68.22225 | 203.4773 | 0.999996 |  |
| STE-3-21 | 3 | 21 | Small | Solar-electric | Electricity | Any | Main | -0.00957 | 19.16904 | 41.32676 | 179.7079 | 0.999998 |  |
| STE-3-22 | 3 | 22 | Small | Solar-electric | Electricity | Any | Main | 0.04234 | 16.12333 | 12.23586 | 180.2728 | 0.999993 |  |
| STE-3-23 | 3 | 23 | Small | Solar-electric | Electricity | Any | Main | 0.080275 | 13.04206 | -17.0136 | 209.6441 | 0.999991 | Propose to exclude |
| STE-3-24 | 3 | 24 | Small | Solar-electric | Electricity | Any | Main | 0.265658 | 0.245965 | 37.36317 | 45.09779 | 0.999994 | Propose to exclude |
| STE-3-25 | 3 | 25 | Medium | Solar-electric | Electricity | Any | Main | -0.37938 | 31.87688 | 115.5276 | 407.0767 | 0.999991 |  |
| STE-3-26 | 3 | 26 | Medium | Solar-electric | Electricity | Any | Main | -0.32912 | 30.31357 | 101.7449 | 372.2813 | 0.999992 |  |
| STE-3-27 | 3 | 27 | Medium | Solar-electric | Electricity | Any | Main | -0.27887 | 28.75026 | 87.96217 | 337.4859 | 0.999992 |  |
| STE-3-28 | 3 | 28 | Medium | Solar-electric | Electricity | Any | Main | -0.22861 | 27.18695 | 74.17947 | 302.6905 | 0.999991 |  |
| STE-3-29 | 3 | 29 | Medium | Solar-electric | Electricity | Any | Main | -0.18332 | 25.43078 | 61.77099 | 275.3484 | 0.999989 |  |
| STE-3-30 | 3 | 30 | Medium | Solar-electric | Electricity | Any | Main | -0.13928 | 23.6264 | 49.70607 | 249.8696 | 0.999985 |  |
| STE-3-31 | 3 | 31 | Medium | Solar-electric | Electricity | Any | Main | -0.09752 | 21.8694 | 37.339 | 227.9479 | 0.999983 |  |
| STE-3-32 | 3 | 32 | Medium | Solar-electric | Electricity | Any | Main | -0.06482 | 20.30198 | 23.76338 | 220.2549 | 0.999984 |  |
| STE-3-33 | 3 | 33 | Medium | Solar-electric | Electricity | Any | Main | -0.03425 | 18.73841 | 10.42493 | 214.9393 | 0.999984 |  |
| STE-3-34 | 3 | 34 | Medium | Solar-electric | Electricity | Any | Main | -0.00863 | 17.18384 | -2.3601 | 215.1712 | 0.999991 |  |
| STE-3-35 | 3 | 35 | Large | Solar-electric | Electricity | Any | Main | -0.11913 | 21.38587 | 72.79583 | 185.4216 | 0.999995 |  |
| STE-3-36 | 3 | 36 | Large | Solar-electric | Electricity | Any | Main | -0.0943 | 20.41085 | 63.82276 | 173.227 | 0.999995 |  |
| STE-3-37 | 3 | 37 | Large | Solar-electric | Electricity | Any | Main | -0.07568 | 19.5675 | 54.15694 | 170.8314 | 0.999997 |  |
| STE-3-38 | 3 | 38 | Large | Solar-electric | Electricity | Any | Main | -0.05775 | 18.73877 | 44.41415 | 169.5246 | 0.999997 |  |
| STE-3-39 | 3 | 39 | Large | Solar-electric | Electricity | Any | Main | -0.03981 | 17.91004 | 34.67135 | 168.2177 | 0.999995 |  |
| STE-3-40 | 3 | 40 | Large | Solar-electric | Electricity | Any | Main | -0.02521 | 17.08779 | 25.38866 | 170.7533 | 0.999994 |  |
| STE-3-41 | 3 | 41 | Large | Solar-electric | Electricity | Any | Main | -0.01144 | 16.26717 | 16.221 | 174.2494 | 0.999992 |  |
| STE-3-42 | 3 | 42 | Large | Solar-electric | Electricity | Any | Main | -0.00522 | 15.68764 | 5.523045 | 183.5055 | 0.999992 |  |
| STE-3-43 | 3 | 43 | Large | Solar-electric | Electricity | Any | Main | -0.00656 | 15.34921 | -6.70519 | 198.5214 | 0.999992 |  |
| STE-3-44 | 3 | 44 | Large | Solar-electric | Electricity | Any | Main | 0.009764 | 14.3709 | -13.6452 | 205.7806 | 0.999993 |  |
| STE-3-45 | 3 | 45 | Large | Solar-electric | Electricity | Any | Main | 0.037588 | 12.94908 | -16.7759 | 207.377 | 0.999988 |  |
| STE-4-17 | 4 | 17 | Small | Solar-electric | Electricity | Any | Main | -0.13731 | 20.08463 | 238.2189 | 664.9692 | 0.999997 |  |
| STE-4-18 | 4 | 18 | Small | Solar-electric | Electricity | Any | Main | -0.11723 | 18.97097 | 210.0392 | 608.2988 | 0.999997 |  |
| STE-4-19 | 4 | 19 | Small | Solar-electric | Electricity | Any | Main | -0.09731 | 17.75321 | 183.5524 | 545.0694 | 0.999996 |  |
| STE-4-20 | 4 | 20 | Small | Solar-electric | Electricity | Any | Main | -0.07977 | 16.5508 | 159.467 | 469.4848 | 0.999995 |  |
| STE-4-21 | 4 | 21 | Small | Solar-electric | Electricity | Any | Main | -0.073 | 15.79145 | 128.4473 | 417.1732 | 0.999997 |  |
| STE-4-22 | 4 | 22 | Small | Solar-electric | Electricity | Any | Main | -0.0571 | 14.66911 | 98.66823 | 370.354 | 0.999992 | Propose to exclude |
| STE-4-23 | 4 | 23 | Small | Solar-electric | Electricity | Any | Main | -0.02821 | 12.85307 | 77.3614 | 289.6894 | 0.999996 | Propose to exclude |
| STE-4-24 | 4 | 24 | Small | Solar-electric | Electricity | Any | Main | -0.02689 | 12.19881 | 43.25572 | 276.8921 | 0.999996 | Propose to exclude |
| STE-4-25 | 4 | 25 | Small | Solar-electric | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| STE-4-26 | 4 | 26 | Small | Solar-electric | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| STE-4-27 | 4 | 27 | Medium | Solar-electric | Electricity | Any | Main | -0.04028 | 15.10954 | 249.5076 | 510.2918 | 0.999991 |  |
| STE-4-28 | 4 | 28 | Medium | Solar-electric | Electricity | Any | Main | -0.03277 | 14.59287 | 231.0886 | 477.5969 | 0.999992 |  |
| STE-4-29 | 4 | 29 | Medium | Solar-electric | Electricity | Any | Main | -0.02523 | 14.04885 | 212.9602 | 443.218 | 0.999993 |  |
| STE-4-30 | 4 | 30 | Medium | Solar-electric | Electricity | Any | Main | -0.01944 | 13.53833 | 196.7251 | 400.9741 | 0.999994 |  |
| STE-4-31 | 4 | 31 | Medium | Solar-electric | Electricity | Any | Main | -0.01741 | 13.1808 | 177.7708 | 366.0485 | 0.999995 |  |
| STE-4-32 | 4 | 32 | Medium | Solar-electric | Electricity | Any | Main | -0.01816 | 12.95171 | 156.0304 | 343.5914 | 0.999995 |  |
| STE-4-33 | 4 | 33 | Medium | Solar-electric | Electricity | Any | Main | -0.0128 | 12.49374 | 137.8175 | 320.6567 | 0.999995 |  |
| STE-4-34 | 4 | 34 | Medium | Solar-electric | Electricity | Any | Main | -0.01143 | 12.20522 | 116.6755 | 307.4195 | 0.999994 | Propose to exclude |
| STE-4-35 | 4 | 35 | Medium | Solar-electric | Electricity | Any | Main | 0.009395 | 11.01676 | 107.4668 | 248.661 | 0.999997 | Propose to exclude |
| STE-4-36 | 4 | 36 | Medium | Solar-electric | Electricity | Any | Main | 0.001658 | 10.95101 | 85.866 | 235.7741 | 0.999993 | Propose to exclude |
| STE-4-37 | 4 | 37 | Medium | Solar-electric | Electricity | Any | Main | 0.003881 | 10.5461 | 63.39686 | 232.0488 | 0.999996 | Propose to exclude |
| STE-4-38 | 4 | 38 | Large | Solar-electric | Electricity | Any | Main | -0.1313 | 16.31283 | 138.6852 | 409.7989 | 1 |  |
| STE-4-39 | 4 | 39 | Large | Solar-electric | Electricity | Any | Main | -0.1257 | 15.98608 | 128.1268 | 394.8471 | 1 |  |
| STE-4-40 | 4 | 40 | Large | Solar-electric | Electricity | Any | Main | -0.11934 | 15.63717 | 118.9264 | 380.9111 | 1 |  |
| STE-4-41 | 4 | 41 | Large | Solar-electric | Electricity | Any | Main | -0.11188 | 15.23264 | 108.3179 | 363.5334 | 0.999999 |  |
| STE-4-42 | 4 | 42 | Large | Solar-electric | Electricity | Any | Main | -0.10808 | 14.98422 | 95.29685 | 356.2913 | 0.999999 |  |
| STE-4-43 | 4 | 43 | Large | Solar-electric | Electricity | Any | Main | -0.09255 | 14.19714 | 89.00761 | 320.1808 | 0.999997 |  |
| STE-4-44 | 4 | 44 | Large | Solar-electric | Electricity | Any | Main | -0.07492 | 13.3039 | 83.66043 | 283.8512 | 0.999999 |  |
| STE-4-45 | 4 | 45 | Large | Solar-electric | Electricity | Any | Main | -0.08239 | 13.40351 | 68.9721 | 278.8225 | 1 |  |
| STG-1-9 | 1 | 9 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -4.1268 | 132.145 | 99.10718 | 1112.035 | 0.999987 |  |
| STG-1-10 | 1 | 10 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -3.97908 | 130.6938 | 20.87734 | 1116.964 | 0.999988 |  |
| STG-1-11 | 1 | 11 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -3.83137 | 129.2425 | -57.3525 | 1121.892 | 0.999989 |  |
| STG-1-12 | 1 | 12 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -3.60344 | 125.4764 | -131.498 | 1165.809 | 0.999989 |  |
| STG-1-13 | 1 | 13 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -3.35545 | 121.1315 | -204.621 | 1219.474 | 0.999984 |  |
| STG-1-14 | 1 | 14 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -3.10747 | 116.7867 | -277.745 | 1273.138 | 0.999971 |  |
| STG-1-15 | 1 | 15 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -2.67668 | 106.4508 | -314.429 | 1279.029 | 0.999951 |  |
| STG-1-16 | 1 | 16 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -1.9717 | 87.12836 | -296.452 | 1213.259 | 0.999919 |  |
| STG-1-17 | 1 | 17 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -1.20235 | 63.67425 | -243.011 | 1088.213 | 0.99987 |  |
| STG-1-18 | 1 | 18 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -1.57748 | 88.33343 | -50.3897 | 1234.767 | 0.999582 |  |
| STG-1-19 | 1 | 19 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -1.49678 | 86.55528 | -91.1418 | 1245.804 | 0.999579 |  |
| STG-1-20 | 1 | 20 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -1.41608 | 84.77713 | -131.894 | 1256.841 | 0.999576 |  |
| STG-1-21 | 1 | 21 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -1.33538 | 82.99899 | -172.646 | 1267.877 | 0.999572 |  |
| STG-1-22 | 1 | 22 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -1.25468 | 81.22084 | -213.398 | 1278.914 | 0.999568 |  |
| STG-1-23 | 1 | 23 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -1.0486 | 74.7886 | -215.735 | 1247.281 | 0.999565 |  |
| STG-1-24 | 1 | 24 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -0.81117 | 67.19283 | -208.468 | 1204.981 | 0.999561 |  |
| STG-1-25 | 1 | 25 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 1.307303 | 4.682713 | 339.1673 | 273.9715 | 0.999713 |  |
| STG-1-26 | 1 | 26 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 1.330429 | 3.59421 | 315.9305 | 296.2521 | 0.999721 |  |
| STG-1-27 | 1 | 27 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 1.353555 | 2.505707 | 292.6936 | 318.5327 | 0.999729 |  |
| STG-1-28 | 1 | 28 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 1.376681 | 1.417204 | 269.4567 | 340.8133 | 0.999738 |  |
| STG-1-29 | 1 | 29 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 1.399807 | 0.328702 | 246.2198 | 363.0939 | 0.999748 |  |
| STG-1-30 | 1 | 30 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 1.422933 | -0.7598 | 222.983 | 385.3745 | 0.999758 |  |
| STG-1-31 | 1 | 31 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 1.446059 | -1.8483 | 199.7461 | 407.6551 | 0.999768 |  |
| STG-1-32 | 1 | 32 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 1.453284 | -3.53693 | 190.8189 | 410.5343 | 0.999773 |  |
| STG-1-33 | 1 | 33 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 1.46051 | -5.22556 | 181.8918 | 413.4136 | 0.999778 |  |
| STG-1-34 | 1 | 34 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 1.467735 | -6.91419 | 172.9646 | 416.2928 | 0.999783 |  |
| STG-1-35 | 1 | 35 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 1.47496 | -8.60281 | 164.0375 | 419.1721 | 0.999788 |  |
| STG-1-36 | 1 | 36 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 1.452157 | -9.8341 | 155.1856 | 420.3568 | 0.999791 |  |
| STG-1-37 | 1 | 37 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 1.399325 | -10.6081 | 146.409 | 419.847 | 0.999787 |  |
| STG-1-38 | 1 | 38 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 1.346493 | -11.382 | 137.6324 | 419.3373 | 0.999776 |  |
| STG-1-39 | 1 | 39 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 1.255681 | -11.2392 | 122.7842 | 429.0847 | 0.999765 |  |
| STG-1-40 | 1 | 40 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 1.107899 | -9.72122 | 98.82886 | 454.2178 | 0.999767 |  |
| STG-1-41 | 1 | 41 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.962584 | -8.37268 | 76.70252 | 474.2803 | 0.999766 |  |
| STG-1-42 | 1 | 42 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.815481 | -7.14189 | 56.48808 | 487.5624 | 0.999753 |  |
| STG-1-43 | 1 | 43 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.618193 | -4.6139 | 28.65725 | 507.0266 | 0.999668 |  |
| STG-1-44 | 1 | 44 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.388478 | -0.99592 | -5.9865 | 530.9588 | 0.999544 |  |
| STG-1-45 | 1 | 45 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.133254 | 3.432486 | -47.8445 | 547.7484 | 0.999113 |  |
| STG-2-9 | 2 | 9 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -3.85938 | 150.7586 | -6.05906 | 1193.664 | 0.999456 |  |
| STG-2-10 | 2 | 10 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -3.73432 | 149.0577 | -95.6656 | 1266.456 | 0.9995 |  |
| STG-2-11 | 2 | 11 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -3.60926 | 147.3567 | -185.272 | 1339.248 | 0.999546 |  |
| STG-2-12 | 2 | 12 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -3.48421 | 145.6558 | -274.879 | 1412.04 | 0.999592 |  |
| STG-2-13 | 2 | 13 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -3.35915 | 143.9549 | -364.485 | 1484.832 | 0.999638 |  |
| STG-2-14 | 2 | 14 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -3.09487 | 137.4354 | -436.112 | 1576.649 | 0.999721 |  |
| STG-2-15 | 2 | 15 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -2.69135 | 126.0974 | -489.758 | 1687.491 | 0.999824 |  |
| STG-2-16 | 2 | 16 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -2.28784 | 114.7594 | -543.404 | 1798.333 | 0.999889 |  |
| STG-2-17 | 2 | 17 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -1.56121 | 88.56794 | -460.959 | 1605.651 | 0.999926 |  |
| STG-2-18 | 2 | 18 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -4.31045 | 192.5994 | -957.707 | 3271.048 | 0.999559 |  |
| STG-2-19 | 2 | 19 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -4.16062 | 188.1931 | -974.147 | 3203.882 | 0.999572 |  |
| STG-2-20 | 2 | 20 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -4.01078 | 183.7869 | -990.586 | 3136.715 | 0.999585 |  |
| STG-2-21 | 2 | 21 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -3.77343 | 175.968 | -981.835 | 3077.698 | 0.999566 |  |
| STG-2-22 | 2 | 22 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -3.5142 | 167.2959 | -966.787 | 3020.719 | 0.999533 |  |
| STG-2-23 | 2 | 23 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -3.25496 | 158.6239 | -951.738 | 2963.74 | 0.999491 |  |
| STG-2-24 | 2 | 24 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -2.99573 | 149.9518 | -936.69 | 2906.761 | 0.999438 |  |
| STG-2-25 | 2 | 25 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.638496 | 34.68411 | 17.92354 | 1157.767 | 0.998056 |  |
| STG-2-26 | 2 | 26 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.65717 | 33.65744 | -5.65443 | 1176.27 | 0.998075 |  |
| STG-2-27 | 2 | 27 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.675843 | 32.63076 | -29.2324 | 1194.773 | 0.998094 |  |
| STG-2-28 | 2 | 28 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.694516 | 31.60409 | -52.8104 | 1213.276 | 0.998115 |  |
| STG-2-29 | 2 | 29 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.71319 | 30.57741 | -76.3884 | 1231.78 | 0.998136 |  |
| STG-2-30 | 2 | 30 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.731863 | 29.55074 | -99.9663 | 1250.283 | 0.998157 |  |
| STG-2-31 | 2 | 31 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.776401 | 26.86332 | -101.674 | 1222.759 | 0.9982 |  |
| STG-2-32 | 2 | 32 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.846804 | 22.51516 | -81.5112 | 1149.209 | 0.998267 |  |
| STG-2-33 | 2 | 33 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.917208 | 18.167 | -61.3484 | 1075.659 | 0.998338 |  |
| STG-2-34 | 2 | 34 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.987611 | 13.81884 | -41.1856 | 1002.109 | 0.998415 |  |
| STG-2-35 | 2 | 35 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 1.058014 | 9.47068 | -21.0228 | 928.5583 | 0.998497 |  |
| STG-2-36 | 2 | 36 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 1.128417 | 5.12252 | -0.86007 | 855.0081 | 0.998587 |  |
| STG-2-37 | 2 | 37 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 1.126468 | 2.578787 | 6.733634 | 806.8797 | 0.998662 |  |
| STG-2-38 | 2 | 38 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 1.076283 | 1.238005 | 5.947953 | 775.6994 | 0.998734 |  |
| STG-2-39 | 2 | 39 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 1.026098 | -0.10278 | 5.162272 | 744.519 | 0.998817 |  |
| STG-2-40 | 2 | 40 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.973641 | -1.42485 | 4.466146 | 713.3321 | 0.998911 |  |
| STG-2-41 | 2 | 41 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.900738 | -2.57852 | 4.576015 | 682.0857 | 0.998964 |  |
| STG-2-42 | 2 | 42 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.827835 | -3.73219 | 4.685883 | 650.8393 | 0.999034 |  |
| STG-2-43 | 2 | 43 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.723842 | -4.32493 | 6.083923 | 614.0592 | 0.999116 |  |
| STG-2-44 | 2 | 44 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.563293 | -3.62188 | -1.23539 | 587.3742 | 0.999186 |  |
| STG-2-45 | 2 | 45 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.296067 | 0.282351 | -33.701 | 600.7759 | 0.99919 |  |
| STG-3-11 | 3 | 11 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -1.16009 | 53.91578 | 479.3895 | 516.226 | 0.999984 |  |
| STG-3-12 | 3 | 12 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -1.17168 | 55.93939 | 398.0708 | 542.2888 | 0.999985 |  |
| STG-3-13 | 3 | 13 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -1.15201 | 56.89358 | 316.1968 | 616.8018 | 0.999988 |  |
| STG-3-14 | 3 | 14 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -1.12887 | 57.72894 | 234.2612 | 696.6981 | 0.999992 |  |
| STG-3-15 | 3 | 15 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -1.10573 | 58.56431 | 152.3255 | 776.5944 | 0.999994 |  |
| STG-3-16 | 3 | 16 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -1.04092 | 57.69104 | 83.33325 | 838.4819 | 0.999994 |  |
| STG-3-17 | 3 | 17 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -0.87889 | 52.83099 | 44.54218 | 858.349 | 0.999991 |  |
| STG-3-18 | 3 | 18 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -0.71686 | 47.97093 | 5.751116 | 878.216 | 0.999985 |  |
| STG-3-19 | 3 | 19 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -0.56308 | 41.86466 | -13.1628 | 856.4545 | 0.999983 |  |
| STG-3-20 | 3 | 20 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -0.42097 | 35.76223 | -34.4567 | 836.2847 | 0.999981 |  |
| STG-3-21 | 3 | 21 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -0.2949 | 29.47866 | -53.97 | 808.4426 | 0.999978 | Propose to exclude |
| STG-3-22 | 3 | 22 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -0.83929 | 54.12975 | 119.5048 | 912.8138 | 0.999923 |  |
| STG-3-23 | 3 | 23 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -0.82188 | 54.25838 | 75.08625 | 945.7854 | 0.999921 |  |
| STG-3-24 | 3 | 24 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -0.74365 | 51.71982 | 57.0718 | 946.3419 | 0.999919 |  |
| STG-3-25 | 3 | 25 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -0.66542 | 49.18127 | 39.05734 | 946.8984 | 0.999917 |  |
| STG-3-26 | 3 | 26 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -0.58719 | 46.64271 | 21.04289 | 947.4548 | 0.999915 |  |
| STG-3-27 | 3 | 27 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -0.50896 | 44.10415 | 3.028436 | 948.0113 | 0.999911 |  |
| STG-3-28 | 3 | 28 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -0.43718 | 41.136 | -7.39329 | 932.9321 | 0.999912 |  |
| STG-3-29 | 3 | 29 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -0.36702 | 38.06044 | -15.9168 | 913.9439 | 0.999913 |  |
| STG-3-30 | 3 | 30 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -0.29686 | 34.98489 | -24.4404 | 894.9556 | 0.999915 |  |
| STG-3-31 | 3 | 31 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -0.24786 | 32.33134 | -34.3241 | 879.7534 | 0.999914 |  |
| STG-3-32 | 3 | 32 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.170621 | 17.56837 | 219.5061 | 430.6241 | 0.999819 |  |
| STG-3-33 | 3 | 33 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.186052 | 16.73569 | 205.0853 | 439.9767 | 0.99982 |  |
| STG-3-34 | 3 | 34 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.201483 | 15.90301 | 190.6644 | 449.3292 | 0.999821 |  |
| STG-3-35 | 3 | 35 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.216914 | 15.07033 | 176.2436 | 458.6818 | 0.999822 |  |
| STG-3-36 | 3 | 36 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.232345 | 14.23765 | 161.8227 | 468.0344 | 0.999823 |  |
| STG-3-37 | 3 | 37 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.232726 | 13.70519 | 146.6624 | 479.8719 | 0.999823 |  |
| STG-3-38 | 3 | 38 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.233107 | 13.17273 | 131.502 | 491.7095 | 0.999824 |  |
| STG-3-39 | 3 | 39 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.233488 | 12.64027 | 116.3416 | 503.547 | 0.999824 |  |
| STG-3-40 | 3 | 40 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.234688 | 12.04399 | 102.1486 | 513.3168 | 0.999825 |  |
| STG-3-41 | 3 | 41 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.237799 | 11.29877 | 90.21272 | 518.2617 | 0.999826 |  |
| STG-3-42 | 3 | 42 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.24091 | 10.55356 | 78.27685 | 523.2066 | 0.999828 |  |
| STG-3-43 | 3 | 43 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.238931 | 9.91631 | 66.19676 | 528.4097 | 0.999823 |  |
| STG-3-44 | 3 | 44 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.231863 | 9.387019 | 53.97245 | 533.8709 | 0.99981 |  |
| STG-3-45 | 3 | 45 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.220041 | 9.003392 | 40.35425 | 543.6929 | 0.999799 |  |
| STG-4-13 | 4 | 13 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -0.73992 | 39.35457 | 507.1789 | 456.0696 | 0.999967 |  |
| STG-4-14 | 4 | 14 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -0.73755 | 40.65351 | 430.7565 | 529.9654 | 0.999972 |  |
| STG-4-15 | 4 | 15 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -0.66549 | 38.83841 | 382.8535 | 555.1283 | 0.999975 |  |
| STG-4-16 | 4 | 16 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -0.576 | 36.24479 | 342.0804 | 568.108 | 0.999977 |  |
| STG-4-17 | 4 | 17 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -0.50914 | 34.06624 | 297.9672 | 588.8263 | 0.999979 |  |
| STG-4-18 | 4 | 18 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -0.4649 | 32.30275 | 250.5141 | 617.2834 | 0.999981 |  |
| STG-4-19 | 4 | 19 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -0.41754 | 30.25557 | 200.2009 | 649.6772 | 0.999984 |  |
| STG-4-20 | 4 | 20 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -0.36395 | 27.77021 | 157.3338 | 668.2872 | 0.999984 | Propose to exclude |
| STG-4-21 | 4 | 21 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -0.32201 | 25.56699 | 117.3075 | 692.1588 | 0.999985 | Propose to exclude |
| STG-4-22 | 4 | 22 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -0.25124 | 21.91194 | 86.83942 | 671.2997 | 0.999983 | Propose to exclude |
| STG-4-23 | 4 | 23 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -0.20863 | 19.21599 | 53.13449 | 658.5717 | 0.99998 | Propose to exclude |
| STG-4-24 | 4 | 24 | Small | Solar-gas | Gas+Elec | Any | Main+Sec | -0.19058 | 17.33531 | 8.556169 | 675.3212 | 0.999974 | Propose to exclude |
| STG-4-25 | 4 | 25 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -0.61169 | 41.1101 | 183.2377 | 911.3411 | 0.999899 |  |
| STG-4-26 | 4 | 26 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -0.57994 | 39.70336 | 162.2726 | 910.4431 | 0.9999 |  |
| STG-4-27 | 4 | 27 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -0.54838 | 38.29593 | 141.4559 | 909.6428 | 0.999901 |  |
| STG-4-28 | 4 | 28 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -0.51858 | 36.88224 | 121.9742 | 909.7224 | 0.999898 |  |
| STG-4-29 | 4 | 29 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -0.48879 | 35.46855 | 102.4925 | 909.8019 | 0.999895 |  |
| STG-4-30 | 4 | 30 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -0.45452 | 33.7673 | 86.20276 | 902.4932 | 0.999896 |  |
| STG-4-31 | 4 | 31 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -0.42146 | 32.0863 | 69.96613 | 896.2051 | 0.999898 |  |
| STG-4-32 | 4 | 32 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -0.39525 | 30.61409 | 52.52316 | 897.2829 | 0.999898 |  |
| STG-4-33 | 4 | 33 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -0.36001 | 28.70506 | 39.54021 | 882.2414 | 0.999897 |  |
| STG-4-34 | 4 | 34 | Medium | Solar-gas | Gas+Elec | Any | Main+Sec | -0.31717 | 26.42748 | 30.43214 | 853.8223 | 0.999896 |  |
| STG-4-35 | 4 | 35 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.216954 | 9.0031 | 340.2743 | 341.4218 | 0.99978 |  |
| STG-4-36 | 4 | 36 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.21305 | 8.870246 | 321.2547 | 357.1115 | 0.999781 |  |
| STG-4-37 | 4 | 37 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.209145 | 8.737393 | 302.2351 | 372.8013 | 0.999782 |  |
| STG-4-38 | 4 | 38 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.202154 | 8.702094 | 283.1655 | 391.7161 | 0.99978 |  |
| STG-4-39 | 4 | 39 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.193839 | 8.708603 | 264.0744 | 412.0132 | 0.999777 |  |
| STG-4-40 | 4 | 40 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.187837 | 8.597831 | 246.1645 | 427.7664 | 0.999777 |  |
| STG-4-41 | 4 | 41 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.185305 | 8.311137 | 230.0264 | 436.7038 | 0.999782 |  |
| STG-4-42 | 4 | 42 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.185128 | 7.909765 | 215.334 | 441.0899 | 0.999788 |  |
| STG-4-43 | 4 | 43 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.186118 | 7.448603 | 201.6213 | 442.4965 | 0.999793 |  |
| STG-4-44 | 4 | 44 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.183492 | 7.137385 | 188.0505 | 444.3954 | 0.999791 |  |
| STG-4-45 | 4 | 45 | Large | Solar-gas | Gas+Elec | Any | Main+Sec | 0.17662 | 6.935308 | 172.4202 | 449.0501 | 0.999785 |  |
| SHP-1-12 | 1 | 12 | Small | Heat-pump | Electricity | Any | Main | 0.091959 | -3.24906 | 416.9757 | 724.4109 | 0.999592 |  |
| SHP-1-13 | 1 | 13 | Small | Heat-pump | Electricity | Any | Main | 0.140995 | -5.09324 | 391.9601 | 596.5096 | 0.999689 |  |
| SHP-1-14 | 1 | 14 | Small | Heat-pump | Electricity | Any | Main | 0.106084 | -3.92744 | 341.742 | 518.0808 | 0.999793 |  |
| SHP-1-15 | 1 | 15 | Small | Heat-pump | Electricity | Any | Main | 0.12252 | -4.02327 | 299.2533 | 418.68 | 0.99981 |  |
| SHP-1-16 | 1 | 16 | Small | Heat-pump | Electricity | Any | Main | 0.003196 | -0.21575 | 225.1419 | 362.5159 | 0.999893 |  |
| SHP-1-17 | 1 | 17 | Small | Heat-pump | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| SHP-1-18 | 1 | 18 | Small | Heat-pump | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| SHP-1-19 | 1 | 19 | Small | Heat-pump | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| SHP-1-20 | 1 | 20 | Small | Heat-pump | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| SHP-1-21 | 1 | 21 | Medium | Heat-pump | Electricity | Any | Main | -0.11394 | 3.672794 | 377.3078 | 889.6594 | 0.999769 |  |
| SHP-1-22 | 1 | 22 | Medium | Heat-pump | Electricity | Any | Main | 0.079148 | -2.91181 | 405.5427 | 707.1847 | 0.999662 |  |
| SHP-1-23 | 1 | 23 | Medium | Heat-pump | Electricity | Any | Main | 0.140995 | -5.09324 | 391.9601 | 596.5096 | 0.999689 |  |
| SHP-1-24 | 1 | 24 | Medium | Heat-pump | Electricity | Any | Main | 0.113361 | -4.27208 | 355.4771 | 536.9144 | 0.999819 |  |
| SHP-1-25 | 1 | 25 | Medium | Heat-pump | Electricity | Any | Main | 0.086116 | -3.24941 | 317.6632 | 487.5951 | 0.999728 |  |
| SHP-1-26 | 1 | 26 | Medium | Heat-pump | Electricity | Any | Main | 0.104405 | -3.46358 | 288.6682 | 410.2126 | 0.999827 |  |
| SHP-1-27 | 1 | 27 | Medium | Heat-pump | Electricity | Any | Main | 0.017766 | -0.78678 | 238.044 | 369.7161 | 0.999891 |  |
| SHP-2-12 | 2 | 12 | Small | Heat-pump | Electricity | Any | Main | -0.20349 | 6.964294 | 312.3135 | 1100.123 | 0.999381 |  |
| SHP-2-13 | 2 | 13 | Small | Heat-pump | Electricity | Any | Main | -0.06813 | 1.556065 | 332.3473 | 897.5665 | 0.999404 |  |
| SHP-2-14 | 2 | 14 | Small | Heat-pump | Electricity | Any | Main | -0.03561 | -0.34601 | 321.0789 | 644.3295 | 0.999574 |  |
| SHP-2-15 | 2 | 15 | Small | Heat-pump | Electricity | Any | Main | -0.10352 | 3.020732 | 238.4 | 606.8925 | 0.999625 |  |
| SHP-2-16 | 2 | 16 | Small | Heat-pump | Electricity | Any | Main | -0.10327 | 3.306375 | 201.6514 | 483.416 | 0.999601 |  |
| SHP-2-17 | 2 | 17 | Small | Heat-pump | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| SHP-2-18 | 2 | 18 | Small | Heat-pump | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| SHP-2-19 | 2 | 19 | Small | Heat-pump | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| SHP-2-20 | 2 | 20 | Small | Heat-pump | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| SHP-2-21 | 2 | 21 | Medium | Heat-pump | Electricity | Any | Main | -0.15865 | 5.958818 | 346.8399 | 1186.423 | 0.999059 |  |
| SHP-2-22 | 2 | 22 | Medium | Heat-pump | Electricity | Any | Main | -0.20654 | 7.046388 | 310.3285 | 1097.758 | 0.999391 |  |
| SHP-2-23 | 2 | 23 | Medium | Heat-pump | Electricity | Any | Main | -0.08714 | 2.257782 | 328.3939 | 913.4675 | 0.999507 |  |
| SHP-2-24 | 2 | 24 | Medium | Heat-pump | Electricity | Any | Main | -0.04937 | 0.219897 | 317.7608 | 662.5108 | 0.999615 |  |
| SHP-2-25 | 2 | 25 | Medium | Heat-pump | Electricity | Any | Main | 0.048709 | -2.67293 | 315.7726 | 536.6234 | 0.999718 |  |
| SHP-2-26 | 2 | 26 | Medium | Heat-pump | Electricity | Any | Main | -0.14158 | 4.444148 | 219.0569 | 624.4597 | 0.99949 |  |
| SHP-2-27 | 2 | 27 | Medium | Heat-pump | Electricity | Any | Main | -0.11757 | 3.80445 | 198.9913 | 505.4383 | 0.999644 |  |
| SHP-3-15 | 3 | 15 | Small | Heat-pump | Electricity | Any | Main | -0.06704 | 1.191972 | 370.5599 | 871.2239 | 0.999953 |  |
| SHP-3-16 | 3 | 16 | Small | Heat-pump | Electricity | Any | Main | 0.021633 | -1.57779 | 355.8127 | 734.8127 | 0.999922 |  |
| SHP-3-17 | 3 | 17 | Small | Heat-pump | Electricity | Any | Main | -0.03585 | 0.867925 | 298.1977 | 712.0684 | 0.999801 |  |
| SHP-3-18 | 3 | 18 | Small | Heat-pump | Electricity | Any | Main | -0.08908 | 3.134024 | 237.5608 | 649.535 | 0.999712 |  |
| SHP-3-19 | 3 | 19 | Small | Heat-pump | Electricity | Any | Main | -0.02576 | 1.179161 | 226.33 | 484.0615 | 0.999974 |  |
| SHP-3-20 | 3 | 20 | Small | Heat-pump | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| SHP-3-21 | 3 | 21 | Small | Heat-pump | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| SHP-3-22 | 3 | 22 | Small | Heat-pump | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| SHP-3-23 | 3 | 23 | Small | Heat-pump | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| SHP-3-24 | 3 | 24 | Small | Heat-pump | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| SHP-3-25 | 3 | 25 | Medium | Heat-pump | Electricity | Any | Main | -0.00431 | -0.21227 | 422.2786 | 935.3679 | 0.99994 |  |
| SHP-3-26 | 3 | 26 | Medium | Heat-pump | Electricity | Any | Main | -0.09096 | 2.175161 | 376.6732 | 926.5617 | 0.999948 |  |
| SHP-3-27 | 3 | 27 | Medium | Heat-pump | Electricity | Any | Main | -0.02828 | 0.010807 | 366.9917 | 815.4698 | 0.999971 |  |
| SHP-3-28 | 3 | 28 | Medium | Heat-pump | Electricity | Any | Main | 0.021633 | -1.57779 | 355.8127 | 734.8127 | 0.999922 |  |
| SHP-3-29 | 3 | 29 | Medium | Heat-pump | Electricity | Any | Main | -0.01476 | 0.035185 | 314.6308 | 715.5944 | 0.999813 |  |
| SHP-3-30 | 3 | 30 | Medium | Heat-pump | Electricity | Any | Main | -0.07407 | 2.377267 | 268.4128 | 705.6776 | 0.999733 |  |
| SHP-3-31 | 3 | 31 | Medium | Heat-pump | Electricity | Any | Main | -0.08856 | 3.117396 | 237.4808 | 648.248 | 0.999714 |  |
| SHP-3-32 | 3 | 32 | Medium | Heat-pump | Electricity | Any | Main | -0.03725 | 1.510446 | 229.2911 | 520.3298 | 0.999924 |  |
| SHP-4-17 | 4 | 17 | Small | Heat-pump | Electricity | Any | Main | -0.05482 | 1.052501 | 360.4329 | 919.6669 | 0.999967 |  |
| SHP-4-18 | 4 | 18 | Small | Heat-pump | Electricity | Any | Main | -0.01208 | -0.20752 | 340.2577 | 813.6756 | 0.999875 |  |
| SHP-4-19 | 4 | 19 | Small | Heat-pump | Electricity | Any | Main | -0.04509 | 1.461461 | 284.3235 | 758.8037 | 0.999938 |  |
| SHP-4-20 | 4 | 20 | Small | Heat-pump | Electricity | Any | Main | -0.0402 | 1.692374 | 251.4177 | 669.3087 | 0.999878 |  |
| SHP-4-21 | 4 | 21 | Small | Heat-pump | Electricity | Any | Main | -0.00793 | 0.686707 | 235.9651 | 520.9468 | 0.999977 |  |
| SHP-4-22 | 4 | 22 | Small | Heat-pump | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| SHP-4-23 | 4 | 23 | Small | Heat-pump | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| SHP-4-24 | 4 | 24 | Small | Heat-pump | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| SHP-4-25 | 4 | 25 | Small | Heat-pump | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| SHP-4-26 | 4 | 26 | Small | Heat-pump | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| SHP-4-27 | 4 | 27 | Medium | Heat-pump | Electricity | Any | Main | -0.09207 | 2.985385 | 385.4124 | 1095.988 | 0.999842 |  |
| SHP-4-28 | 4 | 28 | Medium | Heat-pump | Electricity | Any | Main | -0.08856 | 2.322809 | 372.1592 | 1024.98 | 0.999894 |  |
| SHP-4-29 | 4 | 29 | Medium | Heat-pump | Electricity | Any | Main | -0.05818 | 1.165128 | 363.2759 | 935.8502 | 0.999967 |  |
| SHP-4-30 | 4 | 30 | Medium | Heat-pump | Electricity | Any | Main | -0.01775 | -0.23953 | 355.6271 | 837.7787 | 0.999911 |  |
| SHP-4-31 | 4 | 31 | Medium | Heat-pump | Electricity | Any | Main | -0.01985 | 0.185184 | 327.0967 | 800.7645 | 0.999899 |  |
| SHP-4-32 | 4 | 32 | Medium | Heat-pump | Electricity | Any | Main | -0.03927 | 1.166936 | 294.1942 | 768.487 | 0.999935 |  |
| SHP-4-33 | 4 | 33 | Medium | Heat-pump | Electricity | Any | Main | -0.04268 | 1.575559 | 268.0641 | 714.5826 | 0.999917 |  |
| SHP-4-34 | 4 | 34 | Medium | Heat-pump | Electricity | Any | Main | -0.03923 | 1.738557 | 244.8366 | 651.4096 | 0.999857 |  |
| SHP-4-35 | 4 | 35 | Medium | Heat-pump | Electricity | Any | Main | -0.00663 | 0.64288 | 235.5955 | 515.5109 | 0.999979 |  |
| SHP-5-17 | 5 | 17 | Small | Heat-pump | Electricity | Any | Main | 0.025523 | -3.21285 | 408.4101 | 920.6249 | 0.99966 |  |
| SHP-5-18 | 5 | 18 | Small | Heat-pump | Electricity | Any | Main | 0.017442 | -2.47 | 360.9696 | 801.5584 | 0.999716 |  |
| SHP-5-19 | 5 | 19 | Small | Heat-pump | Electricity | Any | Main | -0.07304 | 1.555914 | 288.6392 | 782.7086 | 0.999845 |  |
| SHP-5-20 | 5 | 20 | Small | Heat-pump | Electricity | Any | Main | -0.09518 | 2.996749 | 246.8648 | 683.4194 | 0.999688 |  |
| SHP-5-21 | 5 | 21 | Small | Heat-pump | Electricity | Any | Main | -0.04855 | 1.692214 | 238.1146 | 505.2433 | 0.999739 |  |
| SHP-5-22 | 5 | 22 | Small | Heat-pump | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| SHP-5-23 | 5 | 23 | Small | Heat-pump | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| SHP-5-24 | 5 | 24 | Small | Heat-pump | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| SHP-5-25 | 5 | 25 | Small | Heat-pump | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| SHP-5-26 | 5 | 26 | Small | Heat-pump | Electricity | Any | Main | a | b | c | d | 0 | Not covered by industry tables |
| SHP-5-27 | 5 | 27 | Medium | Heat-pump | Electricity | Any | Main | -0.23905 | 8.302842 | 322.1053 | 1421.644 | 0.999548 |  |
| SHP-5-28 | 5 | 28 | Medium | Heat-pump | Electricity | Any | Main | -0.13073 | 3.295425 | 366.6909 | 1156.862 | 0.999877 |  |
| SHP-5-29 | 5 | 29 | Medium | Heat-pump | Electricity | Any | Main | -0.00962 | -1.88746 | 406.2076 | 980.5941 | 0.999795 |  |
| SHP-5-30 | 5 | 30 | Medium | Heat-pump | Electricity | Any | Main | 0.041395 | -3.76067 | 404.6988 | 876.4071 | 0.999638 |  |
| SHP-5-31 | 5 | 31 | Medium | Heat-pump | Electricity | Any | Main | 0.045885 | -3.72081 | 382.93 | 804.4329 | 0.999639 |  |
| SHP-5-32 | 5 | 32 | Medium | Heat-pump | Electricity | Any | Main | -0.02277 | -0.70161 | 329.9221 | 797.4945 | 0.999793 |  |
| SHP-5-33 | 5 | 33 | Medium | Heat-pump | Electricity | Any | Main | -0.07596 | 1.745842 | 283.1325 | 769.6205 | 0.999859 |  |
| SHP-5-34 | 5 | 34 | Medium | Heat-pump | Electricity | Any | Main | -0.09307 | 2.859215 | 250.8524 | 692.897 | 0.999732 |  |
| SHP-5-35 | 5 | 35 | Medium | Heat-pump | Electricity | Any | Main | -0.09134 | 3.241526 | 226.4615 | 589.9594 | 0.99941 |  |

# Appendix C – Water Heater Performance Coefficients for monthly share of energy by climate zone for Whole of Home rating

This Appendix sets out the coefficients to determine the monthly share of purchased water heater energy *EAnnual-input* (energy input). This is based on a third order polynomial with different coefficients for each type of system, each climate zone and month of the year. The application of coefficients *amonth*, *bmonth*, *cmonth* and *dmonth* is defined in Equation 22, which is repeated below for convenience:



Where *EAnnual-output* (hot water demand) is defined in Equation 20.

Separate coefficients are supplied for solar thermal electric boost water heaters for each month and in each climate zone. The sum of values for each of the 12 months from Equation 22 for solar thermal electric should be equal to 1.0000.

For solar thermal gas boost systems, two sets of coefficients are provided to separately estimate the share of gas and electricity in each month (noting that the total annual purchased energy estimated from Equation 21 is gas plus electrical energy). The sum of values for each of the 12 months from Equation 22 for gas plus the 12 months for electricity for solar thermal electric should be equal to 1.0000.

To assist product developers, the monthly coefficients in the same format are provided for all water heater types and climate zones (noting that for most systems parameters a, b and c above will be zero, giving a fixed breakdown of energy by month that is independent of hot water demand).

Codes used to identify each water heater type and climate are in the following general format:

XXX-Y-MMM

Where:

XXX is a three letter code to identify the water heater type – see Table 27

Y is an integer to identify the climate zone (1 to 5 for heat pump systems and 1 to 4 for all other water heater types)

MMM is a three letter abbreviation for each month consisting of the first three letters (e.g. JAN = January, NOV = November).

A validation spreadsheet is available – this contains an electronic copy of all coefficients and worked examples for all climates, water heater types and selected household sizes. This can be used to validate software.

Table 47: Modelling coefficients for monthly share of annual energy input for all water heaters, all climates (Equation 22)

| **System ID** | **Climate** | **Month** | **Description** | **Fuel** | **Energisation** | **Function** | **a-month** | **b-month** | **c-month** | **d-month** | **Notes** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| SOF-1-JAN | 1 | JAN | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.065728 | Assumes input in line with hot water energy by month |
| SOF-1-FEB | 1 | FEB | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.067848 |  |
| SOF-1-MAR | 1 | MAR | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.079812 |  |
| SOF-1-APR | 1 | APR | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.081781 |  |
| SOF-1-MAY | 1 | MAY | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.089202 |  |
| SOF-1-JUN | 1 | JUN | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.090868 |  |
| SOF-1-JUL | 1 | JUL | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.093897 |  |
| SOF-1-AUG | 1 | AUG | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.093897 |  |
| SOF-1-SEP | 1 | SEP | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.090868 |  |
| SOF-1-OCT | 1 | OCT | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.089202 |  |
| SOF-1-NOV | 1 | NOV | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.081781 |  |
| SOF-1-DEC | 1 | DEC | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.075117 |  |
| SOF-2-JAN | 2 | JAN | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.065728 | Assumes input in line with hot water energy by month |
| SOF-2-FEB | 2 | FEB | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.067848 |  |
| SOF-2-MAR | 2 | MAR | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.079812 |  |
| SOF-2-APR | 2 | APR | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.081781 |  |
| SOF-2-MAY | 2 | MAY | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.089202 |  |
| SOF-2-JUN | 2 | JUN | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.090868 |  |
| SOF-2-JUL | 2 | JUL | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.093897 |  |
| SOF-2-AUG | 2 | AUG | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.093897 |  |
| SOF-2-SEP | 2 | SEP | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.090868 |  |
| SOF-2-OCT | 2 | OCT | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.089202 |  |
| SOF-2-NOV | 2 | NOV | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.081781 |  |
| SOF-2-DEC | 2 | DEC | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.075117 |  |
| SOF-3-JAN | 3 | JAN | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.065728 | Assumes input in line with hot water energy by month |
| SOF-3-FEB | 3 | FEB | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.067848 |  |
| SOF-3-MAR | 3 | MAR | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.079812 |  |
| SOF-3-APR | 3 | APR | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.081781 |  |
| SOF-3-MAY | 3 | MAY | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.089202 |  |
| SOF-3-JUN | 3 | JUN | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.090868 |  |
| SOF-3-JUL | 3 | JUL | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.093897 |  |
| SOF-3-AUG | 3 | AUG | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.093897 |  |
| SOF-3-SEP | 3 | SEP | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.090868 |  |
| SOF-3-OCT | 3 | OCT | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.089202 |  |
| SOF-3-NOV | 3 | NOV | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.081781 |  |
| SOF-3-DEC | 3 | DEC | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.075117 |  |
| SOF-4-JAN | 4 | JAN | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.065728 | Assumes input in line with hot water energy by month |
| SOF-4-FEB | 4 | FEB | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.067848 |  |
| SOF-4-MAR | 4 | MAR | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.079812 |  |
| SOF-4-APR | 4 | APR | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.081781 |  |
| SOF-4-MAY | 4 | MAY | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.089202 |  |
| SOF-4-JUN | 4 | JUN | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.090868 |  |
| SOF-4-JUL | 4 | JUL | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.093897 |  |
| SOF-4-AUG | 4 | AUG | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.093897 |  |
| SOF-4-SEP | 4 | SEP | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.090868 |  |
| SOF-4-OCT | 4 | OCT | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.089202 |  |
| SOF-4-NOV | 4 | NOV | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.081781 |  |
| SOF-4-DEC | 4 | DEC | Solid fuel | Solid | Any | Main | 0 | 0 | 0 | 0.075117 |  |
| ESS-1-JAN | 1 | JAN | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.06726 |  |
| ESS-1-FEB | 1 | FEB | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.068112 |  |
| ESS-1-MAR | 1 | MAR | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.079116 |  |
| ESS-1-APR | 1 | APR | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.081341 |  |
| ESS-1-MAY | 1 | MAY | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.089275 |  |
| ESS-1-JUN | 1 | JUN | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.091331 |  |
| ESS-1-JUL | 1 | JUL | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.09458 |  |
| ESS-1-AUG | 1 | AUG | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.093801 |  |
| ESS-1-SEP | 1 | SEP | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.090378 |  |
| ESS-1-OCT | 1 | OCT | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.088496 |  |
| ESS-1-NOV | 1 | NOV | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.081063 |  |
| ESS-1-DEC | 1 | DEC | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.075246 |  |
| ESS-2-JAN | 2 | JAN | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.066291 |  |
| ESS-2-FEB | 2 | FEB | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.067257 |  |
| ESS-2-MAR | 2 | MAR | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.079446 |  |
| ESS-2-APR | 2 | APR | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.081744 |  |
| ESS-2-MAY | 2 | MAY | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.089981 |  |
| ESS-2-JUN | 2 | JUN | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.092057 |  |
| ESS-2-JUL | 2 | JUL | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.096551 |  |
| ESS-2-AUG | 2 | AUG | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.095126 |  |
| ESS-2-SEP | 2 | SEP | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.090638 |  |
| ESS-2-OCT | 2 | OCT | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.086926 |  |
| ESS-2-NOV | 2 | NOV | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.080089 |  |
| ESS-2-DEC | 2 | DEC | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.073893 |  |
| ESS-3-JAN | 3 | JAN | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.067444 |  |
| ESS-3-FEB | 3 | FEB | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.068012 |  |
| ESS-3-MAR | 3 | MAR | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.079017 |  |
| ESS-3-APR | 3 | APR | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.081422 |  |
| ESS-3-MAY | 3 | MAY | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.089667 |  |
| ESS-3-JUN | 3 | JUN | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.091182 |  |
| ESS-3-JUL | 3 | JUL | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.094737 |  |
| ESS-3-AUG | 3 | AUG | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.093803 |  |
| ESS-3-SEP | 3 | SEP | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.089597 |  |
| ESS-3-OCT | 3 | OCT | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.088773 |  |
| ESS-3-NOV | 3 | NOV | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.08105 |  |
| ESS-3-DEC | 3 | DEC | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.075297 |  |
| ESS-4-JAN | 4 | JAN | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.0685 |  |
| ESS-4-FEB | 4 | FEB | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.067213 |  |
| ESS-4-MAR | 4 | MAR | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.07976 |  |
| ESS-4-APR | 4 | APR | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.081207 |  |
| ESS-4-MAY | 4 | MAY | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.089133 |  |
| ESS-4-JUN | 4 | JUN | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.090702 |  |
| ESS-4-JUL | 4 | JUL | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.094094 |  |
| ESS-4-AUG | 4 | AUG | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.093308 |  |
| ESS-4-SEP | 4 | SEP | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.089879 |  |
| ESS-4-OCT | 4 | OCT | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.088624 |  |
| ESS-4-NOV | 4 | NOV | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.081401 |  |
| ESS-4-DEC | 4 | DEC | Electric storage small | Electricity | Continuous | Main | 0 | 0 | 0 | 0.076177 |  |
| ESL-1-JAN | 1 | JAN | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.068464 |  |
| ESL-1-FEB | 1 | FEB | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.068555 |  |
| ESL-1-MAR | 1 | MAR | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.079118 |  |
| ESL-1-APR | 1 | APR | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.08125 |  |
| ESL-1-MAY | 1 | MAY | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.089145 |  |
| ESL-1-JUN | 1 | JUN | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.091102 |  |
| ESL-1-JUL | 1 | JUL | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.094403 |  |
| ESL-1-AUG | 1 | AUG | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.093397 |  |
| ESL-1-SEP | 1 | SEP | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.089872 |  |
| ESL-1-OCT | 1 | OCT | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.08813 |  |
| ESL-1-NOV | 1 | NOV | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.080884 |  |
| ESL-1-DEC | 1 | DEC | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.07568 |  |
| ESL-2-JAN | 2 | JAN | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.067171 |  |
| ESL-2-FEB | 2 | FEB | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.067434 |  |
| ESL-2-MAR | 2 | MAR | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.07958 |  |
| ESL-2-APR | 2 | APR | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.081799 |  |
| ESL-2-MAY | 2 | MAY | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.090075 |  |
| ESL-2-JUN | 2 | JUN | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.092043 |  |
| ESL-2-JUL | 2 | JUL | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.096947 |  |
| ESL-2-AUG | 2 | AUG | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.095111 |  |
| ESL-2-SEP | 2 | SEP | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.090215 |  |
| ESL-2-OCT | 2 | OCT | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.086103 |  |
| ESL-2-NOV | 2 | NOV | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.079625 |  |
| ESL-2-DEC | 2 | DEC | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.073896 |  |
| ESL-3-JAN | 3 | JAN | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.068749 |  |
| ESL-3-FEB | 3 | FEB | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.068445 |  |
| ESL-3-MAR | 3 | MAR | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.079009 |  |
| ESL-3-APR | 3 | APR | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.081363 |  |
| ESL-3-MAY | 3 | MAY | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.08964 |  |
| ESL-3-JUN | 3 | JUN | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.090877 |  |
| ESL-3-JUL | 3 | JUL | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.094569 |  |
| ESL-3-AUG | 3 | AUG | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.09337 |  |
| ESL-3-SEP | 3 | SEP | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.088844 |  |
| ESL-3-OCT | 3 | OCT | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.088481 |  |
| ESL-3-NOV | 3 | NOV | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.080877 |  |
| ESL-3-DEC | 3 | DEC | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.075776 |  |
| ESL-4-JAN | 4 | JAN | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.070196 |  |
| ESL-4-FEB | 4 | FEB | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.067396 |  |
| ESL-4-MAR | 4 | MAR | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.079996 |  |
| ESL-4-APR | 4 | APR | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.08108 |  |
| ESL-4-MAY | 4 | MAY | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.088931 |  |
| ESL-4-JUN | 4 | JUN | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.090234 |  |
| ESL-4-JUL | 4 | JUL | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.093713 |  |
| ESL-4-AUG | 4 | AUG | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.092709 |  |
| ESL-4-SEP | 4 | SEP | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.089183 |  |
| ESL-4-OCT | 4 | OCT | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.088274 |  |
| ESL-4-NOV | 4 | NOV | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.081332 |  |
| ESL-4-DEC | 4 | DEC | Electric storage large | Electricity | Controlled | Main | 0 | 0 | 0 | 0.076957 |  |
| EIN-1-JAN | 1 | JAN | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.065728 | Assumes input in line with hot water energy by month |
| EIN-1-FEB | 1 | FEB | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.067848 |  |
| EIN-1-MAR | 1 | MAR | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.079812 |  |
| EIN-1-APR | 1 | APR | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.081781 |  |
| EIN-1-MAY | 1 | MAY | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.089202 |  |
| EIN-1-JUN | 1 | JUN | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.090868 |  |
| EIN-1-JUL | 1 | JUL | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.093897 |  |
| EIN-1-AUG | 1 | AUG | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.093897 |  |
| EIN-1-SEP | 1 | SEP | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.090868 |  |
| EIN-1-OCT | 1 | OCT | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.089202 |  |
| EIN-1-NOV | 1 | NOV | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.081781 |  |
| EIN-1-DEC | 1 | DEC | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.075117 |  |
| EIN-2-JAN | 2 | JAN | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.065728 | Assumes input in line with hot water energy by month |
| EIN-2-FEB | 2 | FEB | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.067848 |  |
| EIN-2-MAR | 2 | MAR | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.079812 |  |
| EIN-2-APR | 2 | APR | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.081781 |  |
| EIN-2-MAY | 2 | MAY | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.089202 |  |
| EIN-2-JUN | 2 | JUN | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.090868 |  |
| EIN-2-JUL | 2 | JUL | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.093897 |  |
| EIN-2-AUG | 2 | AUG | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.093897 |  |
| EIN-2-SEP | 2 | SEP | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.090868 |  |
| EIN-2-OCT | 2 | OCT | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.089202 |  |
| EIN-2-NOV | 2 | NOV | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.081781 |  |
| EIN-2-DEC | 2 | DEC | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.075117 |  |
| EIN-3-JAN | 3 | JAN | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.065728 | Assumes input in line with hot water energy by month |
| EIN-3-FEB | 3 | FEB | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.067848 |  |
| EIN-3-MAR | 3 | MAR | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.079812 |  |
| EIN-3-APR | 3 | APR | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.081781 |  |
| EIN-3-MAY | 3 | MAY | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.089202 |  |
| EIN-3-JUN | 3 | JUN | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.090868 |  |
| EIN-3-JUL | 3 | JUL | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.093897 |  |
| EIN-3-AUG | 3 | AUG | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.093897 |  |
| EIN-3-SEP | 3 | SEP | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.090868 |  |
| EIN-3-OCT | 3 | OCT | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.089202 |  |
| EIN-3-NOV | 3 | NOV | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.081781 |  |
| EIN-3-DEC | 3 | DEC | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.075117 |  |
| EIN-4-JAN | 4 | JAN | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.065728 | Assumes input in line with hot water energy by month |
| EIN-4-FEB | 4 | FEB | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.067848 |  |
| EIN-4-MAR | 4 | MAR | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.079812 |  |
| EIN-4-APR | 4 | APR | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.081781 |  |
| EIN-4-MAY | 4 | MAY | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.089202 |  |
| EIN-4-JUN | 4 | JUN | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.090868 |  |
| EIN-4-JUL | 4 | JUL | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.093897 |  |
| EIN-4-AUG | 4 | AUG | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.093897 |  |
| EIN-4-SEP | 4 | SEP | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.090868 |  |
| EIN-4-OCT | 4 | OCT | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.089202 |  |
| EIN-4-NOV | 4 | NOV | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.081781 |  |
| EIN-4-DEC | 4 | DEC | Electric instantaneous | Electricity | Continuous | Main | 0 | 0 | 0 | 0.075117 |  |
| GST-1-JAN | 1 | JAN | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.068949 |  |
| GST-1-FEB | 1 | FEB | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.068458 |  |
| GST-1-MAR | 1 | MAR | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.078475 |  |
| GST-1-APR | 1 | APR | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.080914 |  |
| GST-1-MAY | 1 | MAY | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.089313 |  |
| GST-1-JUN | 1 | JUN | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.091704 |  |
| GST-1-JUL | 1 | JUL | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.095169 |  |
| GST-1-AUG | 1 | AUG | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.09362 |  |
| GST-1-SEP | 1 | SEP | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.089811 |  |
| GST-1-OCT | 1 | OCT | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.087761 |  |
| GST-1-NOV | 1 | NOV | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.08036 |  |
| GST-1-DEC | 1 | DEC | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.075465 |  |
| GST-2-JAN | 2 | JAN | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.067004 |  |
| GST-2-FEB | 2 | FEB | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.066762 |  |
| GST-2-MAR | 2 | MAR | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.079144 |  |
| GST-2-APR | 2 | APR | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.081723 |  |
| GST-2-MAY | 2 | MAY | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.090709 |  |
| GST-2-JUN | 2 | JUN | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.093133 |  |
| GST-2-JUL | 2 | JUL | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.09905 |  |
| GST-2-AUG | 2 | AUG | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.096237 |  |
| GST-2-SEP | 2 | SEP | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.090333 |  |
| GST-2-OCT | 2 | OCT | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.084673 |  |
| GST-2-NOV | 2 | NOV | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.078447 |  |
| GST-2-DEC | 2 | DEC | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.072784 |  |
| GST-3-JAN | 3 | JAN | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.069262 |  |
| GST-3-FEB | 3 | FEB | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.068256 |  |
| GST-3-MAR | 3 | MAR | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.07831 |  |
| GST-3-APR | 3 | APR | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.081091 |  |
| GST-3-MAY | 3 | MAY | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.090074 |  |
| GST-3-JUN | 3 | JUN | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.09139 |  |
| GST-3-JUL | 3 | JUL | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.095443 |  |
| GST-3-AUG | 3 | AUG | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.093621 |  |
| GST-3-SEP | 3 | SEP | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.088298 |  |
| GST-3-OCT | 3 | OCT | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.088326 |  |
| GST-3-NOV | 3 | NOV | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.080363 |  |
| GST-3-DEC | 3 | DEC | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.075566 |  |
| GST-4-JAN | 4 | JAN | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.071274 |  |
| GST-4-FEB | 4 | FEB | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.066707 |  |
| GST-4-MAR | 4 | MAR | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.079769 |  |
| GST-4-APR | 4 | APR | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.080684 |  |
| GST-4-MAY | 4 | MAY | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.089029 |  |
| GST-4-JUN | 4 | JUN | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.090453 |  |
| GST-4-JUL | 4 | JUL | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.094178 |  |
| GST-4-AUG | 4 | AUG | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.092666 |  |
| GST-4-SEP | 4 | SEP | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.088869 |  |
| GST-4-OCT | 4 | OCT | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.088046 |  |
| GST-4-NOV | 4 | NOV | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.081058 |  |
| GST-4-DEC | 4 | DEC | Gas storage - all star ratings | Gas | Continuous | Main | 0 | 0 | 0 | 0.077267 |  |
| GIN-1-JAN | 1 | JAN | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.065728 | Assume electric and gas energy breakdown in line with hot water energy by month |
| GIN-1-FEB | 1 | FEB | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.067848 |  |
| GIN-1-MAR | 1 | MAR | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.079812 |  |
| GIN-1-APR | 1 | APR | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.081781 |  |
| GIN-1-MAY | 1 | MAY | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.089202 |  |
| GIN-1-JUN | 1 | JUN | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.090868 |  |
| GIN-1-JUL | 1 | JUL | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.093897 |  |
| GIN-1-AUG | 1 | AUG | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.093897 |  |
| GIN-1-SEP | 1 | SEP | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.090868 |  |
| GIN-1-OCT | 1 | OCT | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.089202 |  |
| GIN-1-NOV | 1 | NOV | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.081781 |  |
| GIN-1-DEC | 1 | DEC | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.075117 |  |
| GIN-2-JAN | 2 | JAN | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.065728 | Assume electric and gas energy breakdown in line with hot water energy by month |
| GIN-2-FEB | 2 | FEB | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.067848 |  |
| GIN-2-MAR | 2 | MAR | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.079812 |  |
| GIN-2-APR | 2 | APR | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.081781 |  |
| GIN-2-MAY | 2 | MAY | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.089202 |  |
| GIN-2-JUN | 2 | JUN | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.090868 |  |
| GIN-2-JUL | 2 | JUL | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.093897 |  |
| GIN-2-AUG | 2 | AUG | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.093897 |  |
| GIN-2-SEP | 2 | SEP | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.090868 |  |
| GIN-2-OCT | 2 | OCT | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.089202 |  |
| GIN-2-NOV | 2 | NOV | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.081781 |  |
| GIN-2-DEC | 2 | DEC | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.075117 |  |
| GIN-3-JAN | 3 | JAN | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.065728 | Assume electric and gas energy breakdown in line with hot water energy by month |
| GIN-3-FEB | 3 | FEB | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.067848 |  |
| GIN-3-MAR | 3 | MAR | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.079812 |  |
| GIN-3-APR | 3 | APR | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.081781 |  |
| GIN-3-MAY | 3 | MAY | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.089202 |  |
| GIN-3-JUN | 3 | JUN | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.090868 |  |
| GIN-3-JUL | 3 | JUL | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.093897 |  |
| GIN-3-AUG | 3 | AUG | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.093897 |  |
| GIN-3-SEP | 3 | SEP | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.090868 |  |
| GIN-3-OCT | 3 | OCT | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.089202 |  |
| GIN-3-NOV | 3 | NOV | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.081781 |  |
| GIN-3-DEC | 3 | DEC | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.075117 |  |
| GIN-4-JAN | 4 | JAN | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.065728 | Assume electric and gas energy breakdown in line with hot water energy by month |
| GIN-4-FEB | 4 | FEB | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.067848 |  |
| GIN-4-MAR | 4 | MAR | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.079812 |  |
| GIN-4-APR | 4 | APR | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.081781 |  |
| GIN-4-MAY | 4 | MAY | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.089202 |  |
| GIN-4-JUN | 4 | JUN | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.090868 |  |
| GIN-4-JUL | 4 | JUL | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.093897 |  |
| GIN-4-AUG | 4 | AUG | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.093897 |  |
| GIN-4-SEP | 4 | SEP | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.090868 |  |
| GIN-4-OCT | 4 | OCT | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.089202 |  |
| GIN-4-NOV | 4 | NOV | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.081781 |  |
| GIN-4-DEC | 4 | DEC | Gas instantaneous - all star ratings | Gas+Electricity | Continuous | Main | 0 | 0 | 0 | 0.075117 |  |
| STE-1-JAN | 1 | JAN | Solar-electric | Electricity | Any | Main | -6.9E-06 | 0.000542 | -0.01051 | 0.095463 | Applies to all system sizes |
| STE-1-FEB | 1 | FEB | Solar-electric | Electricity | Any | Main | -7.1E-05 | 0.002462 | -0.02408 | 0.101802 |  |
| STE-1-MAR | 1 | MAR | Solar-electric | Electricity | Any | Main | -2.9E-05 | 0.000975 | -0.00778 | 0.062139 |  |
| STE-1-APR | 1 | APR | Solar-electric | Electricity | Any | Main | -5.9E-05 | 0.002037 | -0.01981 | 0.118365 |  |
| STE-1-MAY | 1 | MAY | Solar-electric | Electricity | Any | Main | 5.6E-05 | -0.0021 | 0.022134 | 0.067442 |  |
| STE-1-JUN | 1 | JUN | Solar-electric | Electricity | Any | Main | 9.4E-05 | -0.00332 | 0.032648 | 0.057811 |  |
| STE-1-JUL | 1 | JUL | Solar-electric | Electricity | Any | Main | 2.4E-05 | -0.001 | 0.011038 | 0.098331 |  |
| STE-1-AUG | 1 | AUG | Solar-electric | Electricity | Any | Main | 1.63E-05 | -0.00055 | 0.004168 | 0.115426 |  |
| STE-1-SEP | 1 | SEP | Solar-electric | Electricity | Any | Main | 3.13E-05 | -0.0012 | 0.014716 | 0.043451 |  |
| STE-1-OCT | 1 | OCT | Solar-electric | Electricity | Any | Main | 6.33E-06 | -0.00035 | 0.006813 | 0.041865 |  |
| STE-1-NOV | 1 | NOV | Solar-electric | Electricity | Any | Main | -3E-05 | 0.001012 | -0.0082 | 0.061458 |  |
| STE-1-DEC | 1 | DEC | Solar-electric | Electricity | Any | Main | -3.2E-05 | 0.001492 | -0.02114 | 0.136447 |  |
| STE-2-JAN | 2 | JAN | Solar-electric | Electricity | Any | Main | -1.5E-05 | 0.000685 | -0.00769 | 0.045454 |  |
| STE-2-FEB | 2 | FEB | Solar-electric | Electricity | Any | Main | -1.3E-05 | 0.000506 | -0.0041 | 0.032746 |  |
| STE-2-MAR | 2 | MAR | Solar-electric | Electricity | Any | Main | -1.2E-05 | 0.000455 | -0.00278 | 0.043174 |  |
| STE-2-APR | 2 | APR | Solar-electric | Electricity | Any | Main | -9.9E-06 | 0.000416 | -0.00469 | 0.087103 |  |
| STE-2-MAY | 2 | MAY | Solar-electric | Electricity | Any | Main | 2.48E-05 | -0.00119 | 0.017044 | 0.032639 |  |
| STE-2-JUN | 2 | JUN | Solar-electric | Electricity | Any | Main | 1.76E-05 | -0.00056 | -0.00011 | 0.196592 |  |
| STE-2-JUL | 2 | JUL | Solar-electric | Electricity | Any | Main | 9.46E-06 | -0.00012 | -0.00766 | 0.242975 |  |
| STE-2-AUG | 2 | AUG | Solar-electric | Electricity | Any | Main | 1.98E-05 | -0.0008 | 0.007611 | 0.116265 |  |
| STE-2-SEP | 2 | SEP | Solar-electric | Electricity | Any | Main | -1E-06 | -6.7E-06 | 0.000811 | 0.093441 |  |
| STE-2-OCT | 2 | OCT | Solar-electric | Electricity | Any | Main | -3.6E-06 | 4.58E-07 | 0.004497 | 0.024375 |  |
| STE-2-NOV | 2 | NOV | Solar-electric | Electricity | Any | Main | -6E-06 | 0.000183 | 0.000158 | 0.049802 |  |
| STE-2-DEC | 2 | DEC | Solar-electric | Electricity | Any | Main | -1.1E-05 | 0.000429 | -0.00309 | 0.035433 |  |
| STE-3-JAN | 3 | JAN | Solar-electric | Electricity | Any | Main | -7E-06 | 0.000278 | -0.00285 | 0.034901 |  |
| STE-3-FEB | 3 | FEB | Solar-electric | Electricity | Any | Main | 1.56E-06 | -7.8E-05 | 0.002106 | 0.018935 |  |
| STE-3-MAR | 3 | MAR | Solar-electric | Electricity | Any | Main | -1.1E-05 | 0.000553 | -0.00783 | 0.086503 |  |
| STE-3-APR | 3 | APR | Solar-electric | Electricity | Any | Main | 2.93E-06 | -0.00024 | 0.006759 | 0.023464 |  |
| STE-3-MAY | 3 | MAY | Solar-electric | Electricity | Any | Main | 1.83E-05 | -0.00075 | 0.005705 | 0.184674 |  |
| STE-3-JUN | 3 | JUN | Solar-electric | Electricity | Any | Main | -2.2E-06 | 0.000308 | -0.01234 | 0.287633 |  |
| STE-3-JUL | 3 | JUL | Solar-electric | Electricity | Any | Main | 2.01E-05 | -0.00085 | 0.008645 | 0.143214 |  |
| STE-3-AUG | 3 | AUG | Solar-electric | Electricity | Any | Main | 4.4E-06 | -0.00035 | 0.00774 | 0.064724 |  |
| STE-3-SEP | 3 | SEP | Solar-electric | Electricity | Any | Main | -1.2E-05 | 0.000414 | -0.00102 | 0.04258 |  |
| STE-3-OCT | 3 | OCT | Solar-electric | Electricity | Any | Main | -5.1E-06 | 0.000251 | -0.00206 | 0.05056 |  |
| STE-3-NOV | 3 | NOV | Solar-electric | Electricity | Any | Main | 1.41E-06 | -3.9E-05 | 0.001452 | 0.023815 |  |
| STE-3-DEC | 3 | DEC | Solar-electric | Electricity | Any | Main | -1.1E-05 | 0.000514 | -0.0063 | 0.038998 |  |
| STE-4-JAN | 4 | JAN | Solar-electric | Electricity | Any | Main | -4.1E-06 | 0.000164 | -0.0015 | 0.01607 |  |
| STE-4-FEB | 4 | FEB | Solar-electric | Electricity | Any | Main | 4.27E-06 | -0.00022 | 0.003686 | 0.001708 |  |
| STE-4-MAR | 4 | MAR | Solar-electric | Electricity | Any | Main | -7.6E-06 | 0.000347 | -0.00347 | 0.034857 |  |
| STE-4-APR | 4 | APR | Solar-electric | Electricity | Any | Main | 1.8E-05 | -0.00086 | 0.01317 | 0.018849 |  |
| STE-4-MAY | 4 | MAY | Solar-electric | Electricity | Any | Main | -7E-06 | 0.000309 | -0.00526 | 0.175851 |  |
| STE-4-JUN | 4 | JUN | Solar-electric | Electricity | Any | Main | -7.3E-06 | 0.000454 | -0.01191 | 0.281097 |  |
| STE-4-JUL | 4 | JUL | Solar-electric | Electricity | Any | Main | -6.5E-06 | 0.000377 | -0.00918 | 0.243305 |  |
| STE-4-AUG | 4 | AUG | Solar-electric | Electricity | Any | Main | -3.1E-06 | 0.000133 | -0.00245 | 0.159941 |  |
| STE-4-SEP | 4 | SEP | Solar-electric | Electricity | Any | Main | 1.37E-05 | -0.00068 | 0.011392 | 0.040615 |  |
| STE-4-OCT | 4 | OCT | Solar-electric | Electricity | Any | Main | 2.68E-06 | -0.00015 | 0.004627 | 0.00819 |  |
| STE-4-NOV | 4 | NOV | Solar-electric | Electricity | Any | Main | -7.9E-07 | 3.45E-05 | 0.001148 | 0.008099 |  |
| STE-4-DEC | 4 | DEC | Solar-electric | Electricity | Any | Main | -2.2E-06 | 8.66E-05 | -0.00026 | 0.011418 |  |
| STG-1-JAN | 1 | JAN | Solar-gas | Gas | Continuous | Main | -1.1E-05 | 0.000494 | -0.00598 | 0.056185 | Gas share of total only, separate equations for electric aux share (STX), gas+elec add to 1.000 |
| STG-1-FEB | 1 | FEB | Solar-gas | Gas | Continuous | Main | -6.5E-06 | 0.00017 | -0.00012 | 0.043814 |  |
| STG-1-MAR | 1 | MAR | Solar-gas | Gas | Continuous | Main | -1.4E-05 | 0.00044 | -0.00246 | 0.050136 |  |
| STG-1-APR | 1 | APR | Solar-gas | Gas | Continuous | Main | -1.1E-05 | 0.00026 | 0.000277 | 0.048508 |  |
| STG-1-MAY | 1 | MAY | Solar-gas | Gas | Continuous | Main | 4.18E-05 | -0.00161 | 0.018507 | 0.051712 |  |
| STG-1-JUN | 1 | JUN | Solar-gas | Gas | Continuous | Main | 4.43E-05 | -0.00169 | 0.019166 | 0.055384 |  |
| STG-1-JUL | 1 | JUL | Solar-gas | Gas | Continuous | Main | 3.09E-05 | -0.00126 | 0.015836 | 0.052003 |  |
| STG-1-AUG | 1 | AUG | Solar-gas | Gas | Continuous | Main | 1.79E-05 | -0.00076 | 0.010367 | 0.056218 |  |
| STG-1-SEP | 1 | SEP | Solar-gas | Gas | Continuous | Main | 1.94E-06 | -0.00024 | 0.006224 | 0.04736 |  |
| STG-1-OCT | 1 | OCT | Solar-gas | Gas | Continuous | Main | -8.3E-06 | 0.000202 | 0.000713 | 0.052224 |  |
| STG-1-NOV | 1 | NOV | Solar-gas | Gas | Continuous | Main | -1.9E-05 | 0.000647 | -0.00478 | 0.050595 |  |
| STG-1-DEC | 1 | DEC | Solar-gas | Gas | Continuous | Main | -7.4E-06 | 0.000368 | -0.00455 | 0.056815 |  |
| STX-1-JAN | 1 | JAN | Solar-gas | Electricity | Continuous | Secondary | -3.9E-06 | 0.000199 | -0.0037 | 0.027782 | Electric aux share (STX), gas+elec add to 1.000 |
| STX-1-FEB | 1 | FEB | Solar-gas | Electricity | Continuous | Secondary | -3.9E-06 | 0.000215 | -0.00416 | 0.031076 |  |
| STX-1-MAR | 1 | MAR | Solar-gas | Electricity | Continuous | Secondary | -3.3E-06 | 0.000186 | -0.00376 | 0.029688 |  |
| STX-1-APR | 1 | APR | Solar-gas | Electricity | Continuous | Secondary | -3.2E-06 | 0.000184 | -0.00371 | 0.029029 |  |
| STX-1-MAY | 1 | MAY | Solar-gas | Electricity | Continuous | Secondary | -7.4E-06 | 0.000343 | -0.00566 | 0.036676 |  |
| STX-1-JUN | 1 | JUN | Solar-gas | Electricity | Continuous | Secondary | -9.2E-06 | 0.000408 | -0.00639 | 0.039096 |  |
| STX-1-JUL | 1 | JUL | Solar-gas | Electricity | Continuous | Secondary | -6.8E-06 | 0.00032 | -0.00535 | 0.035053 |  |
| STX-1-AUG | 1 | AUG | Solar-gas | Electricity | Continuous | Secondary | -5.1E-06 | 0.000257 | -0.00462 | 0.032761 |  |
| STX-1-SEP | 1 | SEP | Solar-gas | Electricity | Continuous | Secondary | -4.1E-06 | 0.000219 | -0.00415 | 0.030869 |  |
| STX-1-OCT | 1 | OCT | Solar-gas | Electricity | Continuous | Secondary | -4.4E-06 | 0.000224 | -0.00415 | 0.030586 |  |
| STX-1-NOV | 1 | NOV | Solar-gas | Electricity | Continuous | Secondary | -3.9E-06 | 0.000202 | -0.00377 | 0.028499 |  |
| STX-1-DEC | 1 | DEC | Solar-gas | Electricity | Continuous | Secondary | -4.4E-06 | 0.000213 | -0.00379 | 0.027931 |  |
| STG-2-JAN | 2 | JAN | Solar-gas | Gas | Continuous | Main | -9E-06 | 0.000408 | -0.00451 | 0.040447 | Gas share of total only, separate equations for electric aux share (STX), gas+elec add to 1.000 |
| STG-2-FEB | 2 | FEB | Solar-gas | Gas | Continuous | Main | -8.2E-06 | 0.000343 | -0.00285 | 0.037067 |  |
| STG-2-MAR | 2 | MAR | Solar-gas | Gas | Continuous | Main | -7E-06 | 0.000239 | -0.00059 | 0.040713 |  |
| STG-2-APR | 2 | APR | Solar-gas | Gas | Continuous | Main | 5.44E-07 | -8.2E-05 | 0.002965 | 0.046132 |  |
| STG-2-MAY | 2 | MAY | Solar-gas | Gas | Continuous | Main | 1.43E-05 | -0.0007 | 0.010492 | 0.049676 |  |
| STG-2-JUN | 2 | JUN | Solar-gas | Gas | Continuous | Main | 2.55E-05 | -0.00113 | 0.013606 | 0.08419 |  |
| STG-2-JUL | 2 | JUL | Solar-gas | Gas | Continuous | Main | 2.4E-05 | -0.00105 | 0.012522 | 0.089443 |  |
| STG-2-AUG | 2 | AUG | Solar-gas | Gas | Continuous | Main | 1.7E-05 | -0.00079 | 0.01067 | 0.068089 |  |
| STG-2-SEP | 2 | SEP | Solar-gas | Gas | Continuous | Main | 9.41E-06 | -0.00049 | 0.0082 | 0.051194 |  |
| STG-2-OCT | 2 | OCT | Solar-gas | Gas | Continuous | Main | -3.5E-06 | 4.4E-05 | 0.002878 | 0.034379 |  |
| STG-2-NOV | 2 | NOV | Solar-gas | Gas | Continuous | Main | -1.9E-06 | 1.86E-05 | 0.002088 | 0.040892 |  |
| STG-2-DEC | 2 | DEC | Solar-gas | Gas | Continuous | Main | -9.1E-06 | 0.000367 | -0.00277 | 0.038935 |  |
| STX-2-JAN | 2 | JAN | Solar-gas | Electricity | Continuous | Secondary | -3.1E-06 | 0.000172 | -0.00333 | 0.025484 | Electric aux share (STX), gas+elec add to 1.000 |
| STX-2-FEB | 2 | FEB | Solar-gas | Electricity | Continuous | Secondary | -2.8E-06 | 0.000159 | -0.00314 | 0.024204 |  |
| STX-2-MAR | 2 | MAR | Solar-gas | Electricity | Continuous | Secondary | -3.3E-06 | 0.000182 | -0.00359 | 0.027421 |  |
| STX-2-APR | 2 | APR | Solar-gas | Electricity | Continuous | Secondary | -2.9E-06 | 0.000164 | -0.00322 | 0.024759 |  |
| STX-2-MAY | 2 | MAY | Solar-gas | Electricity | Continuous | Secondary | -5E-06 | 0.000266 | -0.00485 | 0.033308 |  |
| STX-2-JUN | 2 | JUN | Solar-gas | Electricity | Continuous | Secondary | -6.2E-06 | 0.000323 | -0.00577 | 0.03837 |  |
| STX-2-JUL | 2 | JUL | Solar-gas | Electricity | Continuous | Secondary | -8.1E-06 | 0.000426 | -0.00758 | 0.05081 |  |
| STX-2-AUG | 2 | AUG | Solar-gas | Electricity | Continuous | Secondary | -6.8E-06 | 0.000353 | -0.00629 | 0.042065 |  |
| STX-2-SEP | 2 | SEP | Solar-gas | Electricity | Continuous | Secondary | -5E-06 | 0.000268 | -0.00493 | 0.034373 |  |
| STX-2-OCT | 2 | OCT | Solar-gas | Electricity | Continuous | Secondary | -3E-06 | 0.000171 | -0.00342 | 0.026713 |  |
| STX-2-NOV | 2 | NOV | Solar-gas | Electricity | Continuous | Secondary | -3.1E-06 | 0.000172 | -0.00338 | 0.026076 |  |
| STX-2-DEC | 2 | DEC | Solar-gas | Electricity | Continuous | Secondary | -2.8E-06 | 0.000159 | -0.00318 | 0.02526 |  |
| STG-3-JAN | 3 | JAN | Solar-gas | Gas | Continuous | Main | -8E-06 | 0.0004 | -0.00575 | 0.051326 | Gas share of total only, separate equations for electric aux share (STX), gas+elec add to 1.000 |
| STG-3-FEB | 3 | FEB | Solar-gas | Gas | Continuous | Main | -7.3E-06 | 0.000321 | -0.00337 | 0.04218 |  |
| STG-3-MAR | 3 | MAR | Solar-gas | Gas | Continuous | Main | -7.2E-06 | 0.000277 | -0.00181 | 0.049192 |  |
| STG-3-APR | 3 | APR | Solar-gas | Gas | Continuous | Main | -1.8E-06 | -3.9E-05 | 0.003465 | 0.046153 |  |
| STG-3-MAY | 3 | MAY | Solar-gas | Gas | Continuous | Main | 3.09E-05 | -0.00141 | 0.018412 | 0.078389 |  |
| STG-3-JUN | 3 | JUN | Solar-gas | Gas | Continuous | Main | 3.45E-05 | -0.00152 | 0.018599 | 0.094321 |  |
| STG-3-JUL | 3 | JUL | Solar-gas | Gas | Continuous | Main | 2.39E-05 | -0.0011 | 0.014615 | 0.081664 |  |
| STG-3-AUG | 3 | AUG | Solar-gas | Gas | Continuous | Main | 1.34E-05 | -0.00069 | 0.011043 | 0.055385 |  |
| STG-3-SEP | 3 | SEP | Solar-gas | Gas | Continuous | Main | -5.6E-06 | 0.000128 | 0.001777 | 0.046305 |  |
| STG-3-OCT | 3 | OCT | Solar-gas | Gas | Continuous | Main | -1.2E-05 | 0.000517 | -0.00461 | 0.05281 |  |
| STG-3-NOV | 3 | NOV | Solar-gas | Gas | Continuous | Main | -1.3E-05 | 0.000577 | -0.00628 | 0.0508 |  |
| STG-3-DEC | 3 | DEC | Solar-gas | Gas | Continuous | Main | -1.1E-05 | 0.000546 | -0.00757 | 0.050007 |  |
| STX-3-JAN | 3 | JAN | Solar-gas | Electricity | Continuous | Secondary | -2.8E-06 | 0.00015 | -0.00287 | 0.02265 | Electric aux share (STX), gas+elec add to 1.000 |
| STX-3-FEB | 3 | FEB | Solar-gas | Electricity | Continuous | Secondary | -2.2E-06 | 0.000124 | -0.00251 | 0.020922 |  |
| STX-3-MAR | 3 | MAR | Solar-gas | Electricity | Continuous | Secondary | -2.4E-06 | 0.000136 | -0.00279 | 0.023408 |  |
| STX-3-APR | 3 | APR | Solar-gas | Electricity | Continuous | Secondary | -2.5E-06 | 0.000147 | -0.00304 | 0.025096 |  |
| STX-3-MAY | 3 | MAY | Solar-gas | Electricity | Continuous | Secondary | -3.7E-06 | 0.000195 | -0.00358 | 0.025975 |  |
| STX-3-JUN | 3 | JUN | Solar-gas | Electricity | Continuous | Secondary | -3.8E-06 | 0.0002 | -0.00371 | 0.027118 |  |
| STX-3-JUL | 3 | JUL | Solar-gas | Electricity | Continuous | Secondary | -4.8E-06 | 0.00025 | -0.00451 | 0.031767 |  |
| STX-3-AUG | 3 | AUG | Solar-gas | Electricity | Continuous | Secondary | -3.8E-06 | 0.000205 | -0.00391 | 0.029389 |  |
| STX-3-SEP | 3 | SEP | Solar-gas | Electricity | Continuous | Secondary | -3E-06 | 0.000168 | -0.00334 | 0.026497 |  |
| STX-3-OCT | 3 | OCT | Solar-gas | Electricity | Continuous | Secondary | -2.6E-06 | 0.000143 | -0.00283 | 0.023366 |  |
| STX-3-NOV | 3 | NOV | Solar-gas | Electricity | Continuous | Secondary | -2.3E-06 | 0.000128 | -0.00263 | 0.022626 |  |
| STX-3-DEC | 3 | DEC | Solar-gas | Electricity | Continuous | Secondary | -2.8E-06 | 0.000146 | -0.0028 | 0.022656 |  |
| STG-4-JAN | 4 | JAN | Solar-gas | Gas | Continuous | Main | -6.9E-06 | 0.000356 | -0.00563 | 0.043172 | Gas share of total only, separate equations for electric aux share (STX), gas+elec add to 1.000 |
| STG-4-FEB | 4 | FEB | Solar-gas | Gas | Continuous | Main | -6.2E-06 | 0.000305 | -0.00432 | 0.034512 |  |
| STG-4-MAR | 4 | MAR | Solar-gas | Gas | Continuous | Main | -7E-06 | 0.000341 | -0.00395 | 0.046267 |  |
| STG-4-APR | 4 | APR | Solar-gas | Gas | Continuous | Main | 2.11E-06 | -0.00013 | 0.003197 | 0.059818 |  |
| STG-4-MAY | 4 | MAY | Solar-gas | Gas | Continuous | Main | 1.54E-05 | -0.00076 | 0.01085 | 0.089318 |  |
| STG-4-JUN | 4 | JUN | Solar-gas | Gas | Continuous | Main | 2.14E-05 | -0.00102 | 0.013514 | 0.112184 |  |
| STG-4-JUL | 4 | JUL | Solar-gas | Gas | Continuous | Main | 1.9E-05 | -0.00091 | 0.012189 | 0.110253 |  |
| STG-4-AUG | 4 | AUG | Solar-gas | Gas | Continuous | Main | 1.4E-05 | -0.0007 | 0.010611 | 0.086547 |  |
| STG-4-SEP | 4 | SEP | Solar-gas | Gas | Continuous | Main | 4.78E-06 | -0.00031 | 0.006634 | 0.059667 |  |
| STG-4-OCT | 4 | OCT | Solar-gas | Gas | Continuous | Main | -1.3E-05 | 0.000556 | -0.0051 | 0.050276 |  |
| STG-4-NOV | 4 | NOV | Solar-gas | Gas | Continuous | Main | -9.5E-06 | 0.00043 | -0.00456 | 0.039979 |  |
| STG-4-DEC | 4 | DEC | Solar-gas | Gas | Continuous | Main | -8.2E-06 | 0.000406 | -0.00553 | 0.040101 |  |
| STX-4-JAN | 4 | JAN | Solar-gas | Electricity | Continuous | Secondary | -1.8E-06 | 0.000101 | -0.00197 | 0.016313 | Electric aux share (STX), gas+elec add to 1.000 |
| STX-4-FEB | 4 | FEB | Solar-gas | Electricity | Continuous | Secondary | -1.4E-06 | 8.01E-05 | -0.00161 | 0.01398 |  |
| STX-4-MAR | 4 | MAR | Solar-gas | Electricity | Continuous | Secondary | -1.8E-06 | 0.0001 | -0.00203 | 0.017569 |  |
| STX-4-APR | 4 | APR | Solar-gas | Electricity | Continuous | Secondary | -1.9E-06 | 0.000105 | -0.00212 | 0.018012 |  |
| STX-4-MAY | 4 | MAY | Solar-gas | Electricity | Continuous | Secondary | -2.4E-06 | 0.000131 | -0.00254 | 0.020068 |  |
| STX-4-JUN | 4 | JUN | Solar-gas | Electricity | Continuous | Secondary | -2.6E-06 | 0.000142 | -0.0027 | 0.020911 |  |
| STX-4-JUL | 4 | JUL | Solar-gas | Electricity | Continuous | Secondary | -3.3E-06 | 0.000178 | -0.00333 | 0.025139 |  |
| STX-4-AUG | 4 | AUG | Solar-gas | Electricity | Continuous | Secondary | -3E-06 | 0.000163 | -0.00305 | 0.023125 |  |
| STX-4-SEP | 4 | SEP | Solar-gas | Electricity | Continuous | Secondary | -2.1E-06 | 0.000119 | -0.00238 | 0.020049 |  |
| STX-4-OCT | 4 | OCT | Solar-gas | Electricity | Continuous | Secondary | -2.2E-06 | 0.00012 | -0.00231 | 0.019152 |  |
| STX-4-NOV | 4 | NOV | Solar-gas | Electricity | Continuous | Secondary | -1.6E-06 | 8.91E-05 | -0.00184 | 0.016658 |  |
| STX-4-DEC | 4 | DEC | Solar-gas | Electricity | Continuous | Secondary | -1.9E-06 | 0.000103 | -0.00201 | 0.016932 |  |
| SHP-1-JAN | 1 | JAN | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.058703 |  |
| SHP-1-FEB | 1 | FEB | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.062888 |  |
| SHP-1-MAR | 1 | MAR | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.071813 |  |
| SHP-1-APR | 1 | APR | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.078434 |  |
| SHP-1-MAY | 1 | MAY | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.092218 |  |
| SHP-1-JUN | 1 | JUN | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.10173 |  |
| SHP-1-JUL | 1 | JUL | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.10526 |  |
| SHP-1-AUG | 1 | AUG | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.100873 |  |
| SHP-1-SEP | 1 | SEP | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.095082 |  |
| SHP-1-OCT | 1 | OCT | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.087002 |  |
| SHP-1-NOV | 1 | NOV | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.077042 |  |
| SHP-1-DEC | 1 | DEC | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.068956 |  |
| SHP-2-JAN | 2 | JAN | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.055245 |  |
| SHP-2-FEB | 2 | FEB | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.057195 |  |
| SHP-2-MAR | 2 | MAR | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.069196 |  |
| SHP-2-APR | 2 | APR | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.079791 |  |
| SHP-2-MAY | 2 | MAY | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.094957 |  |
| SHP-2-JUN | 2 | JUN | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.100638 |  |
| SHP-2-JUL | 2 | JUL | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.129193 |  |
| SHP-2-AUG | 2 | AUG | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.106036 |  |
| SHP-2-SEP | 2 | SEP | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.095443 |  |
| SHP-2-OCT | 2 | OCT | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.07981 |  |
| SHP-2-NOV | 2 | NOV | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.069322 |  |
| SHP-2-DEC | 2 | DEC | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.063175 |  |
| SHP-3-JAN | 3 | JAN | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.057955 |  |
| SHP-3-FEB | 3 | FEB | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.061267 |  |
| SHP-3-MAR | 3 | MAR | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.070289 |  |
| SHP-3-APR | 3 | APR | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.078875 |  |
| SHP-3-MAY | 3 | MAY | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.094748 |  |
| SHP-3-JUN | 3 | JUN | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.099447 |  |
| SHP-3-JUL | 3 | JUL | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.108934 |  |
| SHP-3-AUG | 3 | AUG | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.10074 |  |
| SHP-3-SEP | 3 | SEP | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.091853 |  |
| SHP-3-OCT | 3 | OCT | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.090796 |  |
| SHP-3-NOV | 3 | NOV | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.077545 |  |
| SHP-3-DEC | 3 | DEC | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.067551 |  |
| SHP-4-JAN | 4 | JAN | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.063054 |  |
| SHP-4-FEB | 4 | FEB | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.057225 |  |
| SHP-4-MAR | 4 | MAR | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.074892 |  |
| SHP-4-APR | 4 | APR | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.077164 |  |
| SHP-4-MAY | 4 | MAY | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.092536 |  |
| SHP-4-JUN | 4 | JUN | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.096631 |  |
| SHP-4-JUL | 4 | JUL | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.106023 |  |
| SHP-4-AUG | 4 | AUG | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.099239 |  |
| SHP-4-SEP | 4 | SEP | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.092708 |  |
| SHP-4-OCT | 4 | OCT | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.090284 |  |
| SHP-4-NOV | 4 | NOV | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.077997 |  |
| SHP-4-DEC | 4 | DEC | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.072247 |  |
| SHP-5-JAN | 5 | JAN | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.054751 |  |
| SHP-5-FEB | 5 | FEB | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.052918 |  |
| SHP-5-MAR | 5 | MAR | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.071121 |  |
| SHP-5-APR | 5 | APR | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.074856 |  |
| SHP-5-MAY | 5 | MAY | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.093851 |  |
| SHP-5-JUN | 5 | JUN | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.115143 |  |
| SHP-5-JUL | 5 | JUL | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.119732 |  |
| SHP-5-AUG | 5 | AUG | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.10675 |  |
| SHP-5-SEP | 5 | SEP | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.096299 |  |
| SHP-5-OCT | 5 | OCT | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.083309 |  |
| SHP-5-NOV | 5 | NOV | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.068849 |  |
| SHP-5-DEC | 5 | DEC | Heat-pump | Electricity | Any | Main | 0 | 0 | 0 | 0.06242 |  |

# Appendix D – Water Heater Performance Coefficients for hourly share of energy by climate zone for Whole of Home rating

This Appendix sets out the coefficients to determine the share of daily energy by hour of the day for storage systems with continuous energisation. The annual purchased water heater energy *EAnnual-input* (energy input) is determined using Equation 21 and coefficients in Appendix B. The monthly and daily energy are then determined in accordance with Equation 22 and Equation 23 using coefficients from Appendix C. The share of daily energy is then determined for four separate components (A, B, C and D) using a third order polynomial with different coefficients for each components as defined in Equation 25 to Equation 28 as reproduced below:









In summary:

* Component A applies to Hours 0% hot water demand = hours 0-6,9,10,14,20-23
* Component B applies to Hours 10% hot water demand = hours 11,13
* Component C applies to Hours 12.5% hot water demand = hours 15,16,17,18
* Component D applies to Hours 15% hot water demand = hours 7,8.

As a check, the following equation should be used to validate the values for the four components (Equation 29 reproduced below):



Table 48: Modelling coefficients for hourly share of daily energy input for selected water heaters, all climates

| **System ID** | **Climate** | **Description** | **Fuel** | **Energisation** | **Component** | **ax** | **bx** | **cx** | **dx** |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| ESS-A | All | Electric storage small | Electricity | Continuous | Component A | -1.6E-05 | 0.000654 | -0.00868 | 0.041667 | Applies to Hours 0%= hrs 0-6,9,10,14,20-23 |
| ESS-B | All | Electric storage small | Electricity | Continuous | Component B | 2.22E-05 | -0.00092 | 0.012147 | 0.041667 | Applies to Hours 10%= hrs 11,13 |
| ESS-C | All | Electric storage small | Electricity | Continuous | Component C | 3.17E-05 | -0.00131 | 0.017352 | 0.041667 | Applies to Hours 12.5%= hrs 15,16,17,18 |
| ESS-D | All | Electric storage small | Electricity | Continuous | Component D | 4.12E-05 | -0.0017 | 0.022558 | 0.041667 | Applies to Hours 15%= hrs 7,8 |
| GST-A | All | Gas storage - all star ratings | Gas | Continuous | Component A | -1.2E-05 | 0.000505 | -0.00719 | 0.041667 | Applies to Hours 0%= hrs 0-6,9,10,14,20-23 |
| GST-B | All | Gas storage - all star ratings | Gas | Continuous | Component B | 1.66E-05 | -0.00071 | 0.010063 | 0.041667 | Applies to Hours 10%= hrs 11,13 |
| GST-C | All | Gas storage - all star ratings | Gas | Continuous | Component C | 2.38E-05 | -0.00101 | 0.014376 | 0.041667 | Applies to Hours 12.5%= hrs 15,16,17,18 |
| GST-D | All | Gas storage - all star ratings | Gas | Continuous | Component D | 3.09E-05 | -0.00131 | 0.018689 | 0.041667 | Applies to Hours 15%= hrs 7,8 |
| GIN-A | All | Gas instantaneous - all star ratings | Electricity | Continuous | Component A | -8.5E-06 | 0.000376 | -0.00582 | 0.041667 | Applies to Hours 0%= hrs 0-6,9,10,14,20-23 |
| GIN-B | All | Gas instantaneous - all star ratings | Electricity | Continuous | Component B | 1.19E-05 | -0.00053 | 0.00815 | 0.041667 | Applies to Hours 10%= hrs 11,13 |
| GIN-C | All | Gas instantaneous - all star ratings | Electricity | Continuous | Component C | 1.7E-05 | -0.00075 | 0.011642 | 0.041667 | Applies to Hours 12.5%= hrs 15,16,17,18 |
| GIN-D | All | Gas instantaneous - all star ratings | Electricity | Continuous | Component D | 2.21E-05 | -0.00098 | 0.015135 | 0.041667 | Applies to Hours 15%= hrs 7,8 |
| SHP-A | All | Heat-pump | Electricity | Continuous | Component A | -1.2E-06 | 6.64E-05 | -0.00182 | 0.041667 | Applies to Hours 0%= hrs 0-6,9,10,14,20-23 |
| SHP-B | All | Heat-pump | Electricity | Continuous | Component B | 1.64E-06 | -9.3E-05 | 0.002551 | 0.041667 | Applies to Hours 10%= hrs 11,13 |
| SHP-C | All | Heat-pump | Electricity | Continuous | Component C | 2.35E-06 | -0.00013 | 0.003644 | 0.041667 | Applies to Hours 12.5%= hrs 15,16,17,18 |
| SHP-D | All | Heat-pump | Electricity | Continuous | Component D | 3.05E-06 | -0.00017 | 0.004738 | 0.041667 | Applies to Hours 15%= hrs 7,8 |

# Appendix E – Postcode List

Under development

# Appendix F – Acknowledgements

These methods have been developed in collaboration with the NatHERS Technical Advisory Committee (TAC), Energy Efficient Strategies (EES), IT Power (Australia), and other industry experts from the residential building and appliance sector. The NatHERS Administrator acknowledges the extensive input from these organisations and committees.

* Airconditioning and Refrigeration Equipment Manufacturers Association of Australia (AREMA)
* Australian Building Sustainability Association (ABSA)
* Australian Institute of Architects (AIA)
* Australian Institute of Refrigeration, Air Conditioning and Heating (AIRAH)
* Australian Sustainable Built Environment Council (ASBEC)
* Australian Windows Association (AWA)
* Commonwealth Scientific and Industrial Research Organisation (CSIRO)
* Design Matters National (DMN)
* Energy Inspection (EI)
* Floyd Energy
* Gas Appliance Manufacturers Association of Australia (GAMAA)
* Graham Energy
* Green Building Council of Australia (GBCA)
* Hero Software (HERO)
* House Energy Raters Association (HERA)
* Insulation Australasia
* Insulation Council of Australia and New Zealand (ICANZ)
* Lighting Council Australia (LCA)
* NSW Department of Planning Industry and Environment (DPIE)
* Rheem Australia
* Royal Melbourne Institute of Technology (RMIT)
* Sustainability Victoria
* Swimming Pool & Spa Association (SPSA)
* University of Melbourne
* University of New South Wales
* University of Tasmania
* Victorian Department of Environment, Land, Water and Planning (DELWP)

1. For further details about how the societal cost of energy is defined, please refer to the ABCB Scoping Study (https://consultation.abcb.gov.au/engagement/energy-efficiency-scoping-study-2019/). [↑](#footnote-ref-2)
2. For the 2013 Determination see: Greenhouse and Energy Minimum Standards (Air Conditioners and Heat Pumps) Determination, <https://www.legislation.gov.au/Details/F2013L01672> [↑](#footnote-ref-3)
3. For the 2019 Determination see: Greenhouse and Energy Minimum Standards (Air Conditioners up to 65kW) Determination, <https://www.legislation.gov.au/Details/F2019L00490> [↑](#footnote-ref-4)
4. Review of hot water energy consumption data as input to the whole of house rating proposal under NatHERS, Energy Efficient Strategies, 2019. [↑](#footnote-ref-5)
5. Based on value adopted in Sustainability Victoria’s Zero Net Carbon Model. [↑](#footnote-ref-6)
6. Pacific Power, The Residential End-Use Study, 1994. [↑](#footnote-ref-7)
7. Proof of Concept: Residential Energy Monitoring Program - Final Report (REMP), 2012. [↑](#footnote-ref-8)
8. Versions of these tables should already exist in NatHERS software tools, or be referenced by software tools, for the existing Thermal simulations. They are required in the Zone information as part of Data Type 3 in the scratch file to set up the internal heat gains assigned to the zones based on people living in the house. For writing the scratch files for Whole of Home simulations, these tables should be referenced. [↑](#footnote-ref-9)
9. These are repetitions of what should already be in existing NatHERS software tools to assign the correct internal loads for the zone into the Chenath scratch file. Note: This is not considered “being dealt with by Chenath” since it requires software providers to correctly write the scratch file. [↑](#footnote-ref-10)
10. Review of hot water energy consumption data as input to the whole of house rating proposal under NatHERS, Energy Efficient Strategies, 2019. [↑](#footnote-ref-11)
11. Value used for ABCB NCC 2022 analysis. [↑](#footnote-ref-12)
12. The direct beam portion is described as “direct solar irradiance on a plane normal to the beam ((W/m2).” [↑](#footnote-ref-13)
13. In the following hour when the sun moves anti-clockwise to the west of the “end of the hour” position shown in Figure 3, the azimuth range subtended by the LHS and RHS of the object would be fully outside the sun’s azimuth range in that hour i.e. no shading [↑](#footnote-ref-14)
14. The suitability of some climate zones is yet to be determined. The NatHERS Administrator will seek advice from the NatHERS Technical Advisory Committee. [↑](#footnote-ref-15)