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 (10^9 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)

1 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.

1.1 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.

1.2 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]. 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.

1.3 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.

1.4 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

[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/).

- 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.

1.5 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

2 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.

2.1 Occupancy

2.1.1 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.

2.1.2 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 m^2 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.

2.1.3 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.

2.2 Thermal Simulation Settings

2.2.1 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.

2.3 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/m^2). 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/m^2 would in any case only have a minor impact on total energy consumption
- Imposing a threshold such as 20 MJ/m^2 means that the assumed service provision will differ depending on whether a zone has a load of 19 MJ/year/m^2 or 21 MJ/year/m^2. 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]) or the new seasonal performance standard (GEMS 2019 Determination[3]) – 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:

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[2] For the 2013 Determination see: Greenhouse and Energy Minimum Standards (Air Conditioners and Heat Pumps) Determination, https://www.legislation.gov.au/Details/F2013L01672

[3] For the 2019 Determination see: Greenhouse and Energy Minimum Standards (Air Conditioners up to 65kW) Determination, https://www.legislation.gov.au/Details/F2019L00490

- 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.

2.4 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] 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.

[4] Review of hot water energy consumption data as input to the whole of house rating proposal under NatHERS, Energy Efficient Strategies, 2019.

2.5 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 $5W/m^2$ 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]. 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], REMP[7]).

2.6 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:

[5] Based on value adopted in Sustainability Victoria's Zero Net Carbon Model.
[6] Pacific Power, The Residential End-Use Study, 1994.
[7] Proof of Concept: Residential Energy Monitoring Program - Final Report (REMP), 2012.

- 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.

2.7 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).

2.8 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.

2.9 Cooking Module

Under development.

3 Part 2: Technical Specifications

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

3.1 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.

3.1.1 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

$$1 \leq N_{Occ} \leq 6$$

Equation 2: Number of occupants determined from floor area

$$N_{Occ} = 1.525 \ln(A_D) - 4.533$$

Where:

N_{Occ} = Number of occupants in the home

A_D = Area of Dwelling

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

N_{Occ} 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.

3.1.2 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.

3.1.3 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

$P_{WoH} = P_{ALLDAY} \times 0.6 + P_{WORKDAY} \times 0.4$

Where

P_{WoH} = The weighted value of the subject parameter i.e. the final WoH assessment value

P_{ALLDAY} = The value of the subject parameter as assessed using the All-day occupancy profile only

$P_{WORKDAY}$ = The value of the subject parameter as assessed using the Work day occupancy profile only

3.1.4 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

Zone	Conditioned	Internal Heat Gains
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.

3.1.5 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.

3.1.6 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, N_{Occ} is defined in Section 3.1.1.

Base Data[8]

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) B_{Lat}
	Appliances and cooking $B_{S.Tot}$	Lighting B_{Light}	People B_{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	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).

[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.

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]

Occupancy factor, F_{Occ}, is defined in Equation 4:

Equation 4: Occupancy factor for internal heat gains

$$F_{Occ} = 0.33 + 0.165 \times N_{Occ}$$

Where

N_{occ} = number of occupants (see Equation 2)

Family Factor, F_{Fam} is defined in Equation 5:

Equation 5: Family factor for internal heat gains

$$F_{Fam} = \frac{N_{Occ}}{4}$$

Where

N_{occ} = number of occupants (see Equation 2)

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

Equation 6: Area factor range for internal heat gains

$$0.1 \leq F_A \leq 2$$

Equation 7: Area factor for internal heat gains

$$F_A = \frac{A_{Zone}}{80}$$

Where:

A_{Zone} = Total floor area of specific Zone in m^2.

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.

[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.

Lighting Factor, F_{Light}, is defined in Equation 8:

Equation 8: Lighting factor for internal heat gains

$$F_{Light} = B_{Light} \times (F_A \times F_{Occ} - 1)$$

Where B_{Light} is the relevant hourly value specified in Table 5 or Table 6 as applicable.

People Factor, F_{People} is defined in Equation 9:

Equation 9: People factor for internal heat gains

$$F_{People} = B_{People} \times (F_A \times F_{Fam} - 1)$$

Total Sensible Heat Gain is defined in Equation 10:

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

$$G_{Sens} = B_{S.Tot} + F_{Light} + F_{People}$$

Where:

$B_{S.Tot}$ = 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

$$G_{Lat} = B_{Lat} + 0.5 \times F_{People}$$

Where:

B_{Lat} = 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

$$G_{Sens} = B_{Light} \times F_A \times F_{Occ} + B_{People} \times F_A \times F_{Fam}$$

Where:

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

B_{People} = 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

$$G_{Lat} = 0.5 \times B_{People} \times F_A \times F_{Fam}$$

3.1.7 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

3.1.8 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.

3.2 Heating and Cooling Modules

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

3.2.1 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).

3.2.2 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.

3.2.3 Hourly Loads

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

3.2.4 Annual Energy Load

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

3.2.5 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

$$E_{z.hr} = \frac{L_{z.hr}}{(1 - LS) \times COP_A}$$

Where:

$E_{z.hr}$ = hourly energy use (energy input) for the zone (MJ)

$L_{z.hr}$ = hourly energy load for the zone, from Chenath simulation (heating or cooling).

COP_A = 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

$$E_{A.hr} = E_{z.hr} \times A$$

$E_{A.hr}$ = Hourly electrical ancillary energy (MJ)

$E_{z.hr}$ = 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.

3.2.5.1 Air conditioners (heat pumps) used for heating

For air conditioners used for heating, the COP_A (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

Heating star rating in specified ZERL climate zone	HSPF
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.

3.2.5.2 Air conditioners (heat pumps) used for cooling

For refrigerative air conditioners used for cooling, the COP_A (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.

3.2.5.3 Ducted gas heaters

For ducted gas heaters, the COP_A (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 COP_A 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

$$COP_A = 0.4 + 0.1 \times GER$$

The value for COP_A 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

$$COP_A = 0.357892 + 0.3114 \times LN(GER)$$

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 COP_A for ducted gas heaters of various star ratings are shown in Table 21.

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

Stars	COP_A
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/

3.2.5.4 Non-ducted gas heaters

For non-ducted gas heaters, the COP_A (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 COP_A for a non-ducted gas heater is set out in Equation 18:

Equation 18: Operating efficiency for non-ducted gas heaters

$$COP_A = 0.61 + 0.06 \times (GER - 1)$$

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 COP_A for non-ducted gas heaters of various star ratings are shown in Table 22.

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

Stars	COP_A
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/

3.2.5.5 Wood heaters

For wood heaters, the COP_A (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 COP_A 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 COP_A (e.g. an AHHA efficiency rating of 75 equates to a COP_A 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.

3.2.5.6 Evaporative coolers

For evaporative coolers, the COP_A (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.

3.2.6 Appliance Demand

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

3.2.7 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.

3.2.8 Zones without conditioning devices

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

3.2.9 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.

3.3 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.

3.3.1 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 N_{Occ} as defined in Section 3.1.1.

3.3.2 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		
From	To	Zone
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

Postcode		
From	To	Zone
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

Postcode		
From	To	Zone
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

Postcode		Zone
From	To	
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

Postcode		Zone
From	**To**	
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

Postcode		Zone
From	**To**	
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.

3.3.3 Hot water systems

Research by Energy Efficient Strategies[10] 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.

3.3.4 Water heater energy calculations

3.3.4.1 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.

[10] Review of hot water energy consumption data as input to the whole of house rating proposal under NatHERS, Energy Efficient Strategies, 2019.

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:

$$N_{Occ} = 1.525\ln(A_D) - 4.533$$

Where:

N_{Occ} = Number of occupants in the home

A_D = Area of Dwelling

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

N_{Occ} 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 (K_{wp}) 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

$$K_{wp} = \frac{40 \times N_{Occ}}{y}$$

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

$$E_{Annual-output} = \frac{K_{wp} \times 365 \times 0.904521}{1000}$$

Where:

$E_{Annual-output}$ is the annual energy output (hot water demand) for the water heater in GJ/year

K_{wp} 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 $E_{Annual-input}$ (energy input) from the annual hot water demand energy $E_{Annual-output}$ (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

$$E_{Annual-input} = a \times (E_{Annual-output})^3 + b \times (E_{Annual-output})^2 + c \times (E_{Annual-output}) + d$$

Where $E_{Annual-output}$ is the annual hot water load (energy output) in GJ/year from Equation 20 and $E_{Annual-input}$ is the annual hot water energy purchased (energy input) in MJ/year.

Note: An earlier version of the water heater module used K_{wp} in Equation 21 to estimate $E_{Annual-input}$. The same general form of equation is used in this update, but $E_{Annual-output}$ 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 <u>large</u> 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 <u>medium or large</u> 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 $4 \leq N_{Occ} < 6$ (medium)	Minimum STC – solar thermal electric boost $N_{Occ} > 6$ (large)	Minimum STC – solar thermal gas boost $4 \leq N_{Occ} < 6$ (medium)	Minimum STC – solar thermal gas boost $N_{Occ} > 6$(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

Water heater code	Water heater type	Suffix details	Notes
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.

3.3.4.2 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 ($F_{m,z}$) 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 ($F_{m,z}$)

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 ($F_{m,z}$)

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 ($F_{m,z}$) (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 ($F_{m,z}$) (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%

Month	Zone HP1-AU	Zone HP2-AU	Zone HP3-AU	Zone HP4-AU	Zone HP5-AU
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

$$E_{Share-month} = a_{month} \times (E_{Annual-output})^3 + b_{month} \times (E_{Annual-output})^2 + c_{month} \times (E_{Annual-output}) + d_{month}$$

Where $E_{Annual\text{-}output}$ (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.

3.3.4.3 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

$$E_{Daily,m} = \frac{F_{m,z} \times E_{Annual-input}}{Days_m}$$

Where:

$F_{m,z}$ = 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.

$E_{Annual\text{-}input}$ is the annual hot water energy purchased (energy input) in MJ/year determined from Equation 21.

$Days_m$ = 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%

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
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 (E_{Hourly}) is defined in Equation 24 using the hourly share (F_{Hourly}) 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

$$E_{Hourly} = F_{Hourly} \times E_{Daily,m}$$

As set out in Table 34, the hourly breakdown of energy (F_{Hourly}) 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 (F_{Hourly}) is given by the following four equations:

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

$$F_{hourly-A} = a_A \times (E_{Annual-output})^3 + b_A \times (E_{Annual-output})^2 + c_A \times (E_{Annual-output}) + d_A$$

Where coefficients a_A, b_A, c_A and d_A 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

$$F_{hourly-B} = a_B \times (E_{Annual-output})^3 + b_B \times (E_{Annual-output})^2 + c_B \times (E_{Annual-output}) + d_B$$

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

$$F_{hourly-C} = a_C \times (E_{Annual-output})^3 + b_C \times (E_{Annual-output})^2 + c_C \times (E_{Annual-output}) + d_C$$

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

$$F_{hourly-D} = a_D \times (E_{Annual-output})^3 + b_D \times (E_{Annual-output})^2 + c_D \times (E_{Annual-output}) + d_D$$

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

$$F_{hourly-A} \times 16 + F_{hourly-B} \times 2 + F_{hourly-C} \times 4 + F_{hourly-A} \times 2 = 1.00000$$

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.

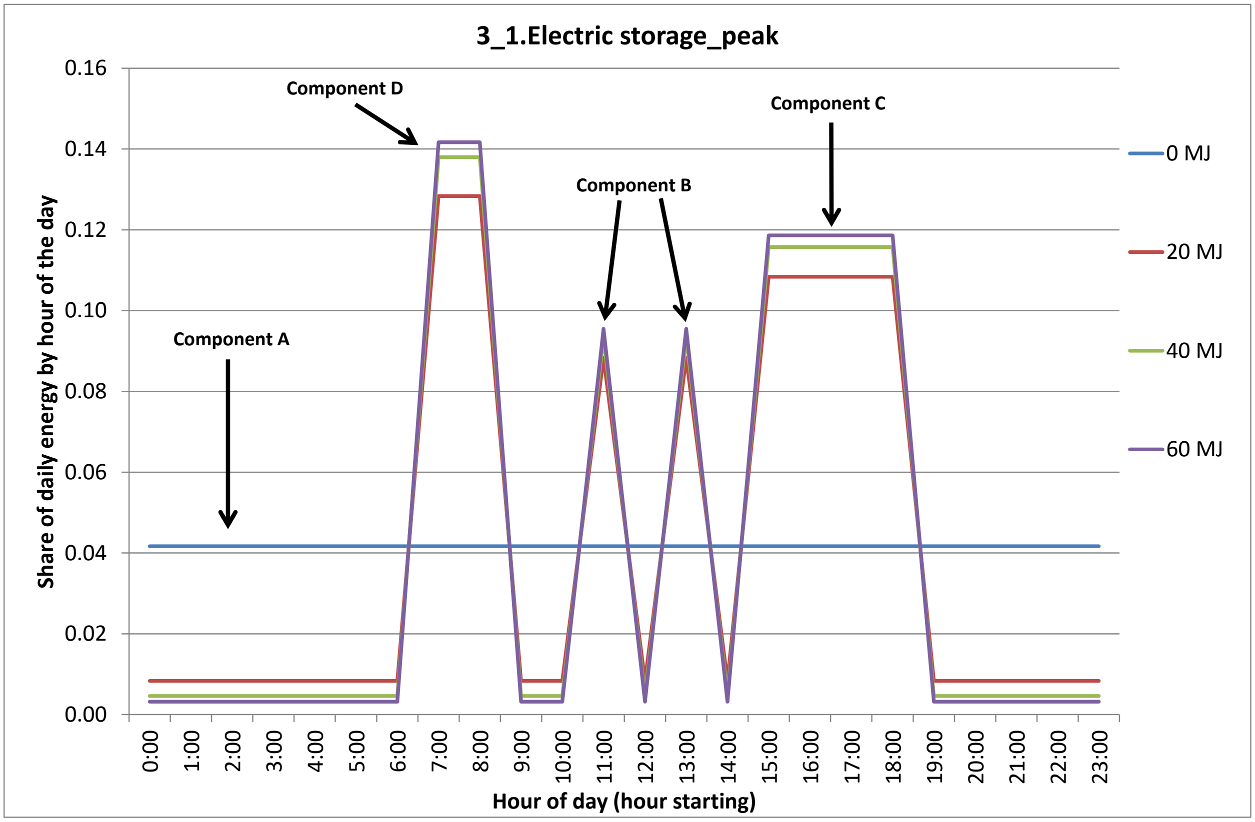

Figure 1: Illustration of changes in hourly share of daily with hot water load for a small electric storage system in Zone 3

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

3.3.4.4 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 m^2 new home in Zone 3.

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

$N_{Occ} = 1.525 \ln(200) - 4.533$ = 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 K_{wp} is defined as follows:

$$K_{wp} = \frac{40 \times 3.55}{5.017}$$ = 27.805 MJ/day winter peak hot water demand.

From Equation 20, the annual hot water demand (energy output) $E_{Annual\text{-}output}$ is defined as follows:

$$E_{Annual-output} = \frac{K_{wp} \times 27.805 \times 0.904521}{1000}$$ = 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 N_{Occ} of less than 4 people (see Table 26).

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

$$E_{Annual-input} = 0.27887 \times (9.1782)^3 + 28.75026 \times (9.1782)^2 + 87.96217 \times (9.1782) + 337.4859$$

$E_{Annual\text{-}input}$ = 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	Day s_m	Month Code	a-month	b-month	c-month	d-month	Monthly share $F_{m.z}$	Monthly energy MJ	Daily energy MJ $E_{Daily.m}$
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

Month	Day s_m	Month Code	a-month	b-month	c-month	d-month	Monthly share $F_{m.z}$	Monthly energy MJ	Daily energy MJ $E_{Daily.m}$
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 N_{Occ} of less than 4 people (see Table 26).

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

$$E_{Annual-input} = 0.233107 \times (9.1782)^3 + 13.17273 \times (9.1782)^2 + 131.502 \times (9.1782) + 491.7095$$

$E_{Annual-input}$ = 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	Day s_m	Month Code Gas	a-month	b-month	c-month	d-month	Monthly share $F_{m.z}$	Monthly energy MJ	Daily energy MJ $E_{Daily.m}$
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

Month	Day s_m	Month Code Gas	a-month	b-month	c-month	d-month	Monthly share $F_{m.z}$	Monthly energy MJ	Daily energy MJ $E_{Daily.m}$
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	Day s_m	Month Code Electricity	a-month	b-month	c-month	d-month	Monthly share $F_{m.z}$	Monthly energy MJ	Daily energy MJ $E_{Daily.m}$
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:

$$E_{Annual-input} = 0.209420838 \times (9.1782)^3 - 8.2968348 \times (9.1782)^2 + 1432.318768 \times (9.1782) + 0$$

$E_{Annual\text{-}input}$ = 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 $E_{Annual\text{-}input}$ = 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	$Days_m$	Month Code Gas	a-month	b-month	c-month	d-month	Monthly share $F_{m.z}$	Monthly energy MJ	Daily energy MJ $E_{Daily.m}$
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

Month	Days$_m$	Month Code Gas	a-month	b-month	c-month	d-month	Monthly share $F_{m.z}$	Monthly energy MJ	Daily energy MJ $E_{Daily.m}$
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	Days$_m$	Month Code Electricity	a-month	b-month	c-month	d-month	Monthly share $F_{m.z}$	Monthly energy MJ	Daily energy MJ $E_{Daily.m}$
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

Month	$Days_m$	Month Code Electricity	a-month	b-month	c-month	d-month	Monthly share $F_{m.z}$	Monthly energy MJ	Daily energy MJ $E_{Daily.m}$
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	F_{hourly}	E_{hourly}
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

Nominal Hour	Component	F_{hourly}	E_{hourly}
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:

$$E_{Annual-input} = 0 \times (9.1782)^3 + 0 \times (9.1782)^2 + 1020.408163 \times (9.1782) + 1681.753$$

$E_{Annual\text{-}input}$ = 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	$Days_m$	Month Code	a-month	b-month	c-month	d-month	Monthly share $F_{m.z}$	Monthly energy MJ	Daily energy MJ $E_{Daily.m}$
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

Month	$Days_m$	Month Code	a-month	b-month	c-month	d-month	Monthly share $F_{m.z}$	Monthly energy MJ	Daily energy MJ $E_{Daily.m}$
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	F_{hourly}	E_{hourly}
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

Nominal Hour	Component	F_{hourly}	E_{hourly}
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

3.3.5 PV Solar Diverters

3.3.5.1 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.

3.3.5.2 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.

3.3.5.3 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.

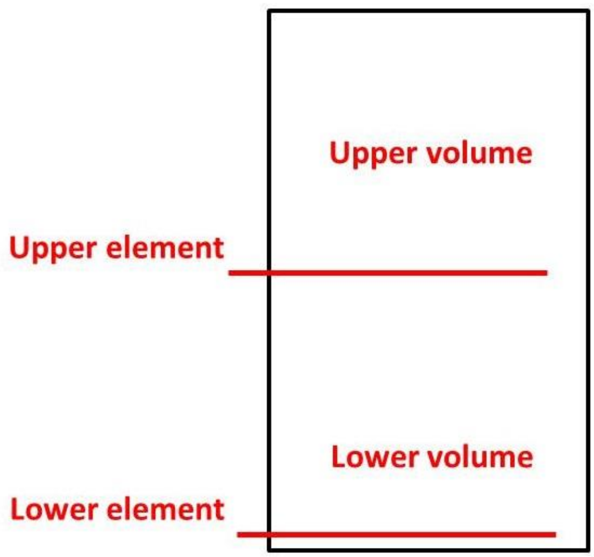

Figure 2: Key elements of a storage water heater in a PV solar diverter model

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.

3.3.5.4 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.

$$Volume(m^3) = \frac{Volume(L)}{1000}$$

V_{lwr} = lower tank volume in litres

V_{upp} = upper tank volume in litres

Note: $V_{lwr} + V_{upp} = Volume(L)$

Equation 30: Calculation of upper tank volume fraction

$$Fraction_{upp} = \frac{V_{upp}}{(V_{lwr} + V_{upp})}$$

Default values for $Fraction_{upp}$ are as follows:

System type	**Type 1**	**Type 2**	**Type 3**
$Fraction_{upp}$	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

$$D_{tank} = \left[\frac{4 \times Volume(m^3)}{\pi \times AR}\right]^{\frac{1}{3}}$$ where diameter is in metres

The tank height is calculated as follows:

Equation 32: Calculation of tank height

$H_{tank} = AR \times D_{tank\ where}$ 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

$$A_{lwr} = \frac{\pi \times (D_{tank})^2}{4} + \pi \times D_{tank} \times H_{tank} \times (1 - Fraction_{upp})$$

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

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

$$A_{upp} = \frac{\pi \times (D_{tank})^2}{4} + \pi \times D_{tank} \times H_{tank} \times (Fraction_{upp})$$

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	R^2
Value	-9.7853	22.0738	-19.7292	10.43019	0.97237	0.999452

Equation 35: Calculation of tank heat loss

Heatloss = B4×*Volume*$(m^3)^4$ + B3×*Volume*$(m^3)^3$ + B2×*Volume*$(m^3)^2$ + B1×*Volume*(m^3) + 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:

$$UA = \frac{Heatloss \times 3.6}{24 \times 55}$$

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

$$U = \frac{UA}{(A_{lwr} + A_{upp})}$$

Where A_{lwr} and A_{upp} are in m^2 and U is in MJ/hour/K/m^2

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

$$Q_{upp} = \frac{V_{upp} \times C_p \times (T_{hot} - T_{cold})}{1000}$$

Where:

Q_{upp} is the heat storage capacity of the upper segment in MJ

V_{upp} is the upper storage volume in litres

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

T_{hot} is the stored hot water heater in °C

T_{cold} is the cold water inlet temperature in °C

1000 is a factor to convert kJ to MJ.

The same equation is used to calculate Q_{lwr} by substituting V_{upp} with V_{lwr}.

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

$$Q_{lwr} = \frac{Vol_{lwr} \times C_p \times (T_{hot} - T_{cold})}{1000}$$

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 (T_{hot}) that are defined for modelling as follows, with default values shown for each system type:

Parameter	Description	Type 1	Type 2	Type 3
T_{grid}	Cutout temperature using grid power	70°C	60°C	47°C
T_{PV}	Cutout temperature using diverted PV power	70°C	70°C	75°C
$T_{primary}$	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 T_{super}, but this is assumed to be equal to T_{PV} 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 T_{grid} 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

$$T_{upp} = \frac{Q_{upp} \times 1000}{C_p \times Vol_{upp}} + T_{cold}$$

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

$$T_{lwr} = \frac{Q_{lwr} \times 1000}{C_p \times Vol_{lwr}} + T_{cold}$$

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
$E_{max-lwr(kW)}$	Power rating for lower element	3.6 kW	3.6 kW	3.6 kW
$E_{max-upp(kW)}$	Power rating for upper element	N/A	N/A	3.6 kW
$E_{max-lwr}$	Power rating for lower element	12.96 MJ/h	12.96 MJ/h	12.96 MJ/h
$E_{max-upp}$	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
$Parasitic_{PV}$	Net heater system controller parasitic load (MJ/hr)	0	0.007 × $E_{max-lwr(kW)}$	0.007 × $E_{max-lwr(kW)}$
Modulation	Heater load fraction that is modulated	0	1	1
Mod_{Eff-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
$Parasitic_{Grid}$	Net heater system controller parasitic load (MJ/hr)	0	0	0
Modulation	Heater load fraction that is modulated	0	0	0
$Mod_{Eff-Grid}$	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.

3.3.5.5 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 (Q_{upp} and Q_{lwr}) 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 T_{PV} – this is the maximum heat storage capacity of the unit – Q_{uppTpv} and Q_{lwrTpv}
- For a hot water temperature of T_{grid} – this is the heat storage capacity of the unit when boosted by grid power (for Type 1 this is the same as for T_{PV}) – $Q_{uppTgrid}$ and $Q_{lwrTgrid}$
- For a hot water temperature of $T_{primary}$ – 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 $Q_{lwrTprimary}$

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) ($Volume(L) = V_{upp} + V_{lwr}$)
Volume(m³)	Total tank hot water storage volume (cubic metres)
V_{upp}	Storage volume of the upper segment (litres)
V_{lwr}	Storage volume of the lower segment (litres)
$Fraction_{upp}$	Fraction of the upper volume to the total volume (no units)
A_{upp}	Inner surface area of the storage tank – upper segment (m^2)
A_{lwr}	Inner surface area of the storage tank – lower segment (m^2)
C_p	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/m^2)
T_{pv}	Control cutout storage maximum temperature for PV boosting (°C)
$T_{primary}$	Control cutout storage intermediate temperature for PV boosting (°C) (Type 3 only)

Variable	Description
T_{grid}	Control cutout storage temperature for grid boosting (°C)
Q_{uppTpv}	Maximum energy stored in the upper segment at temperature T_{PV} (MJ)
$Q_{uppTprimary}$	Maximum energy stored in the upper segment at temperature $T_{primary}$ (MJ) (Type 3 only)
$Q_{uppTgrid}$	Maximum energy stored in the upper segment at temperature T_{grid} (MJ)
Q_{lwrTpv}	Maximum energy stored in the upper segment at temperature T_{PV} (MJ)
$Q_{lwrTprimary}$	Maximum energy stored in the upper segment at temperature $T_{primary}$ (MJ) (Type 3 only)
$Q_{lwrTgrid}$	Maximum energy stored in the upper segment at temperature T_{grid} (MJ) (not Type 3)
Q_{upp0}	Energy stored in the upper segment at the start of the time period (MJ)
Q_{upp1}	Energy stored in the upper segment after heat loss and hot water use (MJ) (time step 1)
Q_{upp4}	Energy stored in the upper segment at the end of the time period (MJ) (= start next period)
Q_{lwr0}	Energy stored in the lower segment at the start of the time period (MJ)
Q_{lwr1}	Energy stored in the lower segment after heat loss and hot water use (MJ) (time step 1)
Q_{lwr4}	Energy stored in the lower segment at the end of the time period (MJ) (= start next period)
T_{upp0}	Temperature in the upper segment at the start of the hour (°C)
T_{upp1}	Temperature in the upper segment after heat loss and hot water use (°C)
T_{upp4}	Temperature in the upper segment at the end of the hour (°C)
T_{lwr0}	Temperature in the lower segment at the start of the hour (°C)
T_{lwr1}	Temperature in the lower segment after heat loss and hot water use (°C)
T_{lwr4}	Temperature in the lower segment at the end of the hour (°C) (= start next hour)
T_{amb}	Ambient outdoor temperature for the hour (°C) (from climate file)
T_{cold}	Cold water inlet temperature for the month and climate (°C) (from AS/NZS4234)
HW_{total}	Total hot water energy drawn from the water heater in the time period (MJ) (HW_{lwr} + HW_{upp})
HW_{lwr}	Hot water energy drawn from the lower segment in the time period (MJ)
HW_{upp}	Hot water energy drawn from the upper segment in the time period (MJ)
$Q_{lwr2\text{-}PV}$	Energy flow from excess PV into the lower segment of the water heater (MJ) (time step 2)
$Q_{upp2\text{-}PV}$	Energy flow from excess PV into the upper segment of the water heater (MJ) (time step 2)
$Q_{lwr3\text{-}PV}$	Energy flow from excess PV into the lower segment of the water heater (MJ) (time step 3)
$Q_{upp3\text{-}PV}$	Energy flow from excess PV into the upper segment of the water heater (MJ) (time step 3)
$Q_{lwr2\text{-}grid}$	Energy flow from the grid into the lower segment of the water heater (MJ) (time step 2a)
$Q_{lwr3\text{-}grid}$	Energy flow from the grid into the lower segment of the water heater (MJ) (time step 3a)
$Q_{upp3\text{-}grid}$	Energy flow from the grid into the upper segment of the water heater (MJ) (time step 3a)

Variable	Description
PV_{usable}	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.

3.3.5.6 Hourly calculations for PV solar diverter modelling

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

Initial heat storage (Q_{upp0} and Q_{lwr0}) and temperature (T_{upp0} and T_{lwr0}) 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.

$Heatloss_{upp} = \underline{U} \times A_{upp} \times (T_{upp0} - T_{amb})$ (IF $Q_{upp0} = 0$, then 0)

$Heatloss_{lwr} = \underline{U} \times A_{lwr} \times (T_{lwr0} - T_{amb})$ (IF $Q_{lwr0} = 0$, then 0)

Where T_{amb} is the ambient temperature for the hour from the climate file in °C and T_{upp0} and T_{lwr0} 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 (Vol_{lwr}) while the storage temperature is above the cold water temperature (i.e. when $Q_{lwr} > 0$). 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:

$Discharge_{signal}$ = IF(T_{upp0}>T_{cold},1,0) + IF(T_{lwr0}>T_{cold},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 T_{cold} so start discharging from the lower segment
- Discharge signal = 1 – the lower segment is empty (equal to or less than T_{cold} 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 T_{lwr} should always be less than or equal to T_{upp}.

If $Discharge_{signal}$ = 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 $Discharge_{signal}$ = 1, then hot water is drawn from the upper segment only, but cannot exceed the heat capacity stored in the upper segment.

HW_{lwr} = MIN(Q_{lwr0}, HW_{total}) where $Discharge_{signal}$ = 2 (otherwise 0)

Where HW_{lwr} is the energy drawn from the lower segment of the tank and HW_{total} 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.

HW_{upp} = MIN (Q_{upp0}, $HW_{total} - HW_{lwr}$)

Where HW_{upp} is the energy drawn from the upper segment of the tank and HW_{total} is the total water demand for the hour in MJ. Where $Discharge_{signal} < 2$, then HW_{lwr} 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.

$Q_{upp1} = Q_{upp0} - HW_{upp} - Heatloss_{upp}$

$Q_{lwr1} = Q_{lwr0} - HW_{lwr} - Heatloss_{lwr}$

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 T_{upp1} and T_{lwr1} 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.

$Charge_{lower}$ 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).

$Charge_{lower}$ = IF ($T_{lwr1} < T_{upp1}$ THEN 1 (TRUE) ELSE 0 (FALSE))

$Grid_{signal}$ 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 $Grid_{signal}$ 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 $Grid_{signal}$ 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 (T_{grid} = 47°C) whenever the upper section falls below that temperature set point.

PV_{signal} 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 PV_{signal} is set to 1 when $Grid_{signal}$ = 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 $PV_{available}$ 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 $PV_{available}$ is set to 0.

The PV_{usable} is calculated after taking into account any system losses:

PV_{usable} = MAX ($E_{max\text{-}lwr} \times Mod_{Eff\text{-}PV} - Parasitic_{PV}$, 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 PV_{usable} 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, $Grid_{signal}$ and PV_{signal} always have the flag set the same. The element operates when $Grid_{signal}$ 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, $Grid_{signal}$ flag is set to one only when grid boost is available (nominally limited hours overnight. PV_{signal} 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 $Charge_{lower}$ 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 T_{PV})(which is the same as T_{grid} for Type 1, these are different for Type 2). Charging rate is limited by the power input of the electrical element $E_{max\text{-}lwr}$. The energy input into the lower segment $Q_{lwr2\text{-}PV}$ from the PV system is minimum of the following three terms where $Charge_{lower}$ flag is 1 and PV_{signal} = 1:

Term 1: $\left[\frac{\left(T_{upp1}\text{-}T_{lwr1}\right)\times C_p \times\ Vol_{lwr}}{1000}\right]$

Term 2: PV_{usable}

Term 3: $E_{max\text{-}lwr} \times Mod_{Eff\text{-}PV} - Parasitic_{PV}$

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). $Q_{lwr3\text{-}PV}$ is the minimum of the following three terms when $PV_{signal} = 1$:

Term 1: $Q_{lwrTpv} - Q_{lwr1} - Q_{lwr2\text{-}PV}$

Term 2: $(PV_{usable} - Q_{lwr2\text{-}PV}) \times (1 - Fraction_{upp})$

Term 3: $(E_{max\text{-}lwr} \times Mod_{Eff\text{-}PV} - Parasitic_{PV} - Q_{lwr2\text{-}PV}) \times (1 - Fraction_{upp})$

$Q_{upp3\text{-}PV}$ is the minimum of the following three terms:

Term 1: $Q_{uppTpv} - Q_{upp1} - Q_{lwr2\text{-}PV}$

Term 2: $(PV_{usable} - Q_{lwr2\text{-}PV}) \times (Fraction_{upp})$

Term 3: $(E_{max\text{-}lwr} \times Mod_{Eff\text{-}PV} - Parasitic_{PV} - Q_{lwr2\text{-}PV}) \times (Fraction_{upp})$

The first term tops up the segment to its potential capacity, the second term shares any remaining PV_{usable} (after allocation of $Q_{lwr2\text{-}PV}$) 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 $Q_{upp2\text{-}PV}$ 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 $Grid_{signal}$ and $Charge_{lower}$ flags are both 1 then $Q_{lwr2\text{-}grid}$ is the minimum of the following three terms:

Term 1: $\left[\dfrac{\left(T_{upp1}\text{-}T_{lwr1}\right)\times C_p \times\ Vol_{lwr}}{1000}\right] - Q_{lwr2PV}$

Term 2: $Q_{lwrTgrid} - Q_{lwr1} - Q_{lwr2\text{-}PV}$ (if this term if less than zero, then it is set to 0)

Term 3: $E_{max\text{-}lwr} \times Mod_{Eff\text{-}Grid} - Parasitic_{Grid} - Q_{lwr2\text{-}PV}$

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 T_{grid} (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 $Mod_{Eff\text{-}Grid}$ is 100% and $Parasitic_{Grid}$ 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 $Grid_{signal}$ flag is 1:

$Q_{lwr3\text{-}grid}$ is the minimum of the following two terms:

Term 1: $Q_{lwrTgrid} - Q_{lwr1} - Q_{lwr2\text{-}PV} - Q_{lwr3\text{-}PV} - Q_{upp3\text{-}PV} - Q_{lwr2\text{-}grid}$ (if this term if less than zero, then it is set to 0)

Term 2: $(E_{max\text{-}lwr} \times Mod_{Eff\text{-}Grid} - Parasitic_{Grid} - Q_{lwr2\text{-}PV} - Q_{lwr3\text{-}PV} - Q_{upp3\text{-}PV} - Q_{lwr2\text{-}grid}) \times (1 - Fraction_{upp})$

$Q_{upp3\text{-}grid}$ is the minimum of the following two terms:

Term 1: $Q_{uppTpv} - Q_{upp1} - Q_{lwr2\text{-}PV} - Q_{lwr3\text{-}PV} - Q_{upp3\text{-}PV} - Q_{lwr2\text{-}grid}$

Term 2: $(E_{max\text{-}lwr} \times Mod_{Eff\text{-}Grid} - Parasitic_{Grid} - Q_{lwr2\text{-}PV} - Q_{lwr3\text{-}PV} - Q_{upp3\text{-}PV} - Q_{lwr2\text{-}grid}) \times (Fraction_{upp})$

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

Note: There is no term $Q_{upp2\text{-}grid}$ 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 $T_{primary}$ then to bottom segment is charged to $T_{primary}$. Once these segments are both to temperature, the top segment is charged to T_{PV} and then the bottom segment is charged to T_{PV}. 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 T_{grid} (nominally 47°C). While the system is assumed to be energised 24 hours a day, grid energy is only used when $T_{upp} < T_{grid}$ – under this condition the $Grid_{signal}$ 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 $Q_{upp2\text{-}PV}$ from the PV system to temperature $T_{primary}$ is minimum of the following three terms where $PV_{signal} = 1$:

Term 1: $Q_{upp\text{-}Tprimary} - Q_{upp1}$

Term 2: PV_{usable}

Term 3: $E_{max\text{-}lwr} \times Mod_{Eff\text{-}PV} - Parasitic_{PV}$

The first terms brings the upper segment to be equal to the heat capacity to $T_{primary}$, 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 $Q_{lwr2\text{-}PV}$ from the PV system to temperature $T_{primary}$ is minimum of the following three terms where $PV_{signal} = 1$:

Term 1: $Q_{lwr\text{-}Tprimary} - Q_{lwr1}$

Term 2: $PV_{usable} - Q_{upp2\text{-}PV}$

Term 3: $E_{max\text{-}lwr} \times Mod_{Eff\text{-}PV} - Parasitic_{PV}$

The first terms brings the lower segment to be equal to the heat capacity to $T_{primary}$, 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 $Q_{upp3\text{-}PV}$ from the PV system to temperature T_{PV} is minimum of the following three terms where $PV_{signal} = 1$:

Term 1: $Q_{upp\text{-}Tpv} - Q_{upp1} - Q_{upp2\text{-}PV}$

Term 2: $PV_{usable} - Q_{upp2PV} - Q_{lwr2\text{-}PV}$

Term 3: $E_{max\text{-}lwr} \times Mod_{Eff\text{-}PV} - Parasitic_{PV}$

The first terms brings the upper segment to be equal to the heat capacity to T_{PV}, 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 $Q_{lwr3\text{-}PV}$ from the PV system to temperature T_{PV} is minimum of the following three terms where PV_{signal} = 1:

Term 1: $Q_{lwr\text{-}Tpv} – Q_{lwr1} – Q_{lwr2\text{-}PV}$

Term 2: $PV_{usable} – Q_{upp2\text{-}PV} – Q_{lwr2\text{-}PV} – Q_{upp3\text{-}PV}$

Term 3: $E_{max\text{-}lwr} \times Mod_{Eff\text{-}PV} – Parasitic_{PV}$

The first terms brings the lower segment to be equal to the heat capacity to T_{PV}, 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 $Grid_{signal}$ = 1 when the $\underline{T_{upp1}}$ is less than T_{grid} (nominally 47°C). Grid boosting never flows into the lower segment for Type 3.

$Q_{upp3\text{-}grid}$ is the minimum of the following two terms:

Term 1: $Q_{uppTgrid} – Q_{upp1} – Q_{upp2\text{-}PV} – Q_{lwr2\text{-}PV} – Q_{upp3\text{-}PV} – Q_{lwr3\text{-}PV}$ (if this term is <0 THEN 0)

Term 2: $(E_{max\text{-}upp} \times Mod_{Eff\text{-}Grid} – Parasitic_{Grid} – Q_{upp2\text{-}PV} – Q_{lwr2\text{-}PV} – Q_{upp3\text{-}PV} – Q_{lwr3\text{-}PV})$

The first term tops up the segment to the heat storage capacity at T_{grid}, the second term shares any remaining electrical element capacity $E_{max\text{-}upp}$ (after allocation of all solar inputs). For Type 3 systems the terms $Q_{lwr2\text{-}grid}$ and $Q_{lwr3\text{-}grid}$ are set to zero.

Note: For grid boosting, the default assumption is that $Mod_{Eff\text{-}Grid}$ is 100% and $Parasitic_{Grid}$ is 0 for all three system types. The term $Q_{upp2\text{-}grid}$ 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:

$$Q_{upp4} = Q_{upp1} + Q_{upp2\text{-}PV} + Q_{upp3\text{-}PV} + Q_{upp3\text{-}grid}$$

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

$$Q_{lwr4} = Q_{lwr1} + Q_{lwr2\text{-}PV} + Q_{lwr3\text{-}PV} + Q_{lwr2\text{-}grid} + Q_{lwr3\text{-}grid}$$

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. $Q_{lwr4} = Q_{lwr0}$, $Q_{upp4} = Q_{upp0}$).

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, $Grid_{signal}$ and PV_{signal} 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

$$\text{Element ON \%} = \frac{(Q_{lwr2-PV} + Q_{lwr2-PV} + Q_{lwr3-PV} + Q_{upp3-PV})}{(E_{\max-lwr} \times Mod_{Eff-PV} - Parasitic_{PV})} + \frac{(Q_{lwr2-grid} + Q_{lwr3-grid} + Q_{upp3-grid})}{(E_{\max-lwr} \times Mod_{Eff-grid} - Parasitic_{grid})}$$

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

$$\text{Element ON \%} = \frac{(Q_{lwr2-PV} + Q_{lwr2-PV} + Q_{lwr3-PV} + Q_{upp3-PV})}{(E_{\max-lwr})} + \frac{(Q_{lwr2-grid} + Q_{lwr3-grid} + Q_{upp3-grid})}{(E_{\max-lwr})}$$

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.

3.4 Lighting Module

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

3.4.1 Annual Load

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

Equation 43: Total lighting energy consumption

$$E_{tot} = \frac{P_L \times H_{avg} \times A_{tot} \times 365 \times 3.6}{1000}$$

Where:

E_{tot} = total annual energy load in MJ

P_L = Light Power density (W/m^2)

H_{avg} = Average hours use per day (hours)

A_{tot} = Total floor area (m^2)

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**
P_L	5 W/m^2 (default, lower value selectable)
H_{avg}	1.6 hours[11]
A_{tot}	Total floor area of all conditioned, unconditioned and garage zones.

The value for P_L 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/m^2 with a lower value and this lower value should then be used in the calculation.

3.4.2 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.

[11] Value used for ABCB NCC 2022 analysis.

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 ($F_{L,hr}$)

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

$E_{m.hr} = E_{tot} \times F_{L.hr}$

Where:

$E_{m.hr}$ = Hourly energy consumption for an hour of the day in a month in MJ

E_{tot} = total annual energy load, defined by Equation 43 (MJ)

$F_{L.hr}$ = Hourly load factor for hour of day in month, defined by Table 37.

3.5 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.

3.5.1 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

$$V_P = 1.5A_P \times 1000$$

Where:

V_P = Pool Volume, L

A_P = Pool Area, m^2

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

3.5.2 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

$$Base\ Size\ (kW) = \frac{0.0598(V_P)^{0.9377}}{1000}$$

3.5.3 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

$$Operating\ Power = Base\ Size\ \times Power\ Adjustment\ Factor$$

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

$$WEF = e^{\left((SR-1)\times\ln(1.25)+\ln(Baseline)\right)}$$

Equation 49: Pool pump baseline efficiency

$$Baseline = \ -4.5\ln(Base\ Size) + 13.5$$

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

$$Flow\ Rate\left(\frac{L}{hr}\right) = WEF \times Operating\ Power \times 1000$$

Run Time

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

Equation 51: Pool pump turnover time

$$T_{Cyc} = \frac{V_P}{Flow\ Rate}$$

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.

3.5.4 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

$$Off\ Time = [On\ Time] + T_{cyc} \times [Cycles\ per\ Day]$$

3.5.5 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	$Power_{Clean}$ = 1kW	$Power_{Clean}$ = 0.07kW
Dual Speed	No additional energy	Use affinity law and Equation 53 to calculate Cleaning Power required for flow rate of 6600L/hr	$Power_{Clean}$ = 1kW	$Power_{Clean}$ = 0.07kW
Multi Speed	No additional energy	Use affinity law and Equation 53 to calculate Filter Power required for flow rate of 6600L/hr	$Power_{Clean}$ = 1kW	$Power_{Clean}$ = 0.07kW

Affinity Law

$$\frac{Power_1}{Power_2} = \left(\frac{Flow_1}{Flow_2}\right)^3$$

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

$$Power_{Clean} = Operating\ power \times \left(\frac{Flow_{Clean}}{Flow_{operating}}\right)^3$$

Operating power is defined in Equation 47.

$Flow_{Clean}$ = 6600 L/hr

$Flow_{Operating}$ is Flow Rate defined in Equation 50.

Filter Time

Filter is assumed to run for 3 hours.

3.5.6 Cleaning Energy

Cleaning energy is defined using Equation 54:

Equation 54: Pool pump cleaning energy

$$Energy_{Clean} = Power_{Clean} \times 3$$

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

$$Off\ Time = [On\ Time] + 3$$

3.6 On-site Energy Generation

3.6.1 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:
    a. Location/climatic conditions (derived from the applicable climate file)
    b. The slope and orientation of the array
    c. 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:
    a. Ambient Temperature Related Losses
    b. Soiling Related Losses
    c. DC Wiring Related Losses
    d. 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.

3.6.2 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

$$Angle\ in\ Radians = \ Angle\ in\ Degrees\ \times \frac{\pi}{180}$$

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.

T_{zn} - 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)

L_{Loc} – Longitude of dwelling, derived from Postcode using the postcode list (part of existing NatHERS Thermal documentation)

G_{SC} – Solar Constant, 1367

ρ_g – Ground reflectance, 0.6

F_d 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

P_s – 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)

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

EL_{pv} – 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 C_i value is less than 0.75 * P_s then issue a warning that “The inverter should be at least 75% of the capacity of the solar array – please check”.

Note 2: If EL_{pv} is greater than NP * 5 and NP = 1, disallow this value with the error “single phase installation cannot be greater than 5kW”. If EL_{pv} 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, T_{Sol}, is defined using Equation 57. Note that T_{sol} should remain as a decimal, not converted to hours and minutes.

Equation 57: Solar time

$$T_{Sol} = T_{Loc} + \frac{4 \times (L_{st} - L_{col}) + E}{60}$$

Where:

T_{Loc} = Local Time

L_{st} is defined by Equation 58.

L_{col} is defined by Equation 59.

E is defined by Equation 60.

Equation 58: Calculation of L_{st}

$$L_{st} = 15 \times (24 - T_{zn})$$

Where:

T_{zn} is GMT time zone.

Equation 59: Calculation of L_{col}

$$L_{col} = 360 - L_{Loc}$$

Where:

L_{Loc} is Longitude of the dwelling location.

Equation 60: Calculation of E

$$E = 229.2 \times (0.000075 + 0.001868 \cos B - 0.032077 \sin B - 0.014615 \cos 2B - 0.04089 \sin 2B)$$

Where:

B is defined by Equation 61.

Equation 61: Earth to sun distance factor

$$B = \frac{(n-1) \times 360}{365} \times \frac{\pi}{180}$$

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

$$\delta = 23.45 \sin\left(\frac{\pi}{180} \times 360 \frac{(284+n)}{365}\right) \times \frac{\pi}{180}$$

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

$$T_{rise} = 12 - \frac{\left(\cos^{-1}(-\tan \emptyset \times \tan \delta) \times \frac{180}{\pi}\right)}{15}$$

Where:

T_{rise} = 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

$$T_{set} = 12 + \frac{\left(\cos^{-1}(-\tan\emptyset \times \tan\delta) \times \frac{180}{\pi}\right)}{15}$$

Where:

T_{set} = 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

$$\omega = \frac{-(12 - T_{sol}) \times 15\pi}{180}$$

Where:

ω = Hour angle in Radians

T_{sol} = 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

$$\omega_{mid} = \frac{-\left(12 - (T_{sol} + 0.5)\right) \times 15\pi}{180}$$

Where:

ω_{mid} = Hour angle for middle of the hour, in Radians

T_{sol} = Solar time

Ratio of Beam Radiation

Solar radiation in the weather files is for horizontal surfaces. R_b 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 R_b are used. R_b is calculated using Equation 67 and Equation 68.

Equation 67: Permitted range for ratio of beam radiation

$$0 \le R_b \le 40$$

Equation 68: Ratio of beam radiation

$$R_b = \frac{\cos\theta}{\cos(\theta_z)}$$

Where:

R_b = 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 θ_z = equation relating Zenith angle of the Sun to the other angles in the system

'Real' angle incidences

The cosines for angles θ and θ_z 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

$$\cos\theta = \begin{cases} \begin{pmatrix} \sin\delta\sin\emptyset\cos\beta - \\ \sin\delta\cos\emptyset\sin\beta\cos\gamma + \\ \cos\delta\cos\emptyset\cos\beta\cos\omega_{mid} + \\ \cos\delta\sin\emptyset\sin\beta\cos\gamma\cos\omega_{mid} + \\ \cos\delta\sin\beta\sin\gamma\sin\omega_{mid} \end{pmatrix}, & T_{rise} < T_{sol} < T_{set} \\ 0, & T_{rise} > T_{sol}\ or\ T_{sol} > T_{set} \end{cases}$$

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

ω_{mid} = Hour angle for middle of the hour, in Radians

T_{sol} = Solar time

T_{rise} = Time of Sunrise in Hours

T_{set} = Time of Sunset in Hours

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

Equation 70: Calculation of cos$\theta_{z.i}$

$$\cos\theta_{z.i} = \cos\emptyset\cos\delta\cos\omega_{mid} + \sin\emptyset\sin\delta$$

Where:

Cos $\theta_{z.i}$ = Initial estimate of cos θ_z

δ = declination angle in Radians

Φ = Latitude of dwelling in Radians

ω_{mid} = Hour angle for middle of the hour, in Radians

Equation 71: Sun zenith angle

$$\theta_z = \frac{180 \times \cos^{-1}(\cos\theta_{z.i})}{\pi}$$

Where:

θ_z = Zenith angle in Degrees

Equation 72: Cos of the sun zenith angle

$$\cos\theta_z = \begin{cases} \cos\theta_{z.i}, & 0 \le \theta_z \le 90 \\ 0, & \theta_z < 0 \; or \; \theta_z > 90 \end{cases}$$

Where:

θ_z = 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

$$I_o \ge 0$$

Equation 74: Calculation of I_O

$$I_o = \frac{12}{\pi} \times G_{sc}\left(1 + 0.033\cos\left(\frac{360n}{365}\right)\right) \times \cos\emptyset\cos\delta\,(\sin\omega_2 - \sin\omega_1) + (\omega_2 - \omega_1) \times \sin\emptyset\sin\delta$$

Where:

I_o = Extraterrestrial radiation for 1 hour in kWh

G_{sc} = Global solar constant

n = Day of year number

Φ = Latitude of dwelling in Radians

δ = declination angle in Radians

ω_1 = Hour angle in Radians at start of hour

ω_2 = 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, I_H is made up from Diffuse, I_{dif}, and Beam, I_b, components. I_H and I_{dif} are included in the weather file. I_b is calculated using Equation 75. Note that by definition Beam radiation requires line-of-sight from the Sun to the panel, thus I_b may only be greater than 0 between sunrise and sunset.

Equation 75: Beam portion of solar radiation

$$I_b = \begin{cases} I_H - I_{dif}, & T_{rise} < T_{sol} < T_{set} \\ 0, & T_{rise} > T_{sol} \ or \ T_{sol} > T_{set} \end{cases}$$

Where:

I_b = Beam portion of solar radiation

I_H = Total solar radiation measured on the horizontal plane

I_{dif} = Diffuse portion of solar radiation

T_{sol} = Solar time

T_{rise} = Time of Sunrise in Hours

T_{set} = 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, A_i, 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. A_i is calculated using Equation 76:

Equation 76: Anisotropy index

$$A_i = \begin{cases} \frac{I_b}{I_o}, & I_o > 0 \\ 0, & I_o = 0 \end{cases}$$

Where:

A_i = Anisotropy index

I_b = Beam portion of solar radiation

I_o = 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 G_{sc}. Values greater than G_{sc} are only likely to occur where the hour angle is very small, ultimately inflating R_b and A_i and should be ignored.

Equation 77: Total available solar radiation

$$I_{T,i} = \left(I_b + I_{dif} A_i\right) R_b + I_{dif}(1 - A_i)\left(\frac{1 + \cos\beta}{2}\right)\left[1 + f\sin^3\left(\frac{\beta}{2}\right)\right] + I_H\,\rho_g\left(\frac{1 - \cos\beta}{2}\right)$$

Where:

$I_{T,i}$ = Initial estimate of total solar radiation on the solar PV panel

I_b = Beam portion of solar radiation

I_{dif} = Diffuse portion of solar radiation

I_H = Total solar radiation measured on the horizontal plane

A_i = Anisotropy index

R_b = Ratio of Beam radiation from horizontal to tilted plane

β = Slope of Solar Panel in Radians

ρ_g = Ground reflectance

f = Modulating factor, calculated using Equation 78

Equation 78: Modulating factor

$$f = \begin{cases} \sqrt{\dfrac{I_b}{I_H}}, & I_H > 0 \\ 0, & I_H \le 0 \end{cases}$$

Equation 79: Realistic solar radiation on the solar PV panel

$$I_T = \begin{cases} I_{T,i}, & I_{T,i} \le G_{sc} \\ 0, & I_{T,i} > G_{sc} \end{cases}$$

Where:

I_T = Realistic solar radiation on the solar PV panel

$I_{T,i}$ = Initial estimate of total solar radiation on the solar PV panel

G_{sc} = 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

$$E_{Sol} \geq 0$$

Equation 81: Electricity generated by the solar panel

$$E_{sol} = \frac{I_T \times F_d \times P_s}{1000}$$

Where:

E_{sol} = Electricity generated by the solar panel for 1 hour in kWh

I_T = Realistic solar radiation on the solar PV panel

F_d = Derating Factor

P_s – Size of the solar array in kW

3.6.3 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] (I_b) 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.

[12] The direct beam portion is described as "direct solar irradiance on a plane normal to the beam ((W/m^2)."

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 (Alt_O)
- Azimuth of the left-hand edge of the object (Az_{O1})
- Azimuth of the right-hand edge of the object (Az_{O2}).

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 (Alt_{S1})
- Elevation angle of the sun – at end of the hour (Alt_{S2})
- Azimuth angle of the sun – at start of the hour (Az_{S1})
- Azimuth angle of the sun – at end of the hour (Az_{S2}).

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 Alt_{S1} and Alt_{S2}) 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].

Where it is determined that overshadowing will occur in a particular hour then the 'Beam portion of solar radiation' (I_b) 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.

[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

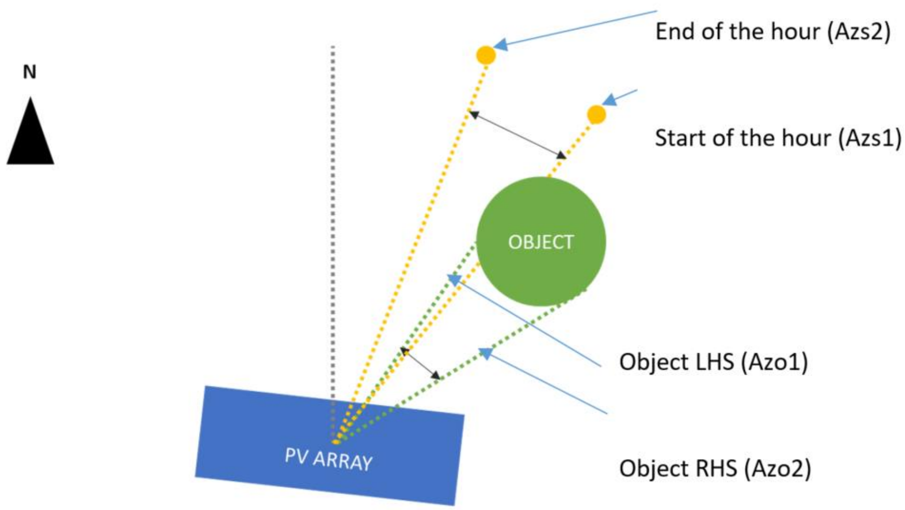

Figure 3: Example of the sun azimuth range covered over one hour with obstructing object (plan view)

Example Calculation:

Assume for the obstruction:
Alt_O = 60°
Az_{O1} = 30°
Az_{O2} = 45°

Looking at a single hour from the climate file with the following parameters:
Alt_{S1} = 55° (Start of hour)
Alt_{S2} = 50° (End of hour)
Az_{S1} = 35° (Start of hour)
Az_{S2} = 20° (End of hour).

Since $Az_{O1} < Az_{S1} < Az_{O2}$ AND
$Alt_{S2} < Alt_O$*
THEN: shading is deemed to occur.
Therefore, set I_b ('Beam portion of solar radiation') to 0. (see Equation 75)

* In this case both Alt_{S2} and Alt_{S1} are less than Alt_O. However only one of these two conditions needs to be true for the PV array to be deemed to be overshadowed in that hour.

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.

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.

3.6.4 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

$$L_{TOT} = (1-L_A) \times (1-L_S) \times (1-L_W) \times (1-L_C)$$

Where:

L_{TOT} = Total PV System Loss Factor

L_A = Ambient Temperature Related Losses

L_S = Soiling Related Losses

L_W = DC Wiring Related Losses

L_C = Conversion Losses

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

Equation 83: Ambient temperature related PV losses

$$L_A = ((T_{amb} + 0.03125 \text{ x } G_{inc}) - 25)) \times 0.4 \ (\%)$$

Where:

L_A = the ambient temperature related losses (%)

T_{amb} = the ambient air temperature (^oC) –the dry bulb temperature in the climate file for that hour

G_{inc} = the incident radiation (W)) – derived from the climate file for that hour

Soiling losses (L_S) 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 (L_W) 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 (L_C) 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

$$E_{solD} = E_{sol} \times L_{TOT}$$

Where:

E_{solD} = Electricity generated by the solar PV system for 1 hour in kWh

E_{sol} = Electricity generated by the solar panel before system losses for 1 hour in kWh – see Equation 81

L_{TOT} = Total PV System Loss Factor – see Equation 82

3.6.5 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

$$E_{solD} \leq C_i$$

Where:

E_{sol} = Electricity generated by the solar panel for 1 hour in kWh

C_i – total capacity of all installed inverters (kW)

3.6.6 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 (E_n). However, any export to the network must be capped at the user specified value for the "generator export limit of the electrical network" (EL_{pv}) i.e.

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

$E_n \leq EL_{pv}$

Where:

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

EL_{pv} = The generator export limit of the electrical network (kW)

3.7 Battery Storage

3.7.1 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).

3.7.2 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. B_{NC} = Battery Nominal Storage Capacity (kWh)
3. B_{DD} = 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 B_{DD} = 90% then the useable capacity would be 9.0 kWh
4. B_{CE} = 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. B_{DE} = 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. B_{CR} = 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 Acid[1]	50%	0.2	89.5%	89.5%	80%	50%
Zinc Bromine[1]	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.

3.7.3 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 (E_{solD}) exceeds the dwellings electrical load in that hour (E_{tot}) 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

$B_{CHARGE\text{-}EXT}$ must be ≤ (B_{NC} - B_{START}) / B_{CE}

$B_{CHARGE\text{-}EXT}$ must be ≤ B_{NC} x B_{CR} / B_{CE}

$B_{CHARGE\text{-}EXT}$ must be ≤ B_{PV} (any excess is assumed to be delivered to the grid)

$B_{CHARGE\text{-}BATT}$ must be ≤ (B_{NC} - B_{START})

$B_{CHARGE\text{-}BATT}$ must be ≤ B_{NC} x B_{CR}

$B_{CHARGE-BATT}$ must be ≤ B_{PV} x B_{CE} (any excess is assumed to be delivered to the grid)

$B_{DISCHARGE-BATT}$ must be ≤ B_{START} - B_{NC} x (1 - B_{DD}) (any shortfall in demand from appliances is assumed to be delivered from the grid and not from the battery)

$B_{DISCHARGE-BATT}$ must be ≤ B_{NC} x B_{CR}

$B_{DISCHARGE-EXT}$ must be ≤ (B_{START} - B_{NC} x (1 - B_{DD})) x B_{DE} (any shortfall in demand from appliances is assumed to be delivered from the grid and not from the battery)

$B_{DISCHARGE-EXT}$ must be ≤ B_{NC} x B_{CR} x B_{DE}

CHARGING ACCOUNTING

Equation 88: Rules for battery charge accounting

IF (B_{NC} - B_{START}) / B_{CE} > B_{NC} x B_{CR} / B_{CE} THEN

$B_{CHARGE-EXTMAX}$ = B_{NC} x B_{CR} / B_{CE} OTHERWISE $B_{CHARGE-EXTMAX}$ = (B_{NC} - B_{START}) / B_{CE}

IF B_{PV} > $B_{CHARGE-EXTMAX}$ THEN

$B_{CHARGE-BATT}$ = $B_{CHARGE-EXTMAX}$ x B_{CE} AND PV_{EXPORT} = B_{PV} - $B_{CHARGE-EXTMAX}$ (If <0 Then = 0)

OTHERWISE

$B_{CHARGE-BATT}$ = B_{PV} x B_{CE}

DISCHARGING ACCOUNTING

Equation 89: Rules for battery discharge accounting

IF (B_{START} - B_{NC} x (1 - B_{DD})) > B_{NC} x B_{CR} THEN

$B_{DISCHARGE-EXTMAX}$ = B_{NC} x B_{CR} x B_{DE} OTHERWISE $B_{DISCHARGE-EXTMAX}$ = (B_{START} - B_{NC} x (1 - B_{DD})) x B_{DE}

IF B_{ED} < $B_{DISCHARGE-EXTMAX}$ THEN

B_{ED2} = 0 AND $B_{DISCHARGE-EXT}$ = B_{ED}

OTHERWISE

B_{ED2} = B_{ED} - $B_{DISCHARGE-EXTMAX}$ AND $B_{DISCHARGE-EXT}$ = $B_{DISCHARGE-EXTMAX}$

TIMESTEP ACCOUNTING

Equation 90: Rules for battery timestep accounting

IF $B_{CHARGE\ BATT}$ > 0 THEN B_{END} = B_{START} + $B_{CHARGE\ BATT}$

IF $B_{DISCHARGE\ BATT}$ > 0 THEN B_{END} = B_{START} - $B_{DISHARGE\ BATT}$

OTHERWISE B_{END} = B_{START}

At timestep N, $B_{START\ (N)}$ = $B_{END\ (N-1)}$

Where:

B_{START} = The total energy in the battery at the commencement of a given hour (kWh)

$B_{CHARGE\text{-}EXT}$ = Additional energy delivered to the battery in any given hour, before charging losses (kWh)

$B_{CHARGE\text{-}BATT}$ = Additional energy delivered to the battery in any given hour, after charging losses (kWh)

$B_{DISCHARGE\text{-}BATT}$ = Energy discharged from the battery in any given hour, before discharging losses (kWh)

$B_{DISCHARGE\text{-}EXT}$ = Energy discharged from the battery in any given hour, after discharging losses (kWh)

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

B_{NC} = Battery Nominal Storage Capacity (kWh)

B_{DD} = Maximum Depth of Discharge (%)

B_{CR} = Battery C-rate

B_{CE} = Charge Efficiency (%)

B_{DE} = Discharge Efficiency (%)

$B_{CHARGE\text{-}EXTMAX}$ = Maximum additional energy that can be delivered to the battery from excess PV generation in any given hour, before charging losses

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

$B_{DISCHARGE\text{-}EXTMAX}$ = Maximum energy that can be discharged from the battery in any given hour, after discharging losses

B_{ED} = 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)

B_{ED2} = As per B_{ED} but allowing for supply by any batteries

B_{END} = The total energy in the battery at the end of a given hour (kWh)

3.8 Plug Loads

3.8.1 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.

3.8.2 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

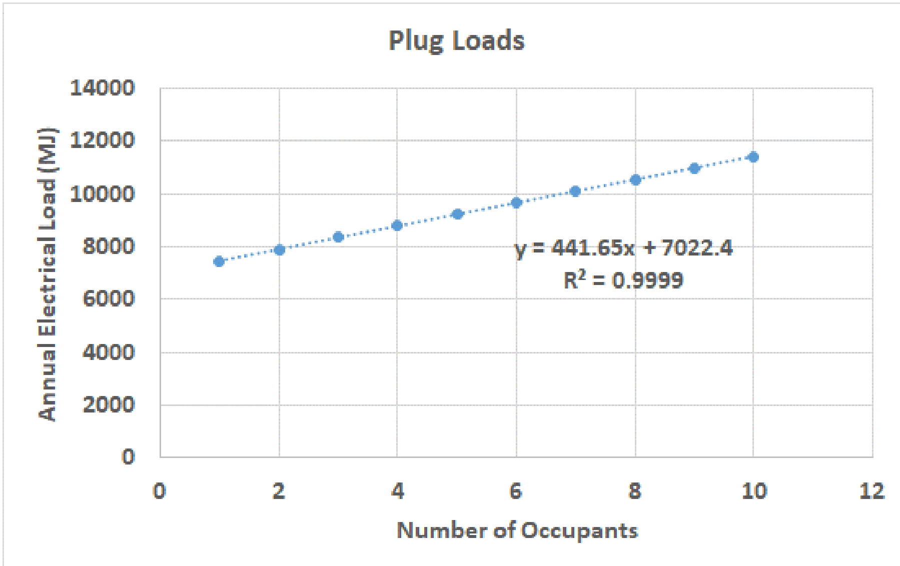

Figure 4: Annual Plug Loads by Number of Occupants

Annual plug loads are calculated using Equation 91.

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

$E_{PLUG} = 7022.4 + N_{OCC} \times 441.65$

Where:

E_{plug} = total annual plug energy load in MJ/year

N_{OCC} = Number of occupants in the home (refer Equation 2).

3.8.3 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

$E_{PLUG.hr} = E_{PLUG} \times F_{PLUG.hr}$

Where:

$E_{PLUG.hr}$ = Hourly energy load for hour of day in each month in MJ

E_{PLUG} = total annual plug energy load defined in Equation 91 in MJ/year

$F_{PLUG.hr}$ = 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

Hour	Jan %	Feb %	Mar %	Apr %	May %	Jun %	Jul %	Aug %	Sep %	Oct %	Nov %	Dec %
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

Hour	Jan %	Feb %	Mar %	Apr %	May %	Jun %	Jul %	Aug %	Sep %	Oct %	Nov %	Dec %
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.

4 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 (°C)	WoH Cooling Set Point (°C)	Applicable GEMS ZERL Zone	Evaporative cooler Suitability[14]
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

[14] The suitability of some climate zones is yet to be determined. The NatHERS Administrator will seek advice from the NatHERS Technical Advisory Committee.

NatHERS CZ	Location	NCC Climate Zone	NatHERS thermal simulation Cooling Set Point (°C)	WoH Cooling Set Point (°C)	Applicable GEMS ZERL Zone	Evaporative cooler Suitability[14]
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

NatHERS CZ	Location	NCC Climate Zone	NatHERS thermal simulation Cooling Set Point (°C)	WoH Cooling Set Point (°C)	Applicable GEMS ZERL Zone	Evaporative cooler Suitability[14]
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

NatHERS CZ	Location	NCC Climate Zone	NatHERS thermal simulation Cooling Set Point (°C)	WoH Cooling Set Point (°C)	Applicable GEMS ZERL Zone	Evaporative cooler Suitability[14]
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

5 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 $E_{Annual\text{-}input}$ (energy input) from the annual hot water demand energy $E_{Annual\text{-}output}$ (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:

$$E_{Annual-input} = a \times (E_{Annual-output})^3 + b \times (E_{Annual-output})^2 + c \times (E_{Annual-output}) + d$$

The annual hot water demand energy $E_{Annual\text{-}output}$ (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	R^2	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

System ID	Climate	STCs	CER Size	Description	Fuel	Energisation	Function	a	b	c	d	R^2	Notes
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	

System ID	Climate	STCs	CER Size	Description	Fuel	Energisation	Function	a	b	c	d	R^2	Notes
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	

System ID	Climate	STCs	CER Size	Description	Fuel	Energisation	Function	a	b	c	d	R^2	Notes
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	

System ID	Climate	STCs	CER Size	Description	Fuel	Energisation	Function	a	b	c	d	R^2	Notes
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	

System ID	Climate	STCs	CER Size	Description	Fuel	Energisation	Function	a	b	c	d	R^2	Notes
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	

System ID	Climate	STCs	CER Size	Description	Fuel	Energisation	Function	a	b	c	d	R^2	Notes
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	

System ID	Climate	STCs	CER Size	Description	Fuel	Energisation	Function	a	b	c	d	R^2	Notes
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	

System ID	Climate	STCs	CER Size	Description	Fuel	Energisation	Function	a	b	c	d	R^2	Notes
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	

System ID	Climate	STCs	CER Size	Description	Fuel	Energisation	Function	a	b	c	d	R^2	Notes
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	

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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	

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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	

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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	

System ID	Climate	STCs	CER Size	Description	Fuel	Energisation	Function	a	b	c	d	R^2	Notes
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	

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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	

System ID	Climate	STCs	CER Size	Description	Fuel	Energisation	Function	a	b	c	d	R^2	Notes
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	

System ID	Climate	STCs	CER Size	Description	Fuel	Energisation	Function	a	b	c	d	R^2	Notes
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	

System ID	Climate	STCs	CER Size	Description	Fuel	Energisation	Function	a	b	c	d	R^2	Notes
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	

System ID	Climate	STCs	CER Size	Description	Fuel	Energisation	Function	a	b	c	d	R^2	Notes
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

System ID	Climate	STCs	CER Size	Description	Fuel	Energisation	Function	a	b	c	d	R^2	Notes
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

System ID	Climate	STCs	CER Size	Description	Fuel	Energisation	Function	a	b	c	d	R^2	Notes
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	

6 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 $E_{Annual\text{-}input}$ (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 a_{month}, b_{month}, c_{month} and d_{month} is defined in Equation 22, which is repeated below for convenience:

$$E_{Share-month} = a_{month} \times (E_{Annual-output})^3 + b_{month} \times (E_{Annual-output})^2 + c_{month} \times (E_{Annual-output}) + d_{month}$$

Where $E_{Annual\text{-}output}$ (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	

System ID	Climate	Month	Description	Fuel	Energisation	Function	a-month	b-month	c-month	d-month	Notes
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	

System ID	Climate	Month	Description	Fuel	Energisation	Function	a-month	b-month	c-month	d-month	Notes
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	

System ID	Climate	Month	Description	Fuel	Energisation	Function	a-month	b-month	c-month	d-month	Notes
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	

System ID	Climate	Month	Description	Fuel	Energisation	Function	a-month	b-month	c-month	d-month	Notes
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	

System ID	Climate	Month	Description	Fuel	Energisation	Function	a-month	b-month	c-month	d-month	Notes
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	

System ID	Climate	Month	Description	Fuel	Energisation	Function	a-month	b-month	c-month	d-month	Notes
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	

System ID	Climate	Month	Description	Fuel	Energisation	Function	a-month	b-month	c-month	d-month	Notes
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	

System ID	Climate	Month	Description	Fuel	Energisation	Function	a-month	b-month	c-month	d-month	Notes
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	

System ID	Climate	Month	Description	Fuel	Energisation	Function	a-month	b-month	c-month	d-month	Notes
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	

System ID	Climate	Month	Description	Fuel	Energisation	Function	a-month	b-month	c-month	d-month	Notes
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	

System ID	Climate	Month	Description	Fuel	Energisation	Function	a-month	b-month	c-month	d-month	Notes
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	

System ID	Climate	Month	Description	Fuel	Energisation	Function	a-month	b-month	c-month	d-month	Notes
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	

System ID	Climate	Month	Description	Fuel	Energisation	Function	a-month	b-month	c-month	d-month	Notes
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	

System ID	Climate	Month	Description	Fuel	Energisation	Function	a-month	b-month	c-month	d-month	Notes
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	

System ID	Climate	Month	Description	Fuel	Energisation	Function	a-month	b-month	c-month	d-month	Notes
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	

System ID	Climate	Month	Description	Fuel	Energisation	Function	a-month	b-month	c-month	d-month	Notes
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	

System ID	Climate	Month	Description	Fuel	Energisation	Function	a-month	b-month	c-month	d-month	Notes
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

System ID	Climate	Month	Description	Fuel	Energisation	Function	a-month	b-month	c-month	d-month	Notes
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	

System ID	Climate	Month	Description	Fuel	Energisation	Function	a-month	b-month	c-month	d-month	Notes
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	

System ID	Climate	Month	Description	Fuel	Energisation	Function	a-month	b-month	c-month	d-month	Notes
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	

System ID	Climate	Month	Description	Fuel	Energisation	Function	a-month	b-month	c-month	d-month	Notes
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	

System ID	Climate	Month	Description	Fuel	Energisation	Function	a-month	b-month	c-month	d-month	Notes
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	

7 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 $E_{Annual\text{-}input}$ (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:

$$F_{hourly-A} = a_A \times (E_{Annual-output})^3 + b_A \times (E_{Annual-output})^2 + c_A \times (E_{Annual-output}) + d_A$$

$$F_{hourly-B} = a_B \times (E_{Annual-output})^3 + b_B \times (E_{Annual-output})^2 + c_B \times (E_{Annual-output}) + d_B$$

$$F_{hourly-C} = a_C \times (E_{Annual-output})^3 + b_C \times (E_{Annual-output})^2 + c_C \times (E_{Annual-output}) + d_C$$

$$F_{hourly-D} = a_D \times (E_{Annual-output})^3 + b_D \times (E_{Annual-output})^2 + c_D \times (E_{Annual-output}) + d_D$$

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 reproduced below):

$$F_{hourly-A} \times 16 + F_{hourly-B} \times 2 + F_{hourly-C} \times 4 + F_{hourly-A} \times 2 = 1.00000$$

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

System ID	Climate	Description	Fuel	Energisation	Component	ax	bx	cx	dx	
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

8 Appendix E – Postcode List

Under development

9 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.

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- 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)
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