Nationwide House Energy Rating Scheme (NatHERS)

NatHERS Whole of Home National Calculations Method

VERSION: 9 June 2023

Please note that parts of this document may be revised and updated over time.

Attribution

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Technical editing: Biotext, Canberra

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Date	Version	Section(s) updated	Notes
17 February 2022	8.1	EES final review and update, includes all original comments	
17 February 2022	9.0	Clean with comments removed and changes accepted	
22 February 2022	9.1	Issued to hot water industry representatives for coordination and comment.	Confidential
Date	**Version**	**Comments**	
04 March 2022	9.210.0	Issued to CSIRO for implementation and coordination including updates to hot water module for TAC and SCG Please refer to comments on title page and refer to page 65 for input from Rheem and Rinnai	
04 July 2022	10.0	Updated to include energy value and Whole of Home rating. Overview of calculation process updated to add flow chart and standardise time notation.	
13 July 2022	10.1	Added cooking loads for electric and induction cooktops and gas oven Separated cooking and plug loads Generalised cooking function Updated rating scale with function for adjustment factor Updated rating scale examples Aligned 'floor area' definition in Lighting to match with definition in Occupancy (exclude garage)	
4 August 2022	10.1	Minor edits such as adding equation numbers and heading, updating table numbers etc.	
9 August 2022	11	Version for ETWG Endorsement, August 2022 out of session. Removed majority of section 2 to avoid confusion over old information. Minor updates based on NatHERS Steering Committee feedback	
23 August 2022	11.1	Error correction on hourly distribution tables for lighting, plug and cooking loads Added clear requirement for the small electrical load in gas instantaneous hot water systems to be included in benchmark building load for ratings	
29 August 2022	11.2	Issue to Biotext for copyedit and proofread	
21 December 2022	11.3	Corrections to PV Diverter hot water system calculations Change ρ_g (ground reflectance) in solar PV calculation to 0.2, aligning with NatHERS thermal shell ground reflectance value (Previously 0.6) Corrected equations for Determination of AEER/ACOP from star rating (2013 GEMS determination) (-18 should have been +18)	
4 January 2023	11.4	Correction to solar PV calculation. Calculations written for Northern hemisphere designated 0^0 as south. Added function to make the adjustment so users may enter Azimuth using 0^0 = north. Added calculation to Water Heater calculations to handle the reducing deeming period for STCs.	
11 January 2023	11.5	Removed "Other non-ducted systems' from Table 14 *Default system losses for specified equipment types*. This row was meant to capture any appliances with distribution losses that weren't captured in the table already. No systems like that are in NatHERS at time of writing, and 15% losses were being incorrectly applied to non-ducted HVAC and gas heaters that should not have had additional losses.	

Date	Version	Section(s) updated	Notes
31 January 2023		Awaiting review of spa module s3.10. Updated stove induction constant Table 74.	
10 February 2023		Corrections to the Solar PV calculation Equation 64, Term2. Q_{lwr3}-grid was removed, as per Lloyd Harrington's advice see correspondence email dated 20221209	
9 June 2023		**3.6 Hot Water Module** Clarified the role small technology certificates (STC) play in sizing the load of a solar and heat pump hot water system. This includes a new heading on page 69 and clarification of the text previously in this chapter in relation to STC and system load. Clarified Appendix B, changes in this appendix are highlighted with the comment "Updated May 2023" and extend to solar hot water only. When using the Clean Energy Regulator STC calculator, clarified the user should use postcode 2000 to obtain the Zone 3 STC value where the project is not in a CER zone 3. **Other edits** Corrected missing and broken cross references. Appendices A to F have been removed from this document and are now provided in a separate MS Excel file.	

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Abbreviations

ABCB	Australian Building Codes Board
ACOP	annual coefficient of performance
AEER	annual energy efficiency ratio
AGA	Australian Gas Association
AS	Australian Standard
AS/NZS	joint Australian–New Zealand Standard
c	cent
CER	Clean Energy Regulator
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 (air conditioner efficiency in heating mode) – dimensionless
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CZ	climate zone
DC	direct current
EER	energy efficiency ratio (air conditioner efficiency in cooling mode) – dimensionless
GEMS	Greenhouse and Energy Minimum Standards (national)
GJ	gigajoule (10^9 joule) (energy for a specific fuel)
h	hour
HSPF	heating seasonal performance factor
kWh	kilowatt-hour
L	litre
LPG	liquefied petroleum gas
m	metre
m^2	square metre
m^3	cubic metre
MEPS	Minimum Energy Performance Standards
MJ	megajoule
MWh	megawatt hour
n/a	not applicable
NatHERS	Nationwide House Energy Rating Scheme
NCC	National Construction Code for residential and commercial buildings
nd	no data
PV	photovoltaic
scratch file	detailed hourly output file from a NatHERS (Chenath) simulation
STC	small-scale technology certificate
TAC	NatHERS Technical Advisory Committee
TCSPF	total cooling seasonal performance factor
TRNSYS	Transient System Simulation Tool
W	watt
ZERL	zoned energy rating label

1 Introduction

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

NatHERS will continue to provide an assessment and star rating out of 10 of a home's thermal performance. However, NatHERS will now also provide an additional assessment and rating for 'Whole of Home' energy use, accounting for the home's appliances, solar and batteries. This assessment gives a second performance rating out of 100.

1.1 About this document

This document outlines the methods that underpin the NatHERS Whole of Home benchmark tool (AccuRate). The document is intended to transparently explain how NatHERS Whole of Home works, and guide commercial tool providers when developing Whole of Home tools for accreditation under the scheme. It is not mandatory for tool developers to adopt the methods outlined in this document; however, tools must meet the accuracy limits the Software Accreditation Protocol – Whole of Home 2022.[1]

Part 1 'Whole of Home modules' provides an overview of each of the modules. 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.

Part 2 includes methods for calculating the energy demand of a home's:

- heating and cooling appliances
- hot water system
- lighting
- pool pump (future developments will include pool heating)
- spa pump (future developments will include spa heating)
- onsite solar photovoltaic (PV) system
- onsite battery
- plug loads (plug-in appliances)
- cooking appliances.

Part 2 also outlines the method used for calculating the of a home for a Whole of Home assessment and the Whole of Home performance rating.

Please note that these methods are for Whole of Home assessments only. While they use aspects of the NatHERS thermal performance methods, the 2 are separate resources. See the NatHERS thermal method.[2]

A separate method is also available for NatHERS In Home assessments.[3]

[1] nathers.gov.au/node/473
[2] hstar.com.au/Chenath/AccuRateChenathRepository.htm
[3] nathers.gov.au/InHome

1.2 Background

In 2019, Energy Ministers agreed upon 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
- 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. They included proposed amendments to the energy efficiency provisions that introduce a Whole of Home annual energy use budget for Class 1 and 2 dwellings.

In August 2022, after acknowledging the extensive input from the community and building industry stakeholders over several years, Building Ministers agreed to raise the minimum energy efficiency standards for new homes through updates to the NCC.

Changes to the NCC include:

- increasing the minimum level of thermal performance from 6 to the equivalent of 7 stars under NatHERS
- introducing a new a Whole of Home annual energy use budget applicable to the home's:
    - heating and cooling equipment
    - hot water systems
    - lighting
    - swimming pool and spa pumps
    - onsite renewable energy systems (such as rooftop PV).

This budget is based on the 'societal cost of energy', which includes the cost of energy used by the building and the broader cost to society of the use of that energy.[4] An onsite renewable electricity generation system, such as rooftop PV, can provide an offset to the societal cost of the energy used in the home.

To support the objectives of the Trajectory, including the new energy efficiency provisions for NCC 2022[5], NatHERS has been expanded to provide Whole of Home energy assessments and ratings. Following a transition period to help industry prepare, energy efficiency changes to the NCC will start from 1 October 2023 (noting that individual jurisdictions may change implementation timeframes).

1.3 Updates to these methods

The methods outlined in this document may be revised and updated as new information, data and modelling methods become 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

[4] For more details about how the societal cost of energy is defined, see the ABCB scoping study at consultation.abcb.gov.au/engagement/energy-efficiency-scoping-study-2019.
[5] https://ncc.abcb.gov.au/editions-national-construction-code

data as far as possible. Reflecting the need for this balance, it is planned that the method will be reviewed regularly, likely in line with future updates to the NCC. Updates will also be considered if there are substantial changes to the NCC that need to be reflected by NatHERS.

Updates to this document 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.

These calculation methods are designed to:

- support alignment with the NCC 2022 energy efficiency provisions
- use the expertise of the NatHERS TAC and other industry experts
- deliver methods appropriate for a national scheme
- support the objectives of the Trajectory
- use established data and calculation methods.

The Whole of Home framework builds on the existing NatHERS framework and technology. NatHERS currently conducts thermal assessments using the CSIRO (Commonwealth Scientific and Industrial Research Organisation) 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 from those used for NatHERS thermal assessments. They are intended to more accurately reflect how the average home is heated and cooled.

Hourly calculations of energy demand allow for reasonable modelling of onsite energy generation and storage influences on the final Whole of Home 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 allows the tool to deliver outputs that can be used to demonstrate compliance with the energy efficiency provision for NCC 2022.

1.5 Acknowledgements

These methods have been developed in collaboration with the NatHERS TAC, Energy Efficient Strategies, 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:

- Air-conditioning and Refrigeration Equipment Manufacturers Association of Australia (AREMA)
- Australian Building Sustainability Association (ABSA)
- Australian Institute of Architects (AIA)

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

2 Part 1: Whole of Home modules

The modules included in a NatHERS Whole of Home assessment are:

- heating
- cooling
- hot water
- lighting
- pool pumps and heating (heating is yet to be implemented)
- spa pumps and heating (heating is yet to be implemented)
- onsite energy generation (solar PV)
- onsite storage (battery systems)
- plug loads
- cooking.

In addition to these modules, the Whole of Home assessment must make several assumptions about occupancy patterns, including:

- number of occupants per home
- hours of occupation
- patterns of use (i.e. which zones in the dwelling are used 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.

3 Part 2: Technical specifications

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

3.1 Overview of the calculation process

The Whole of Home calculation works out the hourly energy loads of a defined set of appliances in the home, using a set of defined behaviour and used assumptions. Figure 1 shows the Whole of Home calculation process.

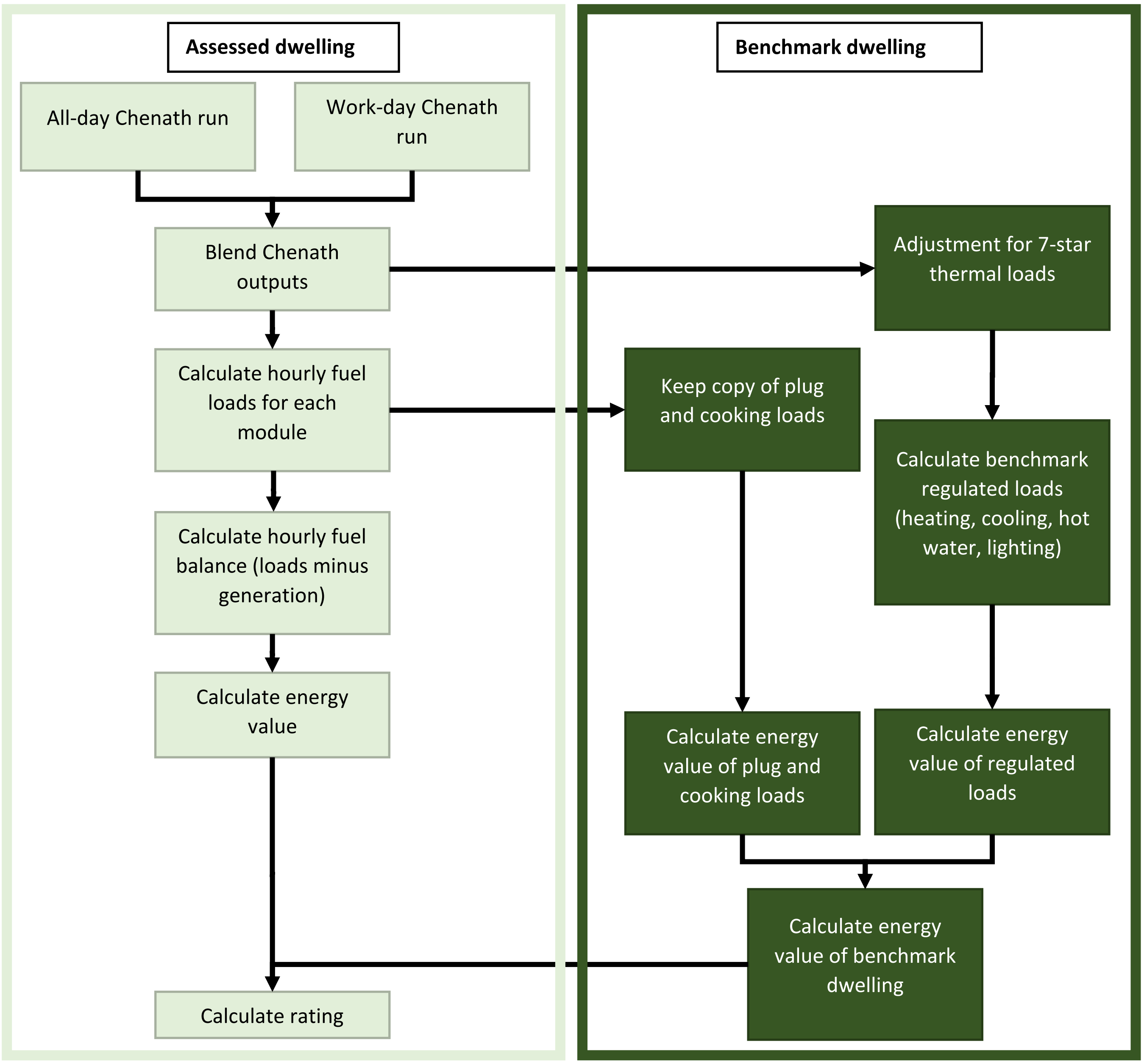


Figure 1: Whole of Home calculation process

Note that the energy value of the assessed building must be calculated hourly and then summed, because the energy balance (net energy in or out) in each hour must be solved so as to apply the correct value (import or export). The benchmark dwelling does not have solar PV, so all energy is imported and there is no need to calculate the balance. As such, the benchmark dwelling may have the annual energy loads grouped into peak, shoulder and off-peak times and then have the relevant energy value factors applied. Find more information about this in sections 3.14 and 3.15.

3.1.1 Time

NatHERS uses hourly time steps for its calculations. Hours are labelled 1 to 24, with hour 1 beginning at midnight and ending at 1 am, and so on, until hour 24, which begins at 11 pm and ends at midnight.

Table 1: Nominal hour labelling

Nominal hour number	Clock hour beginning	Clock hour ending
1	00:00	01:00
2	01:00	02:00
3	02:00	03:00
4	03:00	04:00
5	04:00	05:00
6	05:00	06:00
7	06:00	07:00
8	07:00	08:00
9	08:00	09:00
10	09:00	10:00
11	10:00	11:00
12	11:00	12:00
13	12:00	13:00
14	13:00	14:00
15	14:00	15:00
16	15:00	16:00
17	16:00	17:00
18	17:00	18:00
19	18:00	19:00
20	19:00	20:00
21	20:00	21:00
22	21:00	22:00
23	22:00	23:00
24	23:00	24:00

3.2 Occupancy and thermal simulation settings

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

For all tables in this specification, the ‘hour’ number indicates the hour of the day ending at the specified clock time – that is, hour 1 is the hour between midnight and 1 am, 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 cover the period between midnight and midnight.

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 at the specified clock time.

Thermostat settings and heat gains are calculated and applied for each zone for each hour of the day.

3.2.1 Number of occupants

For 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

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

Where:

N_{Occ} = number of occupants in the home

A_D = area of dwelling.

The area of the dwelling is defined as the sum of the floor areas of all zones, excluding the garage.

N_{Occ} shall be rounded the nearest 2nd decimal (i.e. #.xx). These equations are also used to determine the hot water plug and cooking loads.

3.2.2 Pattern of occupation

Two new daily profiles have been defined for use in the Whole of Home Chenath thermal assessment calculation that is used to determine heating and cooling energy consumption. This is in contrast to the single profile used in the current Chenath thermal performance assessment. Separate Chenath simulation runs are therefore required when conducting a Whole of Home assessment, as compared with conducting the current thermal performance assessment to determine the building shell star rating. One Chenath run is done for each occupancy profile, and the results are processed and combined when calculating a Whole of Home assessment, as detailed in section 3.2.3.

The 2 daily profiles used in the Whole of Home calculation method are the all-day profile and the work-day profile.

All-day profile

The all-day profile assumes that at least 1 person is at home for the whole 24 hours. While 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** be used for the Whole of Home assessment.

Work-day profile

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

3.2.3 Blending occupancy profiles

When calculating the building's Whole of Home thermal load, entirely separate thermal simulations must be undertaken in parallel for each of the occupant profiles noted in section 3.2.2 (all day and work day).

To obtain a single Whole of Home thermal load, the results of the thermal simulations must be weighted using Equation 3. As the Whole of Home calculation is performed on an hourly basis and appliances are allocated to each zone, this must be done for each hour and in each zone.

Equation 3: Weighting of all-day and work-day profiles for a given zone

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

Where:

P_{WoH} = weighted value of the Whole of Home thermal load in a zone for a given hour

P_{ALLDAY} = thermal load in a zone for a given hour using the all-day occupancy profile only

$P_{WORKDAY}$ = thermal load in a zone for a given hour using the work-day occupancy profile only.

All schedules that are not related to heating and cooling are already blended, so only one schedule is provided in this document for each of those modules.

3.2.4 Thermostat settings

NatHERS thermal zone types are listed in Table 2.

Table 2: NatHERS thermal zone types

Zone	Conditioned	Internal heat gains
Living/kitchen	Yes	Yes
Living	Yes	Yes
Daytime	Yes	No
Bedroom	Yes	Yes
Night-time	Yes	No
Unconditioned	No	No
Garage	No	No
Garage – conditioned	Yes	No

Note that the other zone types (subfloor, roof space, glazed common area, basement carpark) are not influenced by the occupant assumptions.

Heating

Heating thermostats for all climate zones are defined in Table 3.

Table 3: Heating thermostat settings

Zone	Thermostat setting (°C)
Living/kitchen	20
Living	20
Daytime	20
Bedroom	18
Night-time	18
Garage – conditioned	20

3.3 Cooling

Cooling thermostat settings for use in a Whole of Home calculation are detailed in section 3.14.

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

3.3.1 Pattern of conditioning

Patterns of conditioning are based on the occupancy profiles defined in section 3.2.2.

Living/kitchen, living, daytime and garage – conditioned are considered 'daytime conditioned' zones, and bedroom and night-time are considered 'night-time conditioned' zones. Patterns of heating are defined in Table 4 and cooling in Table 5,

Table 4: 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**

Note: Hour definition is hour ending at the specified clock hour (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 method.

Table 5: Cooling 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	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

Note: Hour definition is hour ending at the specified clock hour (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 method.

3.3.2 Internal heat gains

Internal heat gains are based on heat gains in AccuRate Sustainability v2.3.3.13.[6] Note that this refers to internal heat gains applied to the thermal calculation engine. This is not applied as part of section 3.4, because the impact will be addressed by the thermal calculation engine and so be reflected in the engine outputs.

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.

Base data[7]

Base information for defining sensible and latent heat gains based on people, lights, cooking and appliances are defined in the following tables

Kitchen all-day

[6] hstar.com.au/Home/Chenath

[7] 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. When writing the scratch files for Whole of Home simulations, these tables should be referenced.

- Table 6
- Kitchen work-day Table 7
- Living all-day Table 8
- Living work-day Table 9
- Bedroom all-day Table 10
- Bedroom work-day Table 11.

Table 6: Kitchen heat gains, all-day profile

Hour	Sensible heat load (W)				Latent heat load (W), 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	1,100	300	210	1,610	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

Note: Hour definition is hour ending at the specified clock hour (refer to section 3.1 regarding hour notation).

Table 7: Kitchen heat gains, work-day profile

Hour	Sensible heat load (W)				Latent heat load (W)
	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	1,100	300	210	1,610	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

Note: Hour definition is hour ending at the specified clock hour (refer to section 3.1 regarding hour notation).

Table 8: Living heat gains, all-day profile

Hour	Sensible heat load (W)			Latent heat load (W)
	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

Note: Hour definition is hour ending at specified clock hour (refer to section 3.1 regarding hour notation).

Table 9: Living heat gains, work-day profile

Hour	Sensible heat load (W)			Latent heat load (W)
	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

Note: Hour definition is hour ending at the specified clock hour (refer to section 3.1 regarding hour notation).

Table 10: Bedroom heat gains, all-day profile

Hour	Sensible heat load (W)			Latent heat load (W)
	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

Note: Hour definition is hour ending at the specified clock hour (refer to section 3.1 regarding hour notation).

Table 11: Bedroom heat gains, work-day profile

Hour	Sensible heat load (W)			Latent heat load (W)
	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

Note: Hour definition is hour ending at the specified clock hour (refer to section 3.1 regarding hour notation).

Adjustment factors[8]

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).

[8] 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 as 'being dealt with by Chenath', because it requires software providers to correctly write the scratch file.

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 permitted 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 square metres (m^2).

Kitchen heat gains

Base data are taken from

Table 6 or Table 7 for each hour of the day for each of the variables specified.

Lighting factor, F_{Light}, is defined in Equation 8.

Equation 8: Lighting factor for internal heat gains

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

Where B_{Light} is the relevant hourly value specified in

Table 6 or Table 7 as applicable. F_A is defined in Equation 7 and F_{Occ} is defined in Equation 4.

People factor, F_{People}, is defined in Equation 9.

Equation 9: People factor for internal heat gains

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

Where B_{People} is the relevant hourly value specified in

Table 6 or Table 7, as applicable. F_A is defined in Equation 7 and F_{Fam} is defined in Equation 5.

Total sensible heat gain, G_{Sens}, is defined in Equation 10.

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

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

Where $B_{S.Tot}$ = base sensible heat load total, and is the relevant hourly value specified in

Table 6 or Table 7, as applicable. F_{light} is determined from Equation 8 and F_{People} is determined from Equation 9.

Total latent heat gain, G_{Lat}, 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, which is the relevant hourly value specified in

Table 6 or Table 7, as applicable, and F_{People} is determined from Equation 9.

Living and bedroom heat gains

Base data are taken from Table 8, Table 9and Table 11.

Total sensible heat gain, G_{Sens}, 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, which is the relevant hourly value specified in, as applicable

B_{People} = base sensible heat load people, which is the relevant hourly value specified in Table 8, Table 9,Table 10and Table 11, as applicable.

Total latent heat gain, G_{Lat}, is defined in Equation 13.

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

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

Where B_{People} = base sensible heat load people, which is the relevant hourly value specified in Table 8, Table 9,Table 10and Table 11, as applicable.

F_A is defined in Equation 7 and F_{Fam} is defined in Equation 5.

3.3.3 Ventilation

Ventilation is the opening and closing of windows and doors.

Ventilation ON and OFF times are defined in Table 12. Ventilation ON times are when occupants are assumed to be home and they can open and close windows or doors to take advantage of favourable outdoor temperature conditions. Ventilation OFF times assume windows and door are closed.

Table 12: Ventilation settings

Hour	All-day profile	Work-day profile
1	ON	ON
2	ON	ON
3	ON	ON
4	ON	ON
5	ON	ON
6	ON	ON
7	ON	ON
8	ON	ON
9	ON	OFF
10	ON	OFF
11	ON	OFF
12	ON	OFF
13	ON	OFF
14	ON	OFF
15	ON	OFF
16	ON	OFF
17	ON	OFF
18	ON	ON
19	ON	ON
20	ON	ON
21	ON	ON
22	ON	ON
23	ON	ON
24	ON	ON

Note: Hour definition is hour ending at the specified clock hour (refer to section 3.1 regarding hour notation).

3.3.4 Shading

Technical constraints limit the control over shading from indoor and outdoor curtains and 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 that for the work-day profile, Chenath will operate curtains as needed (i.e. as if someone was home), even though it is assumed that nobody is present, and conditioning equipment will not be operated. It is assumed that if Chenath closes the curtains on a hot day, the occupant would have done this before leaving the house.

3.4 Heating and cooling modules

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

3.4.1 Required user inputs

User inputs for heating and cooling modules are:

- appliance type
- appliance-reported conversion efficiency for heating ('star rating' if applicable) in the relevant climate zone
- appliance-reported conversion efficiency for cooling ('star rating' if applicable) in the relevant climate zone
- zones serviced by the appliance.

Appliance fuel type is derived from the appliance type.

Note 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 3.2.4).

3.4.2 Default appliances

The default heating and cooling devices, in cases where equipment characteristics are not specified by the user, are defined in Table 13.

Table 13: Default heating and cooling devices

Heating or cooling factor	Description	Fuel type	Cold climate	Mixed climate	Hot/humid climate
Heating HSPF	MEPS level non-ducted reverse-cycle air conditioner (heat pump)	Electric	2.5	3.5	4.0
Cooling TCSPF	MEPS level non-ducted refrigerative air conditioner (heat pump)	Electric	3.5	3.5	4.0

HSPF = heating seasonal performance factor; MEPS = Minimum Energy Performance Standards; TCSPF = total cooling seasonal performance factor

Notes:

1. All values are seasonal performance factors as per AS/NZS3823.4 for climate zones defined under the zoned energy rating label (ZERL).
2. Refer to section 3.14 for a full concordance of NatHERS climates with Greenhouse and Energy Minimum Standards (GEMS) ZERL climates.
3. Heating HSPF and TCSPF are used to calculate the hourly energy as specified in section 3.4.5.

Note that unlimited capacity simulates an occupant installing a device large enough to cover the required load or several devices such that the load is met. Further work on guidance about 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 or cooling load in the specified heating or cooling zones, and this information can be used to provide advice to tool users.

3.4.3 Hourly thermal loads

The hourly thermal loads are calculated by the Chenath engine based on inputs defined in section 3.1, and blended using Equation 3 in section 3.2.3. This is the ‘demand’ for space heating or cooling in that zone for that hour, not the amount of fuel consumed.

3.4.4 Annual energy load

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

3.4.5 Energy use

Calculating end energy use requires definitions of the appliance to be entered by the user. Appliances may service a single zone or several zones. A single zone is assumed to be serviced only by 1 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 (megajoule; MJ)

$L_{z.hr}$ = hourly energy load for the zone, from Chenath simulation (heating or cooling); obtained by blending the all-day and work-day simulation outputs (see Equation 3).

COP_A = coefficient of performance for the specified appliance (W/W)

LS = system loss, where specified for the system type (e.g. ductwork), with a valid range of 0 to 1, such that a loss of 20% equates to a value of LS = 0.2.

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

Table 14: Default system losses for specified equipment types

Equipment type	Default system loss, *LS*
Ducted systems (less than 10 years old)	0.15
Ducted systems (more than 10 years old)	0.25
Hydronic heaters (panel type)	0.10
Concrete slab heating (any type)	0.15

Where a heating system uses a fuel other than electricity as the main energy source, the ancillary electrical load is calculated using Equation 15.

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

$$E_{A.hr} = \left(\sum E_{a.z.hr}\right) \times A$$

Where:

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

$E_{a.z.hr}$ = hourly energy use for each zone serviced by a given appliance (MJ)

A = ancillary electrical energy consumption factor (e.g. for electric fans).

Default ancillary loads for specified equipment types are set out in Table 15.

Table 15: Default ancillary loads for specified equipment types

Equipment type	Default ancillary load *A*
Fans for gas ducted systems	$0.0104 + 0.0044 \times GER^a$
Fans for GEMS regulated heat pumps[b]	0%
Fans for evaporative coolers[b]	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%

GEMS = Greenhouse and Energy Minimum Standards (national)

a GER is the Australian Gas Association (AGA) gas star rating (as a decimal) from 1.0 to 6.0.

b For heat pumps and evaporative systems, ancillary energy consumption is already included in the overall system energy estimates.

Note: Ancillary loads are assumed to be electrical in cases where the main fuel used is not electricity.

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

3.5 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 Greenhouse and Energy Minimum Standards (GEMS) determination for air conditioners[9] for the relevant zoned energy rating label (ZERL) climate zone (cold, mixed or hot/humid). The relevant ZERL climate zones for each of the 69 NatHERS climate zones are set out in section 3.14. 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 heating star rating is specified, the HSPF values shall be determined from Equation 16 or Table 16.

[9] energyrating.gov.au/sites/default/files/documents/F2019L00490.pdf

Equation 16: Determination of HSPF from seasonal heating star rating or seasonal heating star rating index

$$HSPF = SRI_{heat-2019} + 1.5$$

Where:

HSPF is the heating seasonal performance factor for a specific ZERL climate zone

$SRI_{heat-2019}$ is the heating star rating index (decimal star rating) for a specific ZERL climate zone from the energy rating website or downloaded file for products that have a climate rating under the 2019 GEMS determination for air conditioners.

Table 16: HSPF values for specified star ratings under the ZERL for air conditioners

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

HSPF = heating seasonal performance factor; ZERL = zoned energy rating label
Note: Heating star rating as per applicable ZERL climate zone.

Where the HSPF value of the selected heat-pump equipment exceeds the applicable value in Table 17, 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 dataset 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 Table 17).

Table 17: Maximum values for HSPF for air conditioners

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

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

Where only the annual coefficient of performance (ACOP) from the previous rating system is available (2010 star rating, 2013 GEMS determination), this value is converted to an equivalent HSPF value in accordance using Equation 18 for the relevant ZERL climate zone and equipment type.

Where only the heating star rating is available, the equivalent HSPF value can be determined from Equation 17 and Equation 18. Alternatively, the heating star rating, rounded down to the nearest 0.5 star, or the ACOP rounded down to the nearest 0.25 ACOP, can be used with Table 19 to determine HSPF for the relevant ZERL climate zone and equipment type.

Equation 17: Determination of ACOP from star rating (2013 GEMS determination)

$$ACOP = \frac{(4 \times SRI_{heat-2013}) + 18}{8}$$

Where:

ACOP = annual coefficient of performance, as specified in the 2013 GEMS determination (where not available from the relevant download file)

$SRI_{heat-2013}$ = heating star rating index (decimal star rating) from the energy rating website or downloaded file for products registered to the 2013 GEMS determination for air conditioners.

Equation 18: Determination of equivalent HSPF values from ACOP

$$HSPF = (H_C + H_V \times ACOP) \times ACOP$$

Where:

HSPF = equivalent heating seasonal performance factor for the relevant ZERL climate and type of air conditioner

ACOP = annual coefficient of performance, as specified in the 2013 GEMS determination from the relevant download file or from Equation 17, as applicable

H_C = relevant heating constant from Table 18 for relevant ZERL climate zone and type of air conditioner

H_V = relevant heating variable factor from Table 18 for relevant ZERL climate zone and type of air conditioner.

Table 18: Conversion factors from ACOP to HSPF

Product type	ZERL climate zone	Heating constant, H_C	Heating variable, H_V
Non-ducted fixed-capacity	Cold	0.722	0
Non-ducted fixed-capacity	Mixed	0.777	0
Non-ducted fixed-capacity	Hot/humid	0.847	0
Non-ducted variable-capacity	Cold	1.03	−0.0297
Non-ducted variable-capacity	Mixed	1.32	−0.0668
Non-ducted variable-capacity	Hot/humid	1.785	−0.1504
Ducted fixed-capacity	Cold	0.786	0
Ducted fixed-capacity	Mixed	0.84	0
Ducted fixed-capacity	Hot/humid	0.851	0
Ducted variable-capacity	Cold	1.02	−0.0479
Ducted variable-capacity	Mixed	1.195	−0.0631
Ducted variable-capacity	Hot/humid	1.61	−0.1422

ACOP = annual coefficient of performance; HSPF = heating seasonal performance factor; ZERL = zoned energy rating label

Notes:

1. The value of ACOP used to calculate this conversion factor is the rated value, which is called Rated ACOP in the Energy Rating CSV download file.
2. Fixed-capacity includes all systems with a single-speed compressor or a 2-speed compressor, classified as a fixed-capacity unit or 2-stage-capacity unit under AS/NZS3823.4.2.
3. Variable capacity includes multistage-capacity units and variable-capacity units (usually inverter driven) under AS/NZS3823.4.2.

Table 19: 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

ACOP = annual coefficient of performance; HSPF = heating seasonal performance factor; ZERL = zoned energy rating label

If no equipment is specified, the equipment characteristics set out in section 3.3.2 will be assumed.

3.6 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[10] for the relevant ZERL climate zone (cold, mixed or hot/humid). The relevant ZERL climate zones for each of the 69 NatHERS climate zones are set out in section 3.14. The NatHERS assessment software should flag the relevant ZERL climate zone to the user.

If available, the TCSPF for the relevant ZERL climate zone for the equipment type selected for the rating shall be provided. Where only the ZERL cooling star rating is specified, the TCSPF values shall be determined using Equation 19 or from Table 20.

Equation 19: Determination of TCSPF from seasonal cooling star rating or seasonal cooling star rating index

$$TCSPF = SRI_{cool-2019} + 1.5$$

Where:

TCSPF = total cooling seasonal performance factor for a specific ZERL climate zone

$SRI_{cool-2019}$ = cooling star rating index (decimal star rating) for a specific ZERL climate from the energy rating website or downloaded file for products that have a climate rating under the 2019 GEMS determination for air conditioners.

[10] energyrating.gov.au/sites/default/files/documents/F2019L00490.pdf

Table 20: 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

TCSPF = total cooling seasonal performance factor; ZERL = zoned energy rating label
Note: Star rating as per applicable ZERL climate zone.

If the TCSPF value of the selected heat-pump equipment exceeds the applicable value in Table 21, 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 dataset 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 Table 21).

Table 21: Maximum values for TCSPF for air conditioners

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

TCSPF = total cooling seasonal performance factor
Note: Values in this table will need to be updated periodically as the market changes over time.

Where only the annual energy efficiency ratio (AEER) from the previous rating system is available (2010 star rating, 2013 GEMS), this value is converted to an equivalent TCSPF value in accordance with Equation 21 for the relevant ZERL climate zone and equipment type.

Where only the cooling star rating is available, the equivalent TCSPF value can be determined from Equation 20 and Equation 21. Alternatively, the cooling star rating, rounded down to the nearest 0.5 star, or the AEER rounded down to the nearest 0.25 ACOP, can be determined from Table 23 for the relevant ZERL climate zone and equipment type.

Equation 20: Determination of AEER from star rating (2013 GEMS determination)

$$AEER = \frac{(4 \times SRI_{cool-2013}) + 18}{8}$$

Where:

AEER = annual energy efficiency ratio as specified in the 2013 GEMS determination (if not available from the relevant download file)

$SRI_{cool-2013}$ = cooling star rating index (decimal star rating) from the energy rating website or downloaded files for products registered to the 2013 GEMS determination for air conditioners.

Equation 21: Determination of equivalent TCSPF values from AEER

$$TCSPF = C_C \times AEER$$

Where:

TCSPF = equivalent total cooling seasonal performance factor for the relevant ZERL climate and type of air conditioner

AEER = annual energy efficiency ratio as specified in the 2013 GEMS determination from the relevant download, file or from Equation 20, as applicable

C_C = relevant constant from Table 22 for relevant ZERL climate zone and type of air conditioner.

Table 22: Conversion factors from AEER to TCSPF

Product type	ZERL climate zone	Cooling constant, C_C
Non-ducted fixed-capacity	Cold	1.023
Non-ducted fixed-capacity	Mixed	1.017
Non-ducted fixed-capacity	Hot/humid	1.076
Non-ducted variable-capacity	Cold	1.25
Non-ducted variable-capacity	Mixed	1.22
Non-ducted variable-capacity	Hot/humid	1.34
Ducted fixed-capacity	Cold	0.999
Ducted fixed-capacity	Mixed	0.995
Ducted fixed-capacity	Hot/humid	1.052
Ducted variable-capacity	Cold	1.11
Ducted variable-capacity	Mixed	1.206
Ducted variable-capacity	Hot/humid	1.332

AEER = annual energy efficiency ratio; TCSPF = equivalent total cooling seasonal performance factor; ZERL = zoned energy rating label

Notes:

1. The value of AEER that is relevant to calculate these conversion factors is the rated value, which is called Rated AEER in the Energy Rating CSV download files.
2. Fixed-capacity includes all systems with a single-speed compressor or a 2 speed compressor, classified as a fixed-capacity unit or 2-stage-capacity unit under AS/NZS3823.4.1.
3. Variable capacity includes multistage-capacity units and variable-capacity units (usually inverter driven) under AS/NZS3823.4.1.

Table 23: 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

AEER = annual energy efficiency ratio; TCSPF = equivalent total cooling seasonal performance factor; ZERL = zoned energy rating label

If no equipment is specified, the equipment characteristics set out in section 3.3.2 will be assumed.

3.6.1 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 (AGA).

The value of COP_A for a ducted gas heater rated from 1 to 3 stars is found using Equation 22.

Equation 22: Operating efficiency for ducted gas heaters of 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 6 stars[11] is found from Equation 23.

Equation 23: Operating efficiency for ducted gas heaters of 3 to 6 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 function (logarithm to base *e*).

In addition, the relevant loss factor from Table 14 and the ancillary energy factor from Table 15 must be applied to ducted gas heaters.

Indicative values of COP_A for ducted gas heaters of various star ratings are shown in Table 24.

Table 24: Nominal values of COP_A for ducted gas heaters by star rating

Stars (GER)	COP_A (%)
1	50.0
2	60.0
3	70.0
4	79.0
5	85.9
6	91.6

COP_A = coefficient of performance for the specified appliance; GER = AGA gas star rating for the appliance

Notes:

1. GER can be a decimal value between 1.0 and 6.0.
2. The AGA publishes the Directory of AGA certified products,[12] which is updated periodically and lists the product star rating to 1 decimal place for all ducted gas heaters (which are called 'indirect fired air heaters').

3.6.2 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 AGA. The value for COP_A for a non-ducted gas heater is set out in Equation 24.

[11] Some suppliers claim more than 6 stars in their product literature, but this specification and the *Directory of AGA certified products* recognises 6.0 stars as the maximum valid star rating.

[12] aga.asn.au/product_directory

Equation 24: 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.

If applicable (that is, when the non-ducted gas heater has a fan), the ancillary energy factor from Table 15 shall be applied.

Indicative values for COP_A for non-ducted gas heaters of various star ratings are shown in Table 25.

Table 25: Nominal values of COP_A for non-ducted gas heaters by star rating

Stars (GER)	COP_A (%)
1	61
2	63
3	73
4	79
5	85
6	91

COP_A = coefficient of performance for the specified appliance; GER = AGA gas star rating for the appliance

Notes:

1. GER can be a decimal value between 1.0 and 6.0.
2. The AGA publishes the Directory of AGA certified products,[13] which is updated periodically and lists the product star rating to 1 decimal place for all ducted gas heaters (which are called 'space heating appliances').

3.6.3 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/NZS4012. Wood heaters shall be classified into 3 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 15 (fans for any other non-ducted system type)
- ducted wood heaters – these systems are assumed to have ancillary electrical consumption as specified in Table 15 (fans for any other ducted system type) plus overall duct losses as specified in Table 14.

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 15).

Australian Home Heating lists current products.[14] Note that the efficiency rating given in this listing is an integer, generally ranging from 60 to 85. This must be divided by 100 to derive a valid value for COP_A (e.g. an Australian Home Heating Association efficiency rating of 75 equates to a COP_A value

[13] aga.asn.au/product_directory

[14] homeheat.com.au/wood-heaters/certified-wood-heaters/

of 0.75 or 75%). Unfortunately, this website does not usually indicate whether the unit has a fan (or not), so additional information – most likely from the supplier – may be required.

3.7 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 15), because ancillary load *A* is set to 0% for evaporative systems.

For evaporative ducted systems, the assumed system losses are as set out in Table 14.

Evaporative systems are most suited to hotter and dryer climates. Where the user has selected an evaporative cooler and the flag in section 3.14 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.

3.7.1 Appliance demand

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

3.7.2 Heating and cooling load limitations

There are no minimum heating or cooling loads in a conditioned zone below which the load is ignored in the Whole of Home 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.

3.7.3 Zones without conditioning devices

Zones where no conditioning device has been specified will have a default appliance specified (refer to section 3.3.2).

3.7.4 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 or cooling equipment (as detailed in the preceding sections) must 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 and cooling load dataset for the particular zone or zones, as derived from the Chenath simulation. The maximum hourly load across the entire year – with some tolerance built in (e.g. 0% to +15%) (and with modifiers, as appropriate) – should be used as the assumed required or recommended 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 load. Such guidance, if provided to builders or owners, should come with caveats about the use of such capacity estimates (i.e. this information should be provided to, and assessed by, the system specifiers and installers).

3.8 Hot water module

The energy used by the hot water system has 3 main components:

- hot water demand (by households)
- location (solar climate zones 1 to 4 + heat-pump zone HP1 to 5-AU)
- hot water system type.

3.8.1 Hot water demand

Delivered hot water is assumed to be a nominal 40 L/person/day, winter peak demand. The number of occupants is N_{Occ} as defined in section 3.2.1.

3.8.2 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 26 for heat-pump systems and Table 27 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 26: 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
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

Table 26: Water heater zone for heat-pump systems by postcode – continued

Postcode			Postcode			Postcode		
From	To	Zone	From	To	Zone	From	To	Zone
3464	3465	HP3-AU	3893	3900	HP5-AU	5220	5223	HP4-AU
3467	3469	HP5-AU	3902	3996	HP4-AU	5231	5261	HP3-AU
3472	3520	HP3-AU	4000	4419	HP3-AU	5262	5263	HP4-AU
3521	3522	HP4-AU	4420	4420	HP1-AU	5264	5270	HP3-AU
3523	3649	HP3-AU	4421	4428	HP3-AU	5271	5291	HP4-AU
3658	3658	HP4-AU	4454	4454	HP1-AU	5301	6256	HP3-AU
3659	3673	HP3-AU	4455	4465	HP3-AU	6258	6262	HP4-AU
3675	3678	HP5-AU	4467	4468	HP1-AU	6271	6317	HP3-AU
3682	3695	HP3-AU	4470	4474	HP2-AU	6318	6338	HP4-AU
3697	3723	HP5-AU	4477	4477	HP1-AU	6341	6341	HP3-AU
3725	3730	HP3-AU	4478	4482	HP2-AU	6343	6348	HP4-AU
3732	3746	HP5-AU	4486	4488	HP3-AU	6350	6353	HP3-AU
3747	3749	HP3-AU	4489	4493	HP2-AU	6355	6357	HP4-AU
3750	3762	HP4-AU	4494	4615	HP3-AU	6358	6395	HP3-AU
3763	3763	HP5-AU	4620	4724	HP1-AU	6396	6398	HP4-AU
3764	3764	HP4-AU	4725	4725	HP2-AU	6401	6438	HP3-AU
3765	3779	HP5-AU	4726	4726	HP1-AU	6440	6440	HP2-AU
3781	3783	HP4-AU	4727	4731	HP2-AU	6442	6443	HP3-AU
3785	3799	HP5-AU	4732	4735	HP1-AU	6445	6452	HP4-AU
3802	3815	HP4-AU	4736	4736	HP2-AU	6460	6640	HP3-AU
3816	3824	HP5-AU	4737	4824	HP1-AU	6642	6725	HP2-AU
3825	3825	HP4-AU	4825	4830	HP2-AU	6726	6743	HP1-AU
3831	3835	HP5-AU	4849	4895	HP1-AU	6751	6799	HP2-AU
3840	3892	HP4-AU	5000	5214	HP3-AU	7000	7470	HP5-AU

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

Table 27: Water heater zone for all other water heater technologies by postcode

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

For the purposes of simulation under AS/NZS4234, 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.

3.8.3 Hot water systems

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[15] in 0.5-star increments)
- solar diverter water heater (see section 3.8.5).

3.8.4 Water heater energy calculations

Water heater annual energy use

The approach taken to modelling the energy consumption of water heaters (excluding solar diverter 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/NZS4234.
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), using 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 system's energisation profile.

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 L/person/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 weekdays 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 Transient System Simulation Tool (TRNSYS) simulations.

[15] https://reg.energyrating.gov.au/comparator/product_types/62/search/?expired_products=on%20%20

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

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

Where:

N_{Occ} = number of occupants in the home (written in the form #.##; that is, rounded to the nearest second decimal)

A_D = area of dwelling (the sum of the floor areas of all zones, excluding the garage).

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 as defined in Equation 25.

Equation 25: 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 1 MJ peak load in winter (for the relevant climate zone; see Table 28)

40 is the nominal average winter peak hot water demand of 40 L/person/day.

Table 28: Average water volume per MJ winter peak hot water demand by climate zone

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

Note: For the purposes of simulation under AS/NZS4234, 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 26.

Equation 26: Determination of annual water demand

$$E_{Annual-output} = \frac{K_{wp} \times 365 \times 0.904521}{1{,}000}$$

Where:

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

K_{wp} = winter peak hot water demand in MJ/day (from Equation 25)

365 = days in a standard year

0.904521 = factor to convert 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

1,000 = factor to convert MJ to GJ.

The fourth step is to estimate the annual purchased energy, $E_{Annual\text{-}input}$ (energy input, MJ/year), from the annual hot water demand energy, $E_{Annual\text{-}output}$ (energy output), using a third-order polynomial whose coefficients (*a*, *b*, *c* and *d*) are specific to each type of water heater in each climate zone. This is defined in Equation 27.

Equation 27: Determination of annual purchase energy from annual hot water demand

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

Where:

$E_{Annual\text{-}output}$ = the annual hot water load (energy output) in GJ/year from Equation 26

$E_{Annual\text{-}input}$ = the annual hot water energy purchased (energy input) in MJ/year.

An earlier version of the water heater module used K_{wp} in an equation much like Equation 27 to estimate $E_{Annual\text{-}input}$. This update uses the same form of equation, but $E_{Annual\text{-}output}$ is now used as the input value. This means that all coefficients *a*, *b*, *c* and *d* have been changed in this updated specification and that $E_{Annual\text{-}output}$ is now in GJ/year.

The following recommendations apply to the sizing of solar thermal electric boost water heaters and solar thermal gas boost water heaters:

- If the number of occupants (from Equation 2) is ≥ 6, then a solar thermal electric boost system or solar thermal gas boost system should be classified as **large** by the Clean Energy Regulator.
- If the number of occupants (from Equation 2) is ≥ to 4 but < 6, then a solar thermal electric boost system or solar thermal gas boost system should be classified as **medium or large** by the Clean Energy Regulator.

Table 29 sets out the solar thermal water heater guidance for larger households in all climate zones. The number of occupants is calculated from Equation 2. The minimum number of small-scale technology certificates (STCs) required for a heat pump for 4 occupants or greater.

Table 29: Minimum recommended system sizes for solar thermal water heaters by household size and climate

Minimum climate zone 3 STCs – solar thermal electric boost; 4 ≤ N_{Occ} < 6	Minimum climate zone 3 STCs – solar thermal electric boost; N_{Occ} > 6	Minimum climate zone 3 STCs – solar thermal gas boost; 4 ≤ N_{Occ} < 6	Minimum climate zone 3 STCs – solar thermal gas boost; N_{Occ} > 6	Minimum climate zone 3 STCs – air-source heat pump 4 ≤ N_{Occ}
25	35	22	32	25

STC = small-scale technology certificate

Notes:

1. The Clean Energy Regulator list of solar water heaters does not indicate system size or boost fuel in accordance with AS/NZS4234, so further information from the supplier may be necessary.
2. The minimum STCs quoted in the table are for the reference year 2020, prior to the deeming period reducing from 2022.
3. For solar thermal systems, the STC values listed for 4 ≤ N_{Occ} < 6 was deemed to be a 'medium load' and STC values listed for N_{Occ} > 6 was deemed to be a large load in accordance with AS/NZS4234:2008.
4. For air-source heat pumps the STC values listed for N_{Occ} > 4 was deemed to be a medium load in accordance with AS/NZS4234:2008.

More requirements may need to be met to ensure the water heater has the capacity to deliver the required hot water.

The coefficients (*a*, *b*, *c* and *d*) for each water heater type and climate zone are given in Appendix B. The codes used in Appendix B – Water heater performance coefficients for annual energy by climate zone for Whole of Home rating are set out in 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 = 3-letter code to identify the water heater type

Y = 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 = 2-digit code for the specific performance level for the water heater type.

More detail for each of these code elements are set out Table 30.

Table 30: Codes for different water heater types

Water heater code	Water heater type	Suffix details	Notes
SOF	Solid fuel	00 for all systems	nd
ESS	Electric storage small	00 for all systems	Assumes 80 L continuous energisation
ESL	Electric storage large	00 for all systems	Assumes 315 L off-peak energisation
EIN	Electric storage instantaneous	00 for all systems	nd
GST	Gas storage	XX is star rating[a,b] × 10	Several equivalent gas star ratings

GIN	Gas instantaneous	XX is star rating[a,b] × 10	Several equivalent gas star ratings, separate gas and electric energy
STE	Solar thermal electric boost	STCs earned[c]	Remote of close coupled, range of STC levels
STG (STX)	Solar thermal gas boost	STCs earned[d]	Inline boosting, range of STC levels, electric+gas
SHP	Heat pump	STCs earned[e]	Range of STC levels

nd = no data; STC = small-scale technology certificate

a Equivalent gas star rating in half-star increments × 10; for example, 55 = star rating of 5.5 stars and the coefficients used in Equation 27 give the gas energy consumption. For gas storage water heaters and gas instantaneous water heaters, an 'equivalent star rating' may be as high as 7 stars – see Table 31.

b Code 99 for GIN is the auxiliary electricity energy consumption for gas instantaneous water heaters.

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 the range varies by climate. Not all STC levels are available in all climates.

d 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 the range 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.

e 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 the range varies by climate. Not all STC levels are available in all climates. Heat pump covers 5 separate climate zones.

For gas storage water heaters and gas instantaneous water heaters, an 'equivalent star rating' is allocated in this specification. It is based on the annual energy consumption in MJ/year, as listed in the GEMS Regulator/Energy Efficiency and Conservation Authority listing of gas water heaters, which is updated daily.[16] The equivalent star ratings are set out in Table 31.

Table 31: Equivalent star rating for gas water heaters for use in this specification

Equivalent gas star rating	System ID suffix	Maximum annual energy (MJ/year)	Minimum annual energy (MJ/year)
4.0	40	22,831	21,819
4.5	45	21,820	20,807
5.0	50	20,808	19,796
5.5	55	19,797	18,784
6.0	60	18,785	17,773
6.5	65	17,774	16,761
7.0	70	16,762	0

Notes: The annual energy consumption ranges set out in the table are used to determine the equivalent gas star rating used in this specification (rounded down to the nearest 0.5 star). The annual energy consumption is the Comparative Annual Energy Consumption for the gas water heater as listed in the GEMS Regulator/Energy Efficiency and Conservation Authority listing of gas water heaters for the specific model. This in turn defines the relevant System ID in Appendix B. System ID suffix gives the last 2 digits of the system code for a gas water heater, as set out in Table 30.

16 https://reg.energyrating.gov.au/comparator/product_types/62/search/?expired_products=on%20%20

Water heater monthly energy use

Once annual energy input (purchased energy) has been determined, this is split into monthly inputs. In doing so, there are 3 main cases:

- The energy input for instantaneous systems will be largely in direct proportion to changes in monthly hot water energy demand. This is because there are no fixed losses for these types (there may be some ongoing auxiliary electrical energy consumption – i.e. 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 will depend on the relative sizes of the heat losses. Heat-pump water heaters behave like conventional storage water heaters in terms of their share of energy in the monthly breakdown.
- For solar thermal systems (electric and gas boost), the monthly breakdown is quite complex because 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 32. This table is also used to allocate annual energy into months for instantaneous water heaters. The monthly share of input energy for each of the hot water systems covered by the Whole of Home assessment is set out in the following tables and equations. A full list of monthly shares of annual energy input (purchased energy) for all water heater types and climates is given in Appendix C – Water heater performance coefficients for monthly share of energy by climate zone for Whole of Home rating.

Table 32: 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**

Notes: This table is derived from the monthly seasonal multiplier defined in AS/NZS4234 Table A5 and the number of days per month in a standard year. It is also used to break down annual energy input ($F_{m,z}$) for instantaneous electric and gas systems for all zones.

Table 33: 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 34: 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 35: 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 36: 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
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**

STC = small-scale technology certificate

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 28: Monthly share of energy for solar thermal systems

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

Where $E_{Annual\text{-}output}$ (hot water demand) is defined in Equation 26. Specific 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 28 for solar thermal electric should be equal to 1.0000.

For solar thermal gas boost systems, 2 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 27 is gas plus electrical energy). The sum of values for each of the 12 months from Equation 28 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 28 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. The coefficients are quoted to more significant figures in the spreadsheet than they are in this report, so for the most accurate results, obtain the coefficients from the spreadsheet.

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 29.

Equation 29: Daily energy input 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 (calculated from Equation 28)

$E_{Annual\text{-}input}$ = annual hot water energy purchased (energy input) in MJ/year (calculated from Equation 27)

$Days_m$ = days in the specified month (for a standard year, $Days_m$ = 365 days).

Hourly loads 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 from the times that hot water would be used by the occupants in real life.

Some initial broad assumptions about time of energy input into the water heater (as opposed to time of hot water delivery) are provided in Table 37.

Table 37: Water heater schedules

Water heater	Energy input (energisation) schedule
Solid fuel (f)	Additional research needed (use time of hot water use as the default)
Off-peak electric storage (e)	Overnight or daytime limited energisation
Continuous electric storage (e)	Energisation dependent on hot water load
Instantaneous electric (e)	Time of hot water use
Solar thermal electric (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

Notes:

1. For solar thermal electric boost systems that are intended to operate on controlled (off-peak) tariffs, the supplier should confirm that the specific water heater has been configured for use with this type of energisation profile and the STCs earned are for this specific configuration. The equations in Appendix B will then be valid.
2. Limited energisation has little impact on heat-pump performance (within valid hot water delivery limits) and there are no configuration changes.
3. Letter in brackets indicates primary fuel: f = solid fuel, e = electricity, g = gas (natural gas or liquefied petroleum gas; LPG).

Schedules are defined in Table 38. Time of hot water use pattern is initially suggested to operate in accordance with AS/NZ4234 Table A4.

Table 38: 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 (share)	Daytime energisation by hour (share)	Overnight energisation by hour (share)	Energisation dependent on hot water load storage systems	Share auxiliary electricity energy for solar thermal gas systems (%)
1	00:00	01:00	0	0	0.25	Component A	1.1
2	01:00	02:00	0	0	0.25	Component A	1.1
3	02:00	03:00	0	0	0.25	Component A	1.1
4	03:00	04:00	0	0	0.25	Component A	1.1
5	04:00	05:00	0	0	0	Component A	1.1
6	05:00	06:00	0	0	0	Component A	1.1
7	06:00	07:00	0	0	0	Component A	1.1
8	07:00	08:00	0.15	0	0	Component D	1.7
9	08:00	09:00	0.15	0.125	0	Component D	1.7
10	09:00	10:00	0	0.125	0	Component A	4.6
11	10:00	11:00	0	0.125	0	Component A	8.1
12	11:00	12:00	0.1	0.125	0	Component B	12.0
13	12:00	13:00	0	0.125	0	Component A	15.1
14	13:00	14:00	0.1	0.125	0	Component B	15.5
15	14:00	15:00	0	0.125	0	Component A	11.6
16	15:00	16:00	0.125	0.125	0	Component C	8.6
17	16:00	17:00	0.125	0	0	Component C	5.1
18	17:00	18:00	0.125	0	0	Component C	1.6
19	18:00	19:00	0.125	0	0	Component C	1.6
20	19:00	20:00	0	0	0	Component A	1.1
21	20:00	21:00	0	0	0	Component A	1.1
22	21:00	22:00	0	0	0	Component A	1.1
23	22:00	23:00	0	0	0	Component A	1.1
24	23:00	24:00	0	0	0	Component A	1.1

Notes:

1. Nominal hour number is hour ending at the specified clock hour (refer to section 3.1 for hour notation).
2. Time of hot water use is as defined in AS/NZS4234 Table A4.
3. Hour 24:00 on the current day is equal to hour 0:00 on the next day.
4. 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 varies from day to day, depending on the weather.

This means that the boost energy required on any one day may be lower or higher than the average value for the month, as estimated by the simulation. Tracking daily variations in solar contribution for solar thermal simulations is possible but very onerous and complex, and gives 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 and the relevant STCs earned for this configuration are specified.

The hourly breakdown of energy (E_{Hourly}) is defined in Equation 30 using the hourly share (F_{Hourly}) from Table 38 for the relevant water heater type, configuration and energisation profile, combined with the daily energy defined in Equation 29.

Equation 30: Hourly energy input for water heaters

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

As set out in Table 38, the hourly breakdown of energy (F_{Hourly}) for water heaters depends on the hot water load. This is because, for storage systems, heat losses (or fixed energy components) are spread throughout the day. As the hot water load increases, the energy used to heat the water becomes larger relative to the heat losses. The distribution of electrical auxiliary energy for gas instantaneous systems throughout the day is similar in that, if there is no hot water load, there is only standby usage. So electrical energy consumption increases with hot water load for those hours with hot water demand.

When modelling the following water heaters, 4 equations are used to apportion the daily energy among the 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 only)
- solar thermal gas boost (electrical auxiliary energy only) – assumed to be the same as gas instantaneous.

For these water heater system types and fuels, Equation 31 to Equation 34 provide the hourly breakdown of energy (F_{Hourly}) for the 4 components defined in Table 38 (components A, B, C and D).

Equation 31: Hourly breakdown of energy for storage type water heaters – component A

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

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.

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

Equation 32: Hourly breakdown of energy for storage type water heaters – component B

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

Equation 33: Hourly breakdown of energy for storage type water heaters – component C

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

Equation 34: Hourly breakdown of energy for storage type water heaters – component D

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

In summary:

- component A applies to hours of 0% hot water demand = hours 1 to 7, 10, 11, 13, 15, 20 to 24
- component B applies to hours of 10% hot water demand = hours 12, 14
- component C applies to hours of 12.5% hot water demand = hours 16, 17, 18, 19
- component D applies to hours of 15% hot water demand = hours 8, 9.

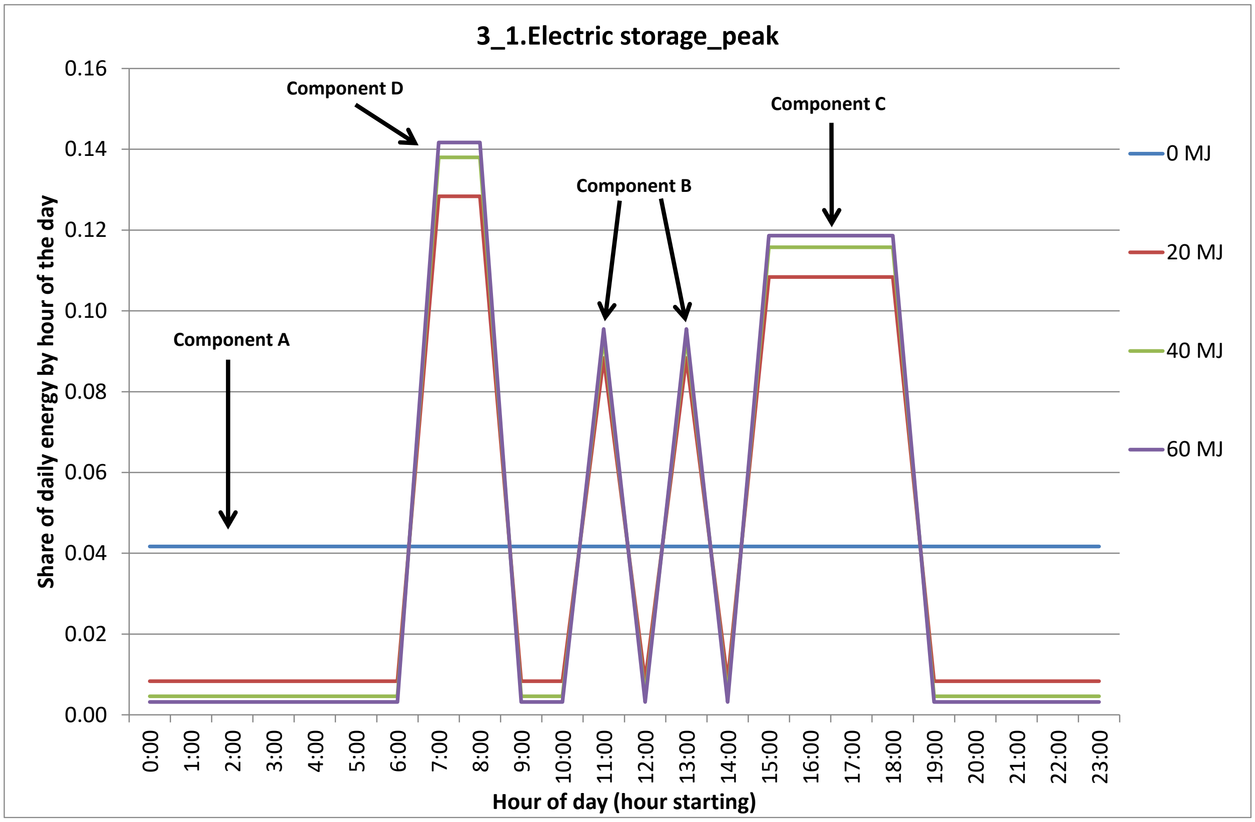
Equation 35 should be used to validate the values for the 4 components.

Equation 35: Validation of hourly components A, B, C and D for storage systems

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

An illustration of how the hourly share of daily energy changes with hot water load is provided in Note: The 4 hot water demands shown are 0 MJ/day, 20 MJ/day, 40 MJ/day and 60 MJ/day (winter peak).

Figure 2. When there is no 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.



Note: The 4 hot water demands shown are 0 MJ/day, 20 MJ/day, 40 MJ/day and 60 MJ/day (winter peak).

Figure 2: Changes in hourly share of daily energy with hot water demand for a small electric storage system in zone 3

Small Technology Certificates for solar and heat pump water heaters

The Clean Energy Regulator maintains a registry of solar water heaters that are eligible for STCs, the Solar hot water models with a capacity of less than 700L Registry[17].

Because the deeming period for awarding STCs for solar water heaters is reducing as the scheme winds down in 2030, the Renewable Energy Certificates Registry calculator[18] calculates how many certificates a system is eligible for based on its installation date.

When using the Solar hot water models with a capacity of less than 700L registry, the STC values in this document are based on 10-year deeming periods, these can be entered as the STC for the system in all zones.

When using the Renewable Energy Certificates Registry calculator Equation 36 is used to identify which of the STC levels listed in Appendix B should be applied to the assessment by converting the calculator figure back to a 10-year deeming period.

[17] https://www.cleanenergyregulator.gov.au/RET/Scheme-participants-and-industry/Agents-and-installers/Small-scale-systems-eligible-for-certificates/Register-of-solar-water-heaters

[18] https://www.rec-registry.gov.au/rec-registry/app/calculators/swh-stc-calculator

Equation 36 10-year equivalent STCs for water heaters

$$STC\ Equivalent = \frac{STCs\ Awarded}{2031 - Installation\ Year} \times 10$$

Where:

STC Equivalent = the number of STCs assumed to be awarded by the system for a 10 year deeming period, rounded up to the next whole number.

STCs Awarded = Number of STCs awarded by the REC Registry calculator

Installation Year = The year entered into the REC Registry calculator for the expected installation date (e.g. 2023)

Note that the STCs awarded will be rounded down using the REC calculator is looked up directly. This also means rounding STC Equivalent up to the next whole number will provide a better estimate of the actual STCs that would have been awarded under a 10-year deeming period.

Equation 36 should also be applied to determine the Zone 3 equivalent STCs, this applies regardless of the CER zone the project is proposed at. If using the REC calculator, for a project not in a CER Zone 3, users will need to enter a postcode into the REC calculator that is within zone 3. The postcode 2000 may be used for this purpose. Note that for project not in a CER Zone 3 the value entered for CER Zone 3 plays no part in annual energy demand in hot water. This value is needed to compare against table 29 as well as to populate table 8 of the certificate.

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.

The number of occupants is given by Equation 2.

$$N_{Occ} = 1.525 \ln(200) - 4.533$$
$$= 3.546934$$
$$= 3.55$$

From Table 28, the value of *y* for zone 3 is equal to 5.107.

The winter peak hot water demand, K_{wp}, is obtained from Equation 25 as follows:

$$K_{wp} = \frac{40 \times 3.55}{5.107} = 27.805 \text{ MJ/day}$$

The annual hot water demand (energy output), $E_{Annual\text{-}output}$, is obtained from Equation 26.

$$E_{Annual-output} = \frac{K_{wp} \times 27.805 \times 0.904521}{1{,}000} = 9.1782 \text{ GJ/year}$$

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. The relevant parameters for Equation 27 are obtained from Appendix B, and shown in Table 39.

Table 39: Annual energy coefficients for a solar thermal electric water heater (27 STCs, zone 3)

***a* (x^3)**	***b* (x^2)**	***c* (x^1)**	***d* (x^0)**
−0.27887	28.75026	87.96217	337.4859

This is a valid selection because the number of STCs earned is not restricted for N_{Occ} of fewer than 4 people (see Table 29).

The annual purchased energy (energy input) can then be determined from Equation 27.

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

$E_{Annual-input}$ = 3,351.994 MJ/year of electricity purchased.

The monthly breakdown of energy is determined from Equation 28 using coefficients taken from Appendix C – Water heater performance coefficients for monthly share of energy by climate zone for Whole of Home rating and shown in Table 40.

Table 40: Example of the determination of monthly and daily energy input for a solar thermal electric water heater

Month	Days in 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	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	0.034970	117.2	3.91
Dec	31	STE-3-DEC	−1.1E-05	0.000514	−0.0063	0.038998	0.015979	53.6	1.73
Year	**365**						**1.000000**	**3,351.8**	

Note: It is recommended that the values of *a*, *b*, *c* and *d* be taken from the source spreadsheet, as these values are provided to greater precision than 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 38.

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. The relevant parameters for Equation 27 are obtained from Appendix B, as shown in Table 41.

Table 41: Annual energy coefficients for a solar thermal gas water heater (38 STCs, zone 3)

a (x^3)	*b* (x^2)	*c* (x^1)	*d* (x^0)
0.233107	13.17273	131.502	491.7095

This is a valid selection because the number of STCs earned is not restricted for N_{Occ} of fewer than 4 people (see Table 29).

The annual purchased energy (energy input) can then be determined from Equation 27.

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

$E_{Annual\text{-}input}$ = 2,989.25 MJ/year of electricity and gas combined.

The monthly breakdown of energy is determined from Equation 28 using coefficients from Appendix C – Water heater performance coefficients for monthly share of energy by climate zone for Whole of Home rating and is shown in Table 42 (gas share) and Table 43 (electricity share).

Table 42: Example of the determination of monthly and daily energy input for a solar thermal gas water heater – gas share

Month	Days in 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	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	0.042180	0.032632	97.5	3.48
Mar	31	STG-3-MAR	−7.2E-06	0.000277	−0.00181	0.049192	0.050308	150.4	4.85
Apr	30	STG-3-APR	−1.8E-06	−3.9E-05	0.003465	0.046153	0.073318	219.2	7.31
May	31	STG-3-MAY	3.09E-05	−0.00141	0.018412	0.078389	0.152409	455.6	14.70
Jun	30	STG-3-JUN	3.45E-05	−0.00152	0.018599	0.094321	0.163372	488.4	16.28
Jul	31	STG-3-JUL	2.39E-05	−0.0011	0.014615	0.081664	0.141675	423.5	13.66
Aug	31	STG-3-AUG	1.34E-05	−0.00069	0.011043	0.055385	0.109328	326.8	10.54
Sep	30	STG-3-SEP	−5.6E-06	0.000128	0.001777	0.046305	0.069000	206.3	6.88
Oct	31	STG-3-OCT	−1.2E-05	0.000517	−0.00461	0.052810	0.044452	132.9	4.29
Nov	30	STG-3-NOV	−1.3E-05	0.000577	−0.00628	0.050800	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**	**2,728.2**	

Table 43: Example of the determination of monthly and daily energy input for a solar thermal gas water heater – electricity share

Month	Days in 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	STX-3-JAN	−2.8E-06	0.000150	−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	0.000200	−0.00371	0.027118	0.006979	20.9	0.70
Jul	31	STX-3-JUL	−4.8E-06	0.000250	−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	−3.0E-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	−0.00280	0.022656	0.007129	21.3	0.69
Year	**365**						**0.087390**	**261.2**	

Note that:

- the sum of all monthly shares for gas (0.91261) PLUS the sum of all monthly shares for electricity (0.08739) adds to 1.0000
- the gas energy (2,728.2 MJ) PLUS the electricity energy (261.2 MJ) add to give total energy input (2,989.4 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 38. The electrical auxiliary energy consumption by hour is as set out in the last column of Table 38.

Example 3

A third example considers a 6-star-equivalent instantaneous gas water heater at the same site.
The relevant code for this water heater is therefore GIN-3-60. The relevant parameters for Equation 27 are obtained from Appendix B, and are shown in Table 44. Note that this only covers the gas energy consumption.

Table 44: Annual energy coefficients for an instantaneous gas water heater (6 stars equivalent) – gas energy

a **(x^3)**	***b*** **(x^2)**	***c*** **(x^1)**	***d*** **(x^0)**
0.209420838	−8.2968348	1,432.318768	0

The annual purchased gas energy (energy input) can then be determined from Equation 27.

$$E_{Annual-input} = +\ 0.209420838 \times (9.1782)^3 - 8.2968348 \times (9.1782)^2 + 1{,}432.318768 \times (9.1782) + 0$$

$E_{Annual\text{-}input}$ = 12,611.26 MJ/year of gas.

The relevant code for the auxiliary electrical energy for this water heater is therefore GIN-3-99. The relevant parameters for Equation 27 are obtained from Appendix B, and are shown in Table 45.

Table 45: Annual energy coefficients for an instantaneous gas water heater – electricity (auxiliary)

a **(x^3)**	***b*** **(x^2)**	***c*** **(x^1)**	***d*** **(x^0)**
0.000855679	−0.0339003	4.686018207	100.9152

The annual purchased energy (energy input) can then be determined from Equation 27 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 28 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 Table 46 (gas energy) and (electricity). 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.

Table 46: Example of the determination of monthly and daily energy input for an instantaneous gas water heater – gas energy

Month	**Days in 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	1,006.5	32.47
Apr	30	GIN-3-APR	0	0	0	0.081781	0.081781	1,031.4	34.38
May	31	GIN-3-MAY	0	0	0	0.089202	0.089202	1,124.9	36.29
Jun	30	GIN-3-JUN	0	0	0	0.090868	0.090868	1,146.0	38.20
Jul	31	GIN-3-JUL	0	0	0	0.093897	0.093897	1,184.2	38.20
Aug	31	GIN-3-AUG	0	0	0	0.093897	0.093897	1,184.2	38.20
Sep	30	GIN-3-SEP	0	0	0	0.090868	0.090868	1,146.0	38.20
Oct	31	GIN-3-OCT	0	0	0	0.089202	0.089202	1,124.9	36.29
Nov	30	GIN-3-NOV	0	0	0	0.081781	0.081781	1,031.4	34.38
Dec	31	GIN-3-DEC	0	0	0	0.075117	0.075117	947.3	30.56
Year	**365**						**1.00000**	**12,611.26**	

Table 47: Example of the determination of monthly and daily energy input for an instantaneous gas water heater – electricity

Month	Days in month, Daysm	Month code (electricity)	amonth	bmonth	cmonth	dmonth	Monthly share, Fm.z	Monthly energy (MJ)	Daily energy (MJ), EDaily.m
Jan	31	GIN-3-JAN	0	0	0	0.065728	0.065728	9.3	0.30
Feb	28	GIN-3-FEB	0	0	0	0.067848	0.067848	9.6	0.34
Mar	31	GIN-3-MAR	0	0	0	0.079812	0.079812	11.3	0.36
Apr	30	GIN-3-APR	0	0	0	0.081781	0.081781	11.6	0.39
May	31	GIN-3-MAY	0	0	0	0.089202	0.089202	12.6	0.41
Jun	30	GIN-3-JUN	0	0	0	0.090868	0.090868	12.9	0.43
Jul	31	GIN-3-JUL	0	0	0	0.093897	0.093897	13.3	0.43
Aug	31	GIN-3-AUG	0	0	0	0.093897	0.093897	13.3	0.43
Sep	30	GIN-3-SEP	0	0	0	0.090868	0.090868	12.9	0.43
Oct	31	GIN-3-OCT	0	0	0	0.089202	0.089202	12.6	0.41
Nov	30	GIN-3-NOV	0	0	0	0.081781	0.081781	11.6	0.39
Dec	31	GIN-3-DEC	0	0	0	0.075117	0.075117	10.6	0.34
Year	**365**						**1.00000**	**141.74**	

For an instantaneous gas system, the hourly energy gas use is assumed to be in line with the hourly hot water demand as set out in Table 38. The electrical auxiliary energy consumption by hour is dependent on the hot water load, so this is defined as the 4 components in Equation 31 to Equation 34. The 4 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 shown in Table 48.

Table 48: Component coefficients for hourly share of load – electrical energy for a gas instantaneous water heater

Component	Code	*a* (x^3)	*b* (x^2)	*c* (x^1)	*d* (x^0)	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 35). Using this data, the hourly breakdown for electrical energy for an instantaneous gas water heater in January (0.30 MJ/day) is shown in Table 49.

Table 49: Example of the determination of hourly energy input for an instantaneous gas water heater – electricity

Nominal hour	Component	F_{hourly} (share)	E_{hourly} (MJ)
1	Component A	0.013357	0.004014
2	Component A	0.013357	0.004014
3	Component A	0.013357	0.004014
4	Component A	0.013357	0.004014
5	Component A	0.013357	0.004014
6	Component A	0.013357	0.004014
7	Component A	0.013357	0.004014
8	Component D	0.115272	0.034641
9	Component D	0.115272	0.034641
10	Component A	0.013357	0.004014
11	Component A	0.013357	0.004014
12	Component B	0.081300	0.024432
13	Component A	0.013357	0.004014
14	Component B	0.081300	0.024432
15	Component A	0.013357	0.004014
16	Component C	0.098286	0.029537
17	Component C	0.098286	0.029537
18	Component C	0.098286	0.029537
19	Component C	0.098286	0.029537
20	Component A	0.013357	0.004014
21	Component A	0.013357	0.004014
22	Component A	0.013357	0.004014
23	Component A	0.013357	0.004014
24	Component A	0.013357	0.004014
	Total day	**1.000000**	**0.300518**

Example 4

A fourth example is examined at the same site – this is a small electric storage water heater. The relevant code for this water heater is therefore ESS-3-00. The relevant parameters for Equation 27 are obtained from Appendix B, as shown in Table 50.

Table 50: Annual energy coefficients for a small electric storage water heater

a (x^3)	b (x^2)	c (x^1)	d (x^0)
0	0	1,020.408163	1,681.753

The annual purchased energy (energy input) can then be determined from Equation 27.

$$E_{Annual-input} = +0 \times (9.1782)^3 + 0 \times (9.1782)^2 + 1{,}020.408163 \times (9.1782) + 1{,}681.753$$

$E_{Annual\text{-}input}$ = 11,048.91 MJ/year of electricity.

The monthly breakdown of energy is determined from Equation 28 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 Table 51.

Table 51: Example of the determination of monthly and daily energy input for a small electric storage water heater

Month	Days in 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	1,007.5	33.58
Jul	31	ESS-3-JUL	0	0	0	0.094737	0.094737	1,046.7	33.77
Aug	31	ESS-3-AUG	0	0	0	0.093803	0.093803	1,036.4	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	0.081050	0.081050	895.5	29.85
Dec	31	ESS-3-DEC	0	0	0	0.075297	0.075297	832.0	26.84
Year	365						1.00000	11,048.91	

For a small electric storage water heater with continuous energisation, the hourly energy use depends on the hot water load, so this is defined by the 4 components in Equation 31 to Equation 34. The 4 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 in Table 52.

Table 52: Component coefficients for hourly share of load – small electric storage water heater

Component	Code	*a* (x^3)	*b* (x^2)	*c* (x^1)	*d* (x^0)	Share of hot water 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

As a check, it is confirmed that 16 × *A* + 2 × *B* + 4 × *C* + 2 × *D* = 1.0000 (Equation 35).

Using this data, the hourly breakdown for electrical energy for a small electric storage water heater in July (33.77 MJ/day) is as shown in Table 53.

Table 53: Example of the determination of hourly energy input for a small electric storage water heater

Nominal hour	Component	F_{hourly} (share)	E_{hourly} (MJ)
1	Component A	0.004861	0.16413
2	Component A	0.004861	0.16413
3	Component A	0.004861	0.16413
4	Component A	0.004861	0.16413
5	Component A	0.004861	0.16413
6	Component A	0.004861	0.16413
7	Component A	0.004861	0.16413
8	Component D	0.137362	4.638121
9	Component D	0.137362	4.638121
10	Component A	0.004861	0.16413
11	Component A	0.004861	0.16413
12	Component B	0.093195	3.146791
13	Component A	0.004861	0.16413
14	Component B	0.093195	3.146791
15	Component A	0.004861	0.16413
16	Component C	0.115278	3.892456
17	Component C	0.115278	3.892456
18	Component C	0.115278	3.892456
19	Component C	0.115278	3.892456
20	Component A	0.004861	0.16413
21	Component A	0.004861	0.16413
22	Component A	0.004861	0.16413
23	Component A	0.004861	0.16413
24	Component A	0.004861	0.16413
	Total	**1.000000**	**33.77**

3.8.5 Solar PV diverters

Some products can divert excess onsite solar 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 solar PV diverter.

This section sets out the design and operation of a solar PV diverter method in NatHERS Whole of Home assessments. The operation of this method is conceptually based on a battery storage module but with altered settings, to allow for the overall operation of a solar PV 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. Solar PV diverters are likely to only work well with larger storage volumes (250 L or more).

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

Simulations based on this detailed specification and used for NatHERS Whole of Home modelling correlate closely with the simulations provided by Rheem for equivalent inputs over a wide range of cases. This allows the reference tool, and other providers, to prepare a compatible simplified software model that will generate reasonably accurate results for simple solar PV diverters. This documentation relies heavily on the Rheem documentation and feedback, and their input to the process is gratefully acknowledged.

This module design only covers so-called ‘dumb’ solar PV diverters – ones that assess the situation hourly. 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 they modify current PV diversion decisions based on future anticipated spot electricity prices. However, preset energisation windows can be defined.

With any simplified model, there are some shortcomings, but in general terms, these do not appear to cause significant inaccuracies. Any technical limitations are noted.

Overview of systems covered

This model specification covers 3 types of solar PV diverter systems.

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, with energisation often controlled by electricity utilities (using timeclocks or ripple control switching). A type 1 solar PV diverter has the element energisation period during the day (nominally 10 am to 3 pm) to maximise the chance that the tank input energy will occur during periods when there may be excess PV generation. For this type of product, the element power is **not** modulated (it is ON or OFF at rated power only) and there is no monitoring of when there may be excess PV available onsite. 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 10 am to 3 pm each day. The SA solar sponge tariff does not require any local PV generation, so would not strictly be classified as a solar PV diverter.

Type 2: Modulated input into an existing storage 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 divert 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 onsite, 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.[19]

Type 3: Bespoke solar PV diverter – dedicated product

This is a specially designed solar PV diverter water heater. The controller can monitor the house load and local PV generation and diverts excess solar energy to the water heater. The water heater has 2 elements (1 lower and 1 upper), but they are electrically interlocked so that only 1 can operate at a 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 that adequate hot water is always available to the user. An example of this product is the Solahart Powerstore.[20]

Limitation note: Because 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 if the temperature has been below 60 °C for a defined period. This is 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 specification.

[19] catchpower.com.au/

[20] solahart.com.au/products/battery-storage/solahart-powerstore

Modelling approach

For all 3 system types, the tank is split into 2 segments – an upper and a lower (Figure 3). The 2 segments represent the stratification of a storage tank, which occurs when hot water is drawn off during use, but boost energy is not necessarily applied until a later time.

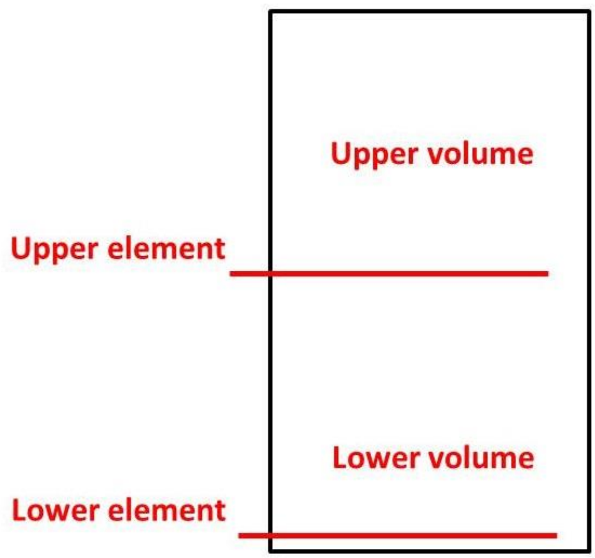


Figure 3: Key elements of a storage water heater in a solar PV diverter model

For all 3 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, because 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 at the hot/cold interface).

Limitation note: Heat loss for all 3 systems is calculated every hour separately for the upper and lower segments and is based on the tank temperature at the start of the hour. This is a simplification, because the tank temperature varies with hot water drawoff and input energy over the hour. But the error will be relatively 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/available 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 accurate, because 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 use, because the model assumes that all PV excess in an hour – where the element is energised – will go to the water heater. But 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). Data are only available in hourly time steps, so there is no 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 use 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 when more detailed modelling data are reviewed.

Initial solar PV diverter modelling calculations

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

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

Equation 37: Calculation of total tank volume (m³)

$$Volume(m^3) = \frac{Volume(L)}{1{,}000}$$

Equation 38: Calculation of upper tank volume fraction

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

Where:

V_{lwr} = lower tank volume in litres

V_{upp} = upper tank volume in litres

V_{lwr} + V_{upp} = *Volume(L).*

Default values for $Fraction_{upp}$ are as shown in Table 54.

Table 54: Default values for $Fraction_{upp}$ for each type of solar PV diverter

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 assumed to be 2.6. The tank diameter is calculated using Equation 38.

Equation 39: Calculation of tank diameter

$$D_{tank} = \left(\frac{4 \times Volume}{\pi \times AR}\right)^{\frac{1}{3}}$$

Where diameter, D_{tank}, is in metres.

The tank height is calculated using Equation 39.

Equation 40: Calculation of tank height

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

Where tank height is in metres.

The internal surface area of the lower segment is calculated using Equation 40.

Equation 41: Calculation of inner surface of lower tank segment

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

The internal surface area of the upper segment is calculated using Equation 41.

Equation 42: Calculation of inner surface of upper tank segment

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

The values of A_{lwr} and A_{upp} are in m^2.

The nominal tank heat loss in accordance with AS/NZS4692.2 Table A1 is calculated from a fourth-order polynomial that is fitted to the data, as shown in Table 55 and Equation 42.

Table 55: Coefficients for a fourth-order polynomial to determine tank heat loss

Coefficient	B_4	B_3	B_2	B_1	B_0	R^2
Value	−9.7853	22.0738	−19.7292	10.43019	0.97237	0.999452

Equation 43: Calculation of tank heat loss

$$Heatloss = B_4 \times Volume^4 + B_3 \times Volume^3 + B_2 \times Volume^2 + B_1 \times Volume + B_0$$

Where:

Heatloss = heat lost from the tank kWh/day and is equal to the MEPS level for electric storage water heaters.

Volume = Tank volume in m^3

These heat-loss values assume only a single element and a single hot side temperature/pressure relief valve, so the values in Table A1 of AS/NZS4692.2 have been increased by 0.2.

The calculated heat loss for a 315-litre tank using this equation is 2.89384 kWh/day.

Firstly, the thermal transmittance (*U*) times the tank surface area is estimated using Equation 43.

Equation 44: Calculation of tank thermal transmittance times surface area

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

Where:

UA is in MJ/hour/kelvin (K)

3.6 is a factor to convert kWh to MJ

24 is the number of hours in a day

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

The overall tank thermal transmittance, U, is then calculated for this heat loss using Equation 44.

Equation 45: Calculation of tank thermal transmittance

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

Where:

A_{lwr} and A_{upp} are in m^2

U is in $MJ/hour/K/m^2$.

The heat storage volume in each segment of the tank is calculated using Equation 45 (upper segment) and Equation 46 (lower segment).

Equation 46: Heat storage capacity of the upper tank volume for specified temperatures

$$Q_{upp} = \frac{V_{upp} \times C_p \times (T_{hot-upp} - T_{cold})}{1{,}000}$$

Where:

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

V_{upp} = upper storage volume in litres

C_p = specific heat of water at constant pressure (average value of 4.185 at 15 °C and 60 °C in kJ/kg/K)

$T_{hot-upp}$ = stored hot water heater in °C in the upper segment

T_{cold} = cold water inlet temperature in °C

1,000 = factor to convert kJ to MJ.

The same equation is used to calculate the heat storage capacity of the lower segment in MJ (Equation 46) by substituting V_{upp} with V_{lwr}.

Equation 47: Heat storage capacity of the lower tank volume for specified temperatures

$$Q_{lwr} = \frac{V_{lwr} \times C_p \times (T_{hot-lwr} - T_{cold})}{1{,}000}$$

Where:

Q_{lwr} = heat storage capacity of the lower segment in MJ

V_{lwr} = lower storage volume in litres.

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. A number of hot water temperature conditions in these equations (T_{hot}) are defined for modelling as follows, with default values shown for each system type shown in Table 56.

Table 56: Default thermostat cutout temperatures for each solar PV diverter system type

Parameter	Description	Type 1 (°C)	Type 2 (°C)	Type 3 (°C)
T_{grid}	Cutout temperature using grid power	70	60	47
T_{PV}	Cutout temperature using diverted PV power	70	70	75
$T_{primary}$	Intermediate temperature using diverted PV power	n/a	N/A	65

n/a = not applicable

Note: 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 conditions and heat storages of the upper and lower segments are 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* (Equation 47 and Equation 48).

Equation 48: Temperature of water in the upper tank volume

$$T_{upp} = \frac{Q_{upp} \times 1{,}000}{C_p \times Vol_{upp}} + T_{cold}$$

Equation 49: Temperature of water in the lower tank volume

$$T_{lwr} = \frac{Q_{lwr} \times 1{,}000}{C_p \times Vol_{lwr}} + T_{cold}$$

Where *Q* is the amount of stored heat energy in MJ and volume is in litres.

The power put into the water heater in any time is limited by the rating of the element. The default values for each type of system are set out in Table 57.

Table 57: Default element power ratings for each type of solar PV diverter system

Parameter	Description	Type 1	Type 2	Type 3
$E_{max\text{-}lwr(kW)}$	Power rating for lower element	3.6 kW	3.6 kW	3.6 kW
$E_{max\text{-}upp(kW)}$	Power rating for upper element	n/a	n/a	3.6 kW
$E_{max\text{-}lwr}$	Power rating for lower element	12.96 MJ/h	12.96 MJ/h	12.96 MJ/h
$E_{max\text{-}upp}$	Power rating for upper element	n/a	n/a	12.96 MJ/h

n/a = not applicable

Note: 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 when PV power is being used are set out in Table 58.

Table 58: Default element losses during PV power diversion for each type of solar PV diverter system

Parameter	Description	Type 1	Type 2	Type 3
$Parasitic_{PV}$	Net heater system controller parasitic load (MJ/h)	0	$0.007 \times E_{max\text{-}lwr(kW)}$	$0.007 \times E_{max\text{-}lwr(kW)}$
Modulation	Heater load fraction that is modulated	0	1	1
$Mod_{Eff\text{-}PV}$	Efficiency of the heater modulating control	1	0.90	0.95

Notes:

1. For a default element rating of 3.6 kW, the parasitic load is 0.0252 MJ/h for types 2 and 3. For type 3, there is only a single parasitic load for the 2 elements.
2. Type 1 system is a time clock, so there are no parasitic load, modulation or modulation losses.
3. 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 when grid power is being used are set out in Table 59.

Table 59: Default element losses during grid power boosting for each type of solar PV diverter system

Parameter	Description	Type 1	Type 2	Type 3
$Parasitic_{grid}$	Net heater system controller parasitic load (MJ/h)	0	0	0
Modulation	Heater load fraction that is modulated	0	0	0
$Mod_{Eff\text{-}grid}$	Efficiency of the heater modulating control	0.987	0.987	0.987

Note: It is assumed, for grid boosting, that there is no power modulation for all system types and no parasitic losses. However, an element efficiency of 98.7% is assumed, which is a typical modelling assumption for electric storage water heaters.

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

Several input parameters must be mapped for each hour over the year to be modelled. Refer to the sample spreadsheet for detailed annotation for each hour of the year. Note that hour 1 means the hour ending at 01:00 (i.e. starting at 00:00 – midnight – and ending at 01:00).

Hourly house electricity load

This should be a realistic profile for the dwelling – in the reference tool, this is based on results from the Whole of Home national calculation. Sample house loads have been included in the sample spreadsheet to enable validation of data. Units are MJ (in each hour).

Hourly local PV generation

This should be hourly PV generation for the dwelling – in the reference tool, this is based on results from Whole of Home national calculation for the selected dwelling, PV system and orientation. Sample PV generation profiles have been included in the sample spreadsheet to enable validation of data. Units are MJ (in each hour).

Limitation note: House electricity loads and solar PV generation vary throughout any particular hour. However, only hourly data are available for these parameters for most models. Types 2 and 3 systems can modulate their power input to track the excess PV minute by minute. This means there is no need to assume any particular 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. 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 second correction is proposed later in this specification, which limits excess PV input into the tank to be in proportion to the element ON time in each hour. For this correction, the only reasonable assumption about hourly power variation is 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. House floor area is used to determine the number of occupants, and another equation then generates the annual hot water demand. Note that:

- the monthly breakdown for the solar PV diverter model is as for 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, because 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 are 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 are °C.

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 a Whole of Home assessment, this is the hourly data from the relevant NatHERS climate zone. For the sample spreadsheet, hourly data from the 5 AS/NZS4234 climate files have been included for validation and checking. Units are °C (in each hour).

Limitation note: Heat-loss calculations assume that the water heater is outside. If inside, an indoor temperature profile must 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. It is assumed no grid or PV boosting occurs outside these hours.
- Type 2: overnight grid boost window of ON at 01:00 and OFF at 05:00 has been selected as the default, but this can be adjusted as required. It is assumed no grid boosting occurs outside these hours, but PV boosting occurs at any time 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 whenever there is excess PV energy.

The following heat storage volumes (Q_{upp} and Q_{lwr}) must 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} must be calculated.
- 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 $Q_{lwrTgrid}$ must be calculated.

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 $Q_{lwrTprimary}$ must be calculated.

Table 60 sets out the list of variables used in this specification.

Table 60: List of key variables for solar PV diverters

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 (m^3)
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)
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 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 period (MJ) (= start next period)
Q_{lwr0}	Energy stored in the lower segment at the start of the period (MJ)

Variable	Description
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 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 period (MJ) (HW_{lwr} + HW_{upp})
HW_{lwr}	Hot water energy drawn from the lower segment in the period (MJ)
HW_{upp}	Hot water energy drawn from the upper segment in the 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)
PV_{usable}	Excess energy available from PV generation in the period after losses (MJ)

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 46 and Equation 47. Water temperatures in each segment are calculated in accordance with Equation 48 and Equation 49.

Hourly calculations for solar PV diverter modelling

For each hour, a cycle of calculations is undertaken as set out in this section.

Initial heat storage (Q_{upp0} and Q_{lwr0}) and temperature (T_{upp0} and T_{lwr0}) of each segment are defined as initial conditions 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, using Equation 50 and Equation 51.

Equation 50: Heat loss of tank, upper segment

$$Heatloss_{upp} = U \times A_{upp} \times \; (T_{upp0} - T_{amb} \;\; (\text{if } Q_{upp0} = 0, \text{then } Heatloss_{upp} = 0, \text{if } Heatloss_{upp} > Q_{upp0} \text{ then } Heatloss_{upp} = Q_{upp0})$$

Equation 51: Heat loss of tank, lower segment

$$Heatloss_{lwr} = U \times A_{lwr} \times \; (T_{lwr0} - T_{amb} \;\; (\text{if } Q_{lwr0} = 0, \text{then } Heatloss_{lwr} = 0, \text{if } Heatloss_{lwr} > Q_{lwr0} \text{ then } Heatloss_{lwr} = Q_{lwr0})$$

Where:

T_{amb} = the ambient temperature for the hour from the climate file (in °C)

T_{upp0} and T_{lwr0} = the temperatures of the upper and lower segments at the start of the hour, as calculated using Equation 48 and Equation 49, respectively.

Note that 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 using Equation 52, which shows IF statements written using Excel's notation.

Equation 52: Discharge signal (flag)

$$Discharge_{signal} = \text{IF}(T_{upp0} > T_{cold}, 1{,}0) \ + \ \text{IF}(T_{lwr0} > T_{cold}, 1{,}0)$$

For the given hour, this equation generates a discharge signal with the following possible values:

- 2 – both upper and lower segments are above T_{cold}, so start discharging from the lower segment
- 1 – the lower segment is empty ($\leq T_{cold}$), so starts discharging from the upper segment
- 0 – both upper and lower segments are empty (no hot water available).

The charge and discharge equations are configured such that T_{lwr} should always $\leq T_{upp}$.

If $Discharge_{signal}$ = 2, hot water is initially drawn from the lower segment, but this cannot exceed the amount of heat stored in the lower segment. If the hot water demand in the hour exceeds the amount of heat stored 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 amount of heat stored in the upper segment. This is shown in Equation 53.

Equation 53: Hot water energy drawn from lower segment

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

Where:

HW_{lwr} = the energy drawn from the lower segment of the tank

HW_{total} = the total water demand for the hour in MJ.

Heatloss_{lwr} = Heat loss of the lower segment of the tank, from Equation 51.

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 (Equation 54).

Equation 54: Hot water energy drawn from upper segment

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

Where:

HW_{upp} = the energy drawn from the upper segment of the tank

HW_{total} = the total water demand for the hour in MJ.

When $Discharge_{signal}$ < 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.

Equation 55: Energy stored in the upper segment after heat loss and hot water use

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

Equation 56: Energy stored in the lower segment after heat loss and hot water use

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

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.

The corresponding temperatures in each segment T_{upp1} and T_{lwr1} after the hot water energy and heat losses have been subtracted are obtained from Equation 48 and Equation 49.

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 3 signals (flags) that must be set to allocate energy flows into the tank according to the relevant control logic.

$Charge_{lower}$ is a signal that indicates that the lower segment is at a lower temperature than the upper segment. If this value is 1 (meaning TRUE), then initially any available charge energy should be added to the lower segment. This signal is only used for types 1 and 2; it is ignored for type 3 systems.

Equation 57: Signal to heat the lower segment

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

$Grid_{signal}$ is a flag that indicates whether grid power is available for heating the water. 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 10 am and OFF at 3 pm) 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 1 am and OFF at 5 am) 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 continuously (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 PV 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 does not 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 used.
- Types 2 and 3: the controller monitors the house load and the local PV generation, and when excess PV is available for diversion to the water heater (PV generation > internal house load), 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). If 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 (Equation 58).

Equation 58: Excess energy available from PV generation in the period after losses

$$PV_{usable} = \text{MAX}\,(PV_{available} \times Mod_{Eff-PV} - Parasitic_{PV}, 0)$$

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 no excess PV is available, it sets PV_{usable} to 0. Parasitic losses are assumed to be 0 at all times when there is no excess PV in the current model. This may require adjustment if there was ongoing parasitic losses for some system types.

Charge logic and sequence for each of the 3 system types is set out below.

Types 1 and 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 available PV is present, then this is consumed (see limitations note). The element is only energised during the day.

For type 2 products, the $Grid_{signal}$ flag is set to 1 only when grid boost is available (nominally limited hours overnight). PV_{signal} is set to 1 when excess PV is available onsite. The system can modulate power, so all available PV can be diverted to the water heater (with temperature constraints).

If the $Charge_{lower}$ flag is 1, the overall strategy is to charge the lower segment up to the same temperature as the upper segment. If additional energy is 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 but different for type 2).

Charging rate is limited by the power input of the electrical element $E_{max-lwr}$. The energy input into the lower segment, $Q_{lwr2-PV}$, from the PV system is the minimum of the following 3 terms where the $Charge_{lower}$ flag is 1 and PV_{signal} is 1 (Equation 59).

Equation 59: Calculation of PV boosting of lower segment $Q_{lwr2-PV}$ (time step 2) (types 1 and 2)

$$Q_{lwr2-PV} = \text{MIN}(Term1, Term2, Term3)$$

Where:

$$Term1 = \left[\frac{(T_{upp1} - T_{lwr1}) \times C_p \times Vol_{lwr}}{1{,}000}\right]$$

$$Term2 = PV_{usable}$$

$$Term3 = E_{max-lwr} \times Mod_{Eff-PV} - Parasitic_{PV}.$$

The first term 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 accurate.

For example, if the element is ON for 10 minutes in the hour (for type 1, this can be only at the element rating because there is no modulation), then only the PV that is present for that 10-minute period should be counted as being diverted to the water heater. This is partly a limitation of a 1-hour time step, because this problem largely disappears at a 1-minute or even a 10-minute 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 an hour is assumed to be diverted to the water heater in a method that is the same for types 1 and 2 systems 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 diverted 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). $Q_{lwr3-PV}$ is the minimum of the following 3 terms when PV_{signal} = 1 (Equation 60 and Equation 61).

Equation 60: Calculation of PV boosting of lower segment $Q_{lwr3-PV}$ (time step 3) (types 1 and 2)

$$Q_{lwr3-PV} = \text{MIN}(Term1, Term2, Term3)$$

Where:

$$Term1 = Q_{lwrTpv} - Q_{lwr1} - Q_{lwr2-PV}$$

$$Term2 = (PV_{usable} - Q_{lwr2-PV}) \times (1 - Fraction_{upp})$$

$$Term3 = (E_{max-lwr} \times Mod_{Eff-PV} - Parasitic_{PV} - Q_{lwr2-PV}) \times (1 - Fraction_{upp}).$$

Equation 61: Calculation of PV boosting of upper segment $Q_{upp3-PV}$ (time step 3) (types 1 and 2)

$$Q_{upp3-PV} = \mathrm{MIN}(Term1, Term2, Term3)$$

Where:

$Term1 = Q_{uppTpv} - Q_{upp1}$

$Term2 = (PV_{usable} - Q_{lwr2-PV}) \times Fraction_{upp}$

$Term3 = (E_{max-lwr} \times Mod_{Eff-PV} - Parasitic_{PV} - Q_{lwr2-PV}) \times Fraction_{upp}.$

The first term gives the energy to heat the segment to its full capacity; the second term shares any remaining PV_{usable} (after allocation of $Q_{lwr2-PV}$) between segments; the third term sets a limit on the energy input. This limit is equal to the element rating (after control losses are taken into account).

There is no term $Q_{upp2-PV}$ for type 1 and 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.

If $Grid_{signal}$ and $Charge_{lower}$ flags are both 1, then $Q_{lwr2-grid}$ is the minimum of 3 terms (Equation 62).

Equation 62: Calculation of grid boosting of lower segment $Q_{lwr2-grid}$ (time step 2) (types 1 and 2)

$$Q_{lwr2-grid} = \mathrm{MIN}(Term1, Term2, Term3)$$

Where:

$$Term1 = \left[\frac{(T_{upp1} - T_{lwr1}) \times C_p \times Vol_{lwr}}{1{,}000}\right] - Q_{lwr2PV}$$

$Term2 = Q_{lwrTgrid} - Q_{lwr1} - Q_{lwr2-PV} \quad (\mathrm{IF}\ Term2 < 0\ \mathrm{THEN}\ Term2 = 0)$

$Term3 = E_{max-lwr} \times Mod_{Eff-grid} - Parasitic_{grid} - Q_{lwr2-PV}.$

The first term gives the energy needed to bring the temperature of the lower segment up to be equal to that of the upper segment (minus PV energy already diverted into the lower segment); the second term is the available heat stored if the lower segment is brought to a maximum temperature of T_{grid} (minus PV energy into the lower segment), the third term sets a limit on the energy input. This limit is equal to the element rating (after control losses are taken into account).

For grid boosting, the default assumption is that $Mod_{Eff-grid}$ = 98.7% and $Parasitic_{grid}$ = 0 (all system types).

After the bottom segment is topped up, both segments are charged with the remaining grid capacity for the hour while the $Grid_{signal}$ flag is 1 (Equation 63 and Equation 64).

Equation 63: Calculation of grid boosting of lower segment $Q_{lwr3\text{-}grid}$ (time step 3) (types 1 and 2)

$$Q_{lwr3-grid} = \mathrm{MIN}(Term1, Term2)$$

Where:

$$Term1 = Q_{lwrTgrid} - Q_{lwr1} - Q_{lwr2-PV} - Q_{lwr3-PV} - Q_{lwr2-grid} \ (\mathrm{IF}\ Term1 < 0\ \mathrm{THEN}\ Term1 = 0)$$

$$Term2 = \left(E_{max-lwr} \times Mod_{Eff-grid} - Parasitic_{grid} - Q_{lwr2-PV} - Q_{lwr3-PV} - Q_{upp3-PV} - Q_{lwr2-grid}\right) \times \left(1 - Fraction_{upp}\right).$$

Equation 64: Calculation of grid boosting of upper segment $Q_{upp3\text{-}grid}$ (time step 3) (types 1 and 2)

$$Q_{upp3-grid} = \mathrm{MIN}(Term1, Term2)$$

$$Term1 = Q_{uppTGrid} - Q_{upp1} - Q_{upp3-PV}$$

$$Term2 = (E_{max-lwr} \times Mod_{Eff-grid} - Parasitic_{grid} - Q_{lwr2-PV} - Q_{lwr3-PV} - Q_{upp3-PV} - Q_{lwr2-grid}) \times Fraction_{upp}$$

The first term gives the energy needed to heat the segment to its full 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) between segments.

There is no term $Q_{upp2\text{-}grid}$ for type 1 and 2 systems (i.e. this parameter is set to 0).

Type 1 systems only charge during the day, so typically receive a mix of any PV energy available when it happens to charge plus grid top-up energy. Type 2 systems send all available PV energy to the water heater during the day (within temperature limits) and top up from the grid overnight (when there is no PV available).

Type 3 charging

The charging approach for type 3 systems is completely different from that for types 1 and 2. There are 2 elements, so there is a lot more flexibility of operation and several different set-point temperatures. When there is any available excess PV energy, it is all diverted to the water heater (within temperature limits).

Firstly, the top segment is charged to temperature $T_{primary}$. Then the 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 to T_{PV} when excess PV energy is available. The unit can top up with grid energy whenever required. This only occurs where the top segment has a temperature of < 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. Because the logic and sequence are completely different from those used for type 1 and 2 systems, a different set of algorithms is required.

The energy input from the PV system into the upper segment to increase its temperature to $T_{primary}$ is $Q_{upp2\text{-}PV}$, and is the minimum of 3 terms when PV_{signal} = 1 (Equation 65)

Equation 65: Calculation of PV boosting of upper segment $Q_{upp2-PV}$ (time step 2) (type 3)

$$Q_{upp2-PV} = \text{MIN}(Term1, Term2, Term3)$$

Where:

$Term1 = \max\left(Q_{upp-Tprimary} - Q_{upp1}, 0\right)$

$Term2 = PV_{usable}$

$Term3 = E_{max-lwr} \times Mod_{Eff-PV} - Parasitic_{PV}.$

The first term gives the energy needed to bring the upper segment to a heat content equivalent to a temperature of $T_{primary}$; 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 from the PV system into the lower segment to increase its temperature to $T_{primary}$ is $Q_{lwr2-PV}$, and is the minimum of 3 terms, when PV_{signal} = 1 (Equation 66).

Equation 66: Calculation of PV boosting of upper segment $Q_{lwr2-PV}$ (time step 2) (type 3)

$$Q_{lwr2-PV} = \text{MIN}(Term1, Term2, Term3)$$

Where:

$Term1 = \max\left(Q_{lwr-Tprimary} - Q_{lwr1}, 0\right)$

$Term2 = PV_{usable} - Q_{upp2-PV}$

$Term3 = E_{max-lwr} \times Mod_{Eff-PV} - Parasitic_{PV}.$

The first term gives the energy needed to bring the lower segment to a heat content equivalent to a temperature of $T_{primary}$; the second term is limited by the available PV, minus energy already put into the lower segment; the third term sets a limit on the energy input. This limit is equal to the element rating (after control losses are taken into account).

The energy input from the PV system into the into the upper segment to increase its temperature to T_{PV} is $Q_{upp3-PV}$ and is the minimum of 3 terms, when PV_{signal} = 1 (Equation 67).

Equation 67: Calculation of PV boosting of upper segment $Q_{upp3-PV}$ (time step 3) (type 3)

$$Q_{upp3-PV} = \text{MIN}(Term1, Term2, Term3)$$

Where:

$Term1 = Q_{upp-Tpv} - Q_{upp1} - Q_{upp2-PV}$

$Term2 = PV_{usable} - Q_{upp2-PV} - Q_{lwr2-PV}$

$Term3 = E_{max-lwr} \times Mod_{Eff-PV} - Parasitic_{PV}.$

The first term gives the energy needed to bring the upper segment to a heat content equivalent to a temperature of 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. This limit is equal to the element rating (after control losses are taken into account).

The energy input from the PV system into the lower segment to increase its temperature to T_{PV} is $Q_{lwr3\text{-}PV}$ and is the minimum 3 terms, when PV_{signal} = 1 (Equation 68).

Equation 68: Calculation of PV boosting of upper segment $Q_{lwr3\text{-}PV}$ (time step 3) (type 3)

$$Q_{lwr3-PV} = \mathrm{MIN}(Term1, Term2, Term3)$$

Where:

$$Term1 = Q_{lwr-Tpv} - Q_{lwr1} - Q_{lwr2-PV}$$

$$Term2 = PV_{usable} - Q_{upp2-PV} - Q_{lwr2-PV} - Q_{upp3-PV}$$

$$Term3 = E_{max-lwr} \times Mod_{Eff-PV} - Parasitic_{PV}.$$

The first term gives the energy needed to bring the lower segment to a heat content equivalent to a temperature of 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. This limit is 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 $T_{upp1} < T_{grid}$ (nominally 47 °C). Grid boosting never flows into the lower segment for type 3.

$Q_{upp3\text{-}grid}$ is the minimum of the following 2 terms (Equation 69).

Equation 69: Calculation of grid boosting of upper segment $Q_{upp3\text{-}grid}$ (time step 3) (type 3)

$$Q_{upp3-grid} = \mathrm{MIN}(Term1, Term2)$$

Where:

$$Term1 = \max\left(Q_{uppTgrid} - Q_{upp1} - Q_{upp2-PV} - Q_{upp3-PV}, 0\right)$$

$$Term2 = E_{max-upp} \times Mod_{Eff-grid} - Parasitic_{grid} - Q_{upp2-PV} - Q_{lwr2-PV} - Q_{upp3-PV} - Q_{lwr3-PV}.$$

The first term gives the energy needed to bring the segment to a heat content equivalent to a temperature of T_{grid}; the second term shares any remaining electrical element capacity, $E_{max\text{-}upp}$, with the other segments (after allocation of all solar inputs). For type 3 systems, the terms $Q_{lwr2\text{-}grid}$ and $Q_{lwr3\text{-}grid}$ are set to 0.

For grid boosting, the default assumption is that $Mod_{Eff\text{-}grid}$ = 100% and $Parasitic_{grid}$ = 0 for all 3 system types. The term $Q_{upp2\text{-}grid}$ is not used for any system type.

Because there is an interlock that prevents both elements from operating simultaneously, the total energy input in an hour is limited by the rating of 1 element. If these upper and lower elements are of 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 0.

Heat capacity in the upper segment at the end of the hour is calculated using Equation 70.

Equation 70: Heat capacity in the upper segment at the end of the hour

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

Heat capacity in the lower segment at the end of the hour is calculated using Equation 71.

Equation 71: Heat capacity in the lower segment at the end of the hour

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

The temperatures of the upper and lower segments are calculated using Equation 48 and Equation 49. 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 that of 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)

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 method documented in section 3.4.5 for type 1 systems 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, just 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 in which the element cannot modulate its power to track excess PV energy in real time (i.e. when *Modulation* ≠ 1). For this correction, the only reasonable assumption about any power variation within an hour (assuming 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, total energy input into the tank from both excess PV and the grid is noted (for type 1 systems, $Grid_{signal}$ and PV_{signal} always have the flag set the same). This is adjusted using a correction factor, which is the total energy input for the hour divided by the rated capacity of the element; this is used to estimate a percentage run time during the hour (noting that if the energy input is equal to the element rating, then the correction factor is 1.0 – 100% – because the element is running for the whole 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 (see Table 57 for power ratings). This calculation is true if the modulation efficiency 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 ON time, as a percentage, would be calculated using Equation 72.

Equation 72: Calculation of element ON time (%) with modulation and parasitic control losses

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

$$Element\ ON\ (\%) = Element\ ON \times 100$$

For type 1 systems, $Q_{upp2-PV}$ and $Q_{upp2-grid}$ are set to 0, so are not shown in this equation.

When the modulating efficiency is 98.7% and the parasitic power is 0 (as is the case for grid/PV boosting for a type 1 system), then this simplifies to:

Equation 73: Calculation of element ON time (%) without modulation and parasitic control losses

$$Element\ ON = \frac{(Q_{lwr2-PV} + Q_{lwr3-PV} + Q_{upp3-PV})}{(E_{max-lwr} \times 0.987)} + \frac{(Q_{lwr2-grid} + Q_{lwr3-grid} + Q_{upp3-grid})}{(E_{max-lwr} \times 0.987)}$$

$$Element\ ON\ (\%) = Element\ ON \times 100$$

Limitation note: This calculation assumes that an upper element (where present) has the same power rating as the lower element. This equation would need adjustment if the upper and lower element have 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, where 3.9 − 2.5579 is a reduction of 1.3421 MJ of PV energy.

The reduced PV energy into the tank 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 if *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.

Equation 74: Corrected energy from PV system added to water heater

$$PV_{HW} = \left(Q_{lwr2-PV} + Q_{lwr3-PV} + Q_{upp3-PV}\right) \times Element\ ON$$

Where:

PV_{HW} = corrected amount of solar PV energy added to the water heater

Equation 75: Total energy added to water heater

$$Q_{added} = Q_{lwr2-PV} + Q_{lwr3-PV} + Q_{upp3-PV} + Q_{lwr2-grid} + Q_{lwr3-grid} + Q_{upp3-grid}$$

Equation 76 Required imports for PV diverter hot water system

$$Import = Q_{added} - PV_{HW}$$

Available export

As there are losses in diverting the PV into the water heater, evidenced by $PV_{available} > PV_{usable}$, the amount exported is not just the difference between the sum of the PV terms and either $PV_{available}$ or $PV_{usable.}$ If 100% of the usable PV is diverted into the hot water system, there is none available for export. However, if 50% of usable is diverted, this means 50% of what is *available* can be exported, as the efficiency of the water heater is not relevant for energy not being diverted into the water heater. Note that this simplifies the parasitic losses for hours where less than 100% of PV_{usable} is used by the water heater.

Equation 77 Electricity export available after PV diverter HWS accounted for

$$Export = \frac{PV_{Available} \times \left(1 - \frac{PV_{HW}}{PV_{Usable}}\right)}{3.6}$$

Where:

Export = Electrical energy available for export (or charging batteries) after water heater is accounted for (kWh)

$PV_{available}$ = PV available after all other household loads are met (MJ)

PV_{HW} = Sum of PV terms for water heater ($Q_{lwr2-PV}$, $Q_{lwr3-PV}$ etc.) (MJ)

PV_{usable} = Excess energy available from PV generation in the time period after losses (MJ)

Note that where $PV_{HW} = PV_{Usable}$, Export = 0.

Energy Balance implication

Homes that do not have a Type 1 solar PV diverter hot water system will only ever be importing *or* exporting electricity in a single hour.

Equation 76 and Equation 77 create a unique situation for the whole of home calculation in that the energy balance for the hour may have *both* imports and exports. These must be accounted for separately as the energy value for imports is different to exports. Not separating these means that there is no benefit for having systems that are able to modulate power and utilise more of the PV energy onsite.

3.9 Lighting module

This module calculates the annual energy used for lighting, and then assigns proportions of this to each hour of the year.

3.9.1 Annual load

The total annual energy consumption for lighting is defined by Equation 78.

Equation 78: Total lighting energy consumption

$$E_{tot} = \frac{P_L \times H_{avg} \times A_D \times 365 \times 3.6}{1{,}000}$$

Where:

E_{tot} = total annual energy load (MJ)

P_L = light power density (W/m^2) (Table 61)

H_{avg} = average hours use per day (hours) (Table 61)

A_D = area of dwelling (Table 61).

The figure of 365 is the number of days per year; 1,000 converts Wh to kWh and 3.6 converts kWh to MJ.

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 are defined in Table 61.

Table 61: Lighting constants

Variable	Value
P_L	5 W/m^2 (default, lower value selectable)
H_{avg}	1.6 hours[21]
A_D	Area of dwelling is defined as the sum of the floor areas of all zones, excluding the garage

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 more efficient lighting system, 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.

3.9.2 Hourly load

Not all lights are on at the same time, so the lighting load is distributed across the day. An average hourly use is 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 to allow tools to show demand, feed-in, and occupancy time cycles, and to allow the greatest flexibility when verifying any requirements that may be established for the NCC 2022. Table 62 shows the factors for the weighted average (all-day and work-day) schedule for each hour of the day across the months of the year, based on selected end-use metering data for lighting.

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[21] Value used for ABCB NCC 2022 analysis.

Table 62: Lighting hourly factor ($F_{L.hr}$) – weighted average schedule

Hour	Jan (%)	Feb (%)	Mar (%)	Apr (%)	May (%)	Jun (%)	Jul (%)	Aug (%)	Sep (%)	Oct (%)	Nov (%)	Dec (%)
1	0.005145	0.005923	0.005556	0.005954	0.005968	0.006380	0.005968	0.005762	0.005741	0.005350	0.005316	0.004939
2	0.002057	0.002370	0.002222	0.002382	0.002387	0.002552	0.002387	0.002304	0.002297	0.002140	0.002126	0.001975
3	0.002057	0.002370	0.002222	0.002382	0.002387	0.002552	0.002387	0.002304	0.002297	0.002140	0.002126	0.001975
4	0.002057	0.002370	0.002222	0.002382	0.002387	0.002552	0.002387	0.002304	0.002297	0.002140	0.002126	0.001975
5	0.002057	0.002370	0.002222	0.002382	0.002387	0.002552	0.002387	0.002304	0.002297	0.002140	0.002126	0.001975
6	0.004116	0.004739	0.004445	0.004763	0.004774	0.005103	0.004774	0.004609	0.004593	0.004280	0.004253	0.003951
7	0.008232	0.009478	0.008890	0.009527	0.009548	0.010207	0.009548	0.009219	0.009186	0.008561	0.008506	0.007902
8	0.008232	0.009478	0.008890	0.009527	0.009548	0.010207	0.009548	0.009219	0.009186	0.008561	0.008506	0.007902
9	0.004341	0.004999	0.004688	0.005024	0.005036	0.005383	0.005036	0.004862	0.004845	0.004515	0.004486	0.004167
10	0.002894	0.003332	0.003126	0.003349	0.003357	0.003589	0.003357	0.003241	0.003230	0.003010	0.002991	0.002779
11	0.002894	0.003332	0.003126	0.003349	0.003357	0.003589	0.003357	0.003241	0.003230	0.003010	0.002991	0.002779
12	0.002894	0.003332	0.003126	0.003349	0.003357	0.003589	0.003357	0.003241	0.003230	0.003010	0.002991	0.002779
13	0.002894	0.003332	0.003126	0.003349	0.003357	0.003589	0.003357	0.003241	0.003230	0.003010	0.002991	0.002779
14	0.002894	0.003332	0.003126	0.003349	0.003357	0.003589	0.003357	0.003241	0.003230	0.003010	0.002991	0.002779
15	0.002894	0.003332	0.003126	0.003349	0.003357	0.003589	0.003357	0.003241	0.003230	0.003010	0.002991	0.002779
16	0.002894	0.003332	0.003126	0.003349	0.003357	0.003589	0.003357	0.003241	0.003230	0.003010	0.002991	0.002779
17	0.012347	0.014217	0.013335	0.014289	0.014323	0.015310	0.014323	0.013829	0.013780	0.012841	0.012759	0.011853
18	0.020578	0.023695	0.022225	0.023816	0.023871	0.025517	0.023871	0.023048	0.022966	0.021402	0.021265	0.019755
19	0.030868	0.035542	0.033337	0.035724	0.035807	0.038276	0.035807	0.034572	0.034449	0.032103	0.031897	0.029633
20	0.036012	0.041465	0.038894	0.041678	0.041774	0.044655	0.041774	0.040334	0.040190	0.037453	0.037212	0.034572
21	0.032925	0.037911	0.035560	0.038106	0.038194	0.040828	0.038194	0.036877	0.036745	0.034243	0.034023	0.031609
22	0.026752	0.030803	0.028892	0.030961	0.031032	0.033172	0.031032	0.029962	0.029856	0.027822	0.027644	0.025682
23	0.020578	0.023695	0.022225	0.023816	0.023871	0.025517	0.023871	0.023048	0.022966	0.021402	0.021265	0.019755
24	0.010289	0.011847	0.011112	0.011908	0.011936	0.012759	0.011936	0.011524	0.011483	0.010701	0.010632	0.009878

Notes:

1. Nominal hour number is hour ending at the specified clock hour (refer to section 3.1 regarding hour notation).
2. The values in this table 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 100% over a 12-month period.

Hourly loads for lighting are calculated using Equation 79:

Equation 79: Hourly lighting energy consumption

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

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

Where:

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

E_{tot} = total annual energy load, defined by Equation 78 (MJ)

$F_{L.hr}$ = hourly load factor for hour of day in month, defined by Table 62.

3.10 Pool and spa equipment

Note 27 January 2023: The pool and spa module have been reviewed, producing Version "B" which is the preferred version. However to expedite accreditation, the old module (Version A) can be used for the NCC 2022 accreditation.

Version A is more conservative and likely to result in larger energy loads modelled and therefore lower ratings achieved.

Version B is the preferred module as it has been reviewed by pool and spa experts and industry representatives.

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

Version A

3.10.1 Version A – 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 80:

Equation 80: Pool volume

$$V_P = 1.5A_P \times 1{,}000$$

Where:

V_P = pool volume (L)

A_P = pool area (m^2).

Equation 80 shall form part of the NatHERS Technical Note and does not necessarily need to be implemented into software tools directly.

3.10.2 Version A – Base pump size

Base pump sizes are assumed to correlate with pool size. Base size, in kW, is defined by Equation 81.

Equation 81: Pool pump base size

$$Base\ Size\ (kW) = \frac{0.0598(V_P)^{0.9377}}{1{,}000}$$

3.10.3 Version A – Pump energy

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

Pump efficiency is based on the 2021 GEMS determination.

Pump type

Pool pumps are designated as either:

- single-speed
- dual-speed
- multispeed.

For the purposes of this calculation, variable-speed pumps are assumed to be the same as multispeed 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 82.

Equation 82: Pool pump operating power

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

Base size is defined using Equation 81.

Power adjustment factor is taken from Table 63.

Table 63: Power adjustment factor

Pump type	Power adjustment factor
Single-speed	1.000
Dual-speed	0.336
Multispeed	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 64.

Table 64: Assumed pump star ratings

Pump type	Star rating
Single-speed	2
Dual-speed	5
Multispeed	8

Energy factor

Having determined the star rating, a weighted energy factor in L/Wh is required to calibrate the star rating against the pump size using Equation 83 and Equation 84.

Equation 83: Pool pump weighted energy factor

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

Equation 84: Pool pump baseline efficiency

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

Where:

SR is the star rating

Base Size is obtained from Equation 81: Pool pump base size.

Flow rate

Average flow rate in L/h is calculated using Equation 85.

Equation 85: Pool pump flow rate

$$Flow\ Rate\left(\frac{L}{hr}\right) = WEF \times Operating\ Power \times 1{,}000$$

Run time

The time, in hours, required to cycle the pool once is calculated using Equation 86.

Equation 86: Pool pump turnover time

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

T_{Cyc} 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 the variable *Operating Power* (see Equation 82).

3.10.4 Version A – Hours of operation

Pool 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 65.

Table 65: Pool pump operating schedule

Cycles per day	ON time
1	8 am

Pump OFF time is defined by Equation 87.

Equation 87: Pool pump OFF time

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

If the pool cleaning is run by using the Main Pump then

3.10.5 Version A – Pool cleaning

Cleaning energy depends on filter and pump type (Table 66).

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

Table 66: Pool cleaning matrix

Pump	Pressure cleaner operated by main filtration pump (*Flow Rate* > 6,600 L/hr)	Pressure cleaner operated by main filtration pump (*Flow Rate* < 6,600 L/hr)	Pressure cleaner operated by booster pump	Robotic cleaner
Single-speed	No additional energy	No additional energy	$Power_{Clean}$ = 1 kW	$Power_{Clean}$ = 0.07 kW
Dual-speed	No additional energy	Use affinity law and Equation 89 to calculate cleaning power required for flow rate of 6,600 L/hr	$Power_{Clean}$ = 1 kW	$Power_{Clean}$ = 0.07 kW
Multispeed	No additional energy	Use affinity law and Equation 89 to calculate filter power required for flow rate of 6,600 L/hr	$Power_{Clean}$ = 1 kW	$Power_{Clean}$ = 0.07 kW

Cleaning Power uses the pump affinity law to calculate the power required to meet the minimum cleaning flow rate for mains filter pressure cleaners.

Equation 88: Affinity law

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

Cleaning power is defined using Equation 89.

Equation 89: Pool pump cleaning power

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

Where:

Operating Power is defined in Equation 82

$Flow_{Clean}$ = 6,600 L/hr

$Flow_{Operating}$ is *Flow Rate* (defined in Equation 85).

Cleaning time

The cleaner is assumed to run for 3 hours.

3.10.6 Version A – Cleaning energy

Cleaning energy is defined using Equation 90.

Equation 90: Pool pump cleaning energy

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

Cleaning ON time is the same as pump ON time, defined in Table 65.

Cleaner OFF time is defined by Equation 91.

Equation 91: Pool cleaner OFF time

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

Version B

The primary purpose of pool pumps is pool filtration and sanitisation. Pool pumps may also be used for pool heating, cleaning, and/or water features, but these are often either achieved:

- using the pool filtration pump while it is also filtering, and therefore their energy use is already included in the filtration pump energy use; or
- by a dedicated additional pump for short periods, in which case their annual energy use is often relatively small compared to that of the filtration pump.

3.10.7 Version B – Pool pump type and star rating

Pool pumps are typically classified as being either:

1) Single speed: The pump only operates at one motor speed (rpm), and the flow rate of the water is determined by the flow resistance of the pool system (pipework diameter, length, turns, equipment, valves, etc.);

2) Dual speed: The pump can be switched between two fixed motor speeds (rpm), and flow rate of the water for each speed (High or Low) is determined by the flow resistance of the pool system (pipework diameter, length, turns, equipment, valves, etc.);
3) Multi-speed: The pump can be switched between three or more fixed motor speeds (rpm), and flow rate of the water for each speed (Max, High, Low, etc.) is determined by the flow resistance of the pool system (pipework diameter, length, turns, equipment, valves, etc.); or
4) Variable speed: The motor speed (rpm) can be adjusted continuously, often for a number of settings, to adjust the flow rate of the water.

The type of a pool pump, and its ability to adjust speed (rpm of the motor) and flow rate (L/min of water), have a significant effect on their energy consumption. The affinity laws for pumps state that, for a constant impeller diameter, pump flow rate (Q) is proportional to pump speed (N), but pump power consumption (P) is proportional to the cube of pump speed, as shown in Equation 92 and Equation 93.

Equation 92: Pump Flow Rate Affinity Law

$$Q_2 / Q_1 = N_2 / N_1$$

Equation 93: Pump Power Consumption Affinity Law

$$P_2 / P_1 = (N_2 / N_1)^3$$

For dual, multi- and variable speed pumps, this means that if the pump speed (rpm) is reduced by a half or a third, then:

- The flow rate will also be reduced by a half or a third, and correspondingly the duration of pump operation needs to be increased by a factor 2 or 3 respectively; and
- the power consumption of the pump will be reduced by 1/8 or 1/27, so the energy used (taking the additional running time into consideration) will be 1/4 or 1/9 of that of the same size single speed pump.

The slower a multi- or variable speed pump is run, the more energy efficient it is, however, there are limitations:

- the pump must still turn over the pool's volume sufficiently every 24 hr to maintain water quality (which is dependent on ambient temperature, amount of pool usage, amount of debris, etc.);
- the pump must create a high enough flow rate to trigger any required flow switches in the pool system; and
- higher speed operation is required at times for back-flushing, cleaning and/or other tasks.

The GEMS Determination for pool pumps[22] assumes that:

- Single speed pumps run at their single speed 100% of the time.
- Dual speed pumps run at their low speed 80% of the time, and at their high speed 20% of the time.

[22] Greenhouse and Energy Minimum Standards (Swimming Pool Pump-units) Determination 2021, https://www.legislation.gov.au/Details/F2022L00025

- Multi- and variable speed pumps run at a low speed (>= 120 L/min) 80% of the time, and at a high speed (>= 80% max flow rate) 20% of the time.

Assuming, for multi- and variable speed pumps that their low speed is 30% of the maximum speed, and their high speed is 80% of their maximum speed (actual operating speeds will depend on the individual installation conditions), and that they operate 80% of the time at low speed and 20% of the time at high speed, this results in the following power and energy consumption reductions, and duration increase, as summarised in Table 67.

Table 67: Single, dual and multi-/variable speed pump power, energy and duration factors

	Single Speed	Dual Speed	Multi- and Variable Speed
Power Factor, F_{power}	1	0.3	0.124
Energy Factor, F_{energy}	1	0.4	0.2
Duration Factor, $F_{duration}$	1	1.8	2.92
"6 hr Duration"	6 hr	10.8 hr	17.5 hr

Variable speed pumps (including dual and multi-speed) are also available in a smaller set of sizes, due to the combined effects of a smaller market (30% of new pump sales), and that they can be adjusted to meet the requirements of the individual pool systems.

The assessor is required to specify the pool and pump features summarised in Table 68, which include the type of pool pump that will be installed (default is set to single speed), and optionally the minimum star rating that will be installed. Default star ratings are defined in Table 69. Only one of water average depth (default = 1.5m) or water volume needs to be specified, with the second being calculated using Equation 94.

Table 68: Assessor pool and pump specifications

Water surface area (m^2)	…
Water average depth (m) *OR* **Water volume (L)**	1.5 Water surface area x average depth x 1000
Pump type	Single-speed Dual speed OR

	Multi- or variable-speed
Pump star-rating	Single-speed = 1 Dual speed = 3 Multi-or variable-speed = 5

Table 69: Default Star Ratings

Pump type	Default star rating
Single speed	1
Dual speed	3
Multi- or variable speed	5

Equation 94: Pool and Spa Water Volume, Surface Area and Average Depth

$$V_p = A_P \times D_p \times 1000$$

Where:

V_P = Water volume of pool, Litres (L)

A_p = Surface area of pool, m^2

D_p = Average depth of pool, m. If unknown, apply average depth from Table 68.

3.10.8 Version B – Pool pump operating power and run time

The operating power and run time of the pump will be strongly dependent on the size of the pump which is installed, its star rating and the pool volume. For single speed pumps, where the pump speed (rpm) is not adjustable, the operating power is assumed to be equal to the nameplate input power (power factor = 1, from Table 67). For dual speed pumps, where the pump speed (rpm) can only be switched between two fixed values, the operating power is assumed to be equal to their power factor (0.3, from Table 67) multiplied by the nameplate input power.

Equation 95: Single and Dual-Speed Pump Operating Power

$$P_{operating} = \max\left(P_{nameplate} \times F_{power}, \frac{1.3 \times V_{Pool}}{12 \times WEF_{pump}}\right)$$

Where:

$P_{operating}$ = Assumed operating power of the pool pump

F_{Power} = Power Factor, defined in Table 67, by pump type

$P_{nameplate}$ = Nameplate Input Power in Watts, defined by Equation 96 for single speed pumps and Table 70 for dual speed pumps.

WEF_{pump} = Weighted Energy Factor for the pump, defined by Equation 99.

The second term in Equation 95 is to ensure that single- and dual speed pumps operate for a maximum of 12 hours during the peak of summer. It is arrived at by combining Equation 103 and Equation 104 and rearranging to solved for $P_{operating}$, using $RunTime_{filter}$ = 12 and $F_{seasonal}$ = 1.3. This provides the maximum $RunTime_{avg}$ allowable to ensure during summer, where pumps are run for longer, the pump only operates for 12 hours.

The size of single speed pool pump required for a pool system is generally based on pool volume, so that the entire volume of the pool is circulated through the filters to maintain pool water quality once per day[23], on average, for residential pools. General guidelines issued by manufacturers / retailers for the purposes of pool pump sizing are that this circulation occurs in a 6-8 hour period, however many of their websites refer customers to ask their pool professional for guidance.

There are likely to be seasonal variations, with higher ambient temperatures and increased pool usage (and corresponding sunscreen, oil and dirt loads from people) requiring more filtration in summer, and less in winter. It is therefore important that pool pumps are not sized based on a 24hr period to circulate the water, as they will have no additional to accommodate higher summer loads if required.

The Nameplate Input Power of individual pumps can vary widely within each nominal size category. For the purposes of the NatHERS assessment, a correlation has been developed between the water volume of the pool and spa system, and the Nameplate Input Power of a single speed pump, as defined by Equation 96.

Equation 96: Nameplate Input Power (W) as a function of Pool Volume (L) for Single Speed Pumps

$$P_{nameplate} = 220 + 0.019 \times V_{pool}$$

Where:

$P_{nameplate}$ = Nameplate Input Power in Watts

V_{pool} = water volume of the pool in Litres

Similarly, a table of values was developed to estimate the Nameplate Input Power of dual, multi and variable speed pumps, as a function of water volume, as defined in Table 70. The nominal size of a selected variable speed pump may be larger than that of a single speed pump to enable a larger reduction in pump speed (rpm) and correspondingly better energy savings.

Table 70: Variable (dual, multi and variable) Speed Pump Sizing and Nameplate Input Power by Pool Volume

Pool Volume, V (L)	Nominal Variable Speed Pump Size (Hp)	Variable Speed Nameplate Input Power (W)

[23] https://www.spasa.com.au/pool-and-spa-owners/faqs-tips-and-tricks/pool-energy-savings-techniques

V < 40,000	1	950
40,000 <= V < 60,000	1.5	1400
60,000 <= V < 80,000	2	1700
V >=80,000	3	2500

For multi- and variable speed pumps, the speed (rpm) of the pump is assumed to be adjusted to achieve the desired flow rate (L/min), based on pool volume. For the purposes of the NatHERS assessment it is assumed that the desired flow rate is one such that the entire pool volume is turned over in 6 hours.

The GEM Determination for pool pumps[24] defines the star rating of a pool pump based on its Nameplate Input Power and Weighted Energy Factor (WEF), which is a measure of the pump's efficiency. The star rating is defined by the star rating index (SRI) rounded down to the nearest 0.5 star between 1 and 6 stars, and rounded down to the nearest 1 star between 6 and 10 stars. The star rating index is defined below in Equation 97.

Equation 97: Star Rating Index

$$SRI = 1 + \left(\frac{\ln\left(\frac{WEF_{pump}}{WEF_{base}}\right)}{\ln 1.25} \right)$$

Where:

WEF_{pump} = the weighted energy factor of the pump tested (L/Wh)

WEF_{base} = the baseline WEF for a pump with the same Nameplate Input Power, from Equation 98

Equation 98: Baseline weighted energy factor

$$WEF_{base} = 13.5 - 4.5 \times \ln\left(\frac{P_{nameplate}}{1000}\right)$$

The WEF of a pump can therefore be estimated from its star rating, and its Nameplate input power, using Equation 99, and the average daily energy consumption (Wh) estimated using Equation 100, assuming that the entire water volume of the pool and spa system is turned over each day.

Equation 99: Weighted Energy Factor

$$WEF_{pump} = \left(13.5 - 4.5 \times \ln\left(\frac{P_{nameplate}}{1000}\right)\right) \times e^{\ln(1.25) \times SR - 1}$$

Where:

$P_{nameplate}$ = Nameplate Input Power (W) from Equation 96

[24] Greenhouse and Energy Minimum Standards (Swimming Pool Pump-units) Determination 2021, https://www.legislation.gov.au/Details/F2022L00025

SR = Star rating of the pool pump

Equation 100: Pump Average Daily Energy Consumption

$$E_{pump.daily} = \frac{V_{pool}}{1000 \times WEF_{pump}}$$

The operating power of a multi-/variable speed pump can then be estimated by dividing the pump average daily energy consumption by the desired run time (6h), as shown in Equation 101.

Equation 101: Multi-/Variable Speed Pump Operating Power

$$P_{operating} = \frac{E_{pump.daily} \times 1000}{RunTime_{avg}}$$

Where:

$P_{operation}$ = Pump operating power in Watts (W)

$RunTime_{avg}$ = Time required to turn over the whole pool volume once in hours (h). Assumed to be 6 hours for multi- and variable speed pumps.

Combining Equation 100 and Equation 101, we can obtain Equation 102.

Equation 102: Multi-/Variable Speed Pump Operating Power

$$P_{operating} = \frac{V_{pool}}{WEF_{pump} \times RunTime_{avg}}$$

For single and dual speed pumps the time it will take them to turn over the whole pool volume once can be calculated using Equation 103.

Equation 103: Single and Dual-Speed Pump Run Time

$$RunTime_{avg} = \frac{V_{pool}}{WEF_{pump} \times P_{operating}}$$

For all pumps, any improvement in star rating may be reflected in either a reduced operating power and/or reduced run time. For the purposes of the NatHERS assessment it is assumed for single and dual speed pumps that improvements in star rating are reflected in run time, maintaining the more conservative value of power consumption. For multi-/variable speed pumps improvements in star rating will be reflected in the operating power, maintaining the assumed run time of 6 hours.

3.10.9 Version B – Pool pump daily operating schedule

For single speed pumps, with their increased noise levels compared to variable speed pumps, pool pump operation is most likely to be scheduled during the day. Timers are often used to enable people to manage the times at which their pool pump runs, in addition to manually turning them on when they are swimming, and can be used to align with solar PV electricity generation and/or off-peak tariffs where available, provided the pumps do not cause noise concerns overnight.

Previously completed pool pump market research (2016)[25] indicated that:

- pumps were most commonly run for 7-8 hours a day during summer (24%);
- the mean duration during summer was 5.6 hr a day;
- pumps were most commonly run for 3-4 hours a day during autumn (29%);
- the mean duration during autumn was 4.1 hr a day;
- pumps were most commonly run for 1-2 hours a day during winter (34%), but one in five ran their pumps for 5 or more hours in winter (20%);
- the mean duration during winter was 3.5 hr a day.

For the purposes of NatHERS, an hourly operation schedule is important in determining how the pump power consumption will interact with PV generation.

In developing a default pool pump operation schedule it is assumed that:

- Pool pumps run for approximately twice as long during summer peak as for winter low;
- Average pool pump operation corresponds to turning over the entire pool volume once per day;
- 1.3 times the pool volume is turned over each day during summer; 1 time during autumn and spring; and 0.65 times during winter.
- Pool pump operation is centred on 1 pm to align with PV generation and the warmer times of the day; and
- Pool pump operation does not occur between 7 PM and 7 AM due to noise concerns.

The pump is assumed to be controlled by a simple timer, with the daily filtration time being defined by Equation 104.

Equation 104: Daily filtration time

$$RunTime_{filter} = RunTime_{avg} \times F_{seasonal}$$

Where:

$RunTime_{filter}$ = time pump is estimated to run each day to effectively operate the filter, in hours (h)

$F_{seasonal}$ = Seasonal factor to account for longer or shorter operation time across the year, from Table 71.

$RunTime_{avg}$ = Time required to turn over pool volume once, in hours. For Single and dual speed pumps use Equation 103, for variable and multi-speed pumps use 6 hours.

[25] *Pool Pumps: An Investigation of Swimming Pool Pumps in Australia and New Zealand,* Woolcott Research & Engagement, Department of the Environment and Energy, August 2016 https://www.energyrating.gov.au/sites/default/files/documents/2016-Pool-Pump-Market-Research-Report_0.pdf

Table 71: Seasonal factor for pool pump run time

Month	Seasonal Factor, Fseasonal
Jan	1.3
Feb	1.3
Mar	1
Apr	1
May	1
Jun	0.65
Jul	0.65
Aug	0.65
Sep	1
Oct	1
Nov	1
Dec	1.3

If heating or heat-up (see Table 71: Seasonal factor for pool pump run time) is required over a longer period than filtration, the pump will need to run for this additional time to circulate water through the heater. The pump run time is then defined by the maximum of the daily filtration time and the pool heater run time, rounded up to the next hour, as described in Equation 105.

Equation 105: Pump Run Time

$$RunTime_{daily} = \max\left(RunTime_{filter}, RunTime_{heater}\right)$$

Where:

$RunTime_{daily}$ = time pump is assumed to run for the given day in hours (h), rounded up to the next whole number.

$RunTime_{heater}$ = time required by the pool heating system for the day, method under development.

If there is no pool heating, then $RunTime_{heater}$ = 0.

The pool pump hourly operation schedule can then with the pump turn on-time defined by Equation 106 and the pump turn-off time defined by Equation 107. The

Equation 106: Pump turn-on time

$$Pump\ On\ Hour = 14 - \frac{RunTime_{daily}}{2}$$

Where:

Pump on hour = Hour of the schedule where the pump is turned on, rounded down to the next whole number. Note the Hour 14 designation means the schedule is centred around 13:00

Equation 107: Pump turn-off time

$$Pump\ Final\ Hour = Pump\ On\ Hour + \ RunTime_{daily} - 1$$

Where:

Pump Final Hour = Last hour of the day where the pump operates, rounded down to the next whole number.

Application of Equation 106 and Equation 107 are inclusive. Note that if $RunTime_{daily}$ is a whole number the time the pool operates based on Equation 106 and Equation 107 will be 1 hour longer than expected. This is an edge case, $RunTime_{daily}$ will not be a whole number in almost all cases.

Pump timing example

Let:

$Runtime_{avg}$ = 6 hours

Month = Jan, therefore $F_{seasonal}$ = 1.3

$$\begin{aligned} RunTime_{filter} &= 6 \times 1.3 \\ &= 7.8 \\ &= 8\ (rounded\ up\ to\ next\ whole\ number) \end{aligned}$$

$$\begin{aligned} Pump\ On\ Hour &= 14 - \frac{8}{2} \\ &= 14 - 4 \\ &= 10 \end{aligned}$$

$$\begin{aligned} Pump\ Final\ Hour &= 10 + \ 8 - 1 \\ &= 17 \end{aligned}$$

In this example, the pump comes on at the start of the 10th hour of the day (9:00 am) and turns off at the end of the 17th hour (5:00 pm).

3.10.10 Version B – Pool pump energy consumption

The pump is then assumed to consume electricity at its operating power, as defined by Equation 95 for single or dual speed pumps and Equation 102 for multi-/variable speed pumps, for each hour that it is ON. Note that these equations present power in W.

3.11 Onsite energy generation

3.11.1 Overview

Onsite generation is currently limited to solar PV systems. This may be expanded to cover other forms of generation.

Calculation of the hourly available electrical supply from a PV installation follows several steps:

1. Calculate the theoretical hourly output from the PV panels (see section 3.11.2), taking into account
   a. location and 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 3.11.3).
3. Account for expected system losses (see section 3.11.4), including those related to
   a. ambient temperature
   b. soiling
   c. direct current (DC) wiring-related losses
   d. conversion.
4. Account for limitations imposed by the rated capacity of the installed inverter (see section 3.11.5) and its connection to the grid.

From these 4 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 onsite consumption from any electrical end-use, including any plug loads (but generally excluding usage by any equipment connected as a controlled load – such as off-peak water heating – unless the energisation period is activated during PV generation).

Any PV generation that is surplus to onsite requirements is then assumed to be delivered to an onsite battery, if one is installed, up to the battery storage limit (see section 3.12 for details for how this is accounted for in the calculations), and/or a PV diverter in a water heater, if present. If there is no onsite battery or PV diverter in a water heater, or if the surplus generation exceeds the capacity of the onsite battery 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 3.11.6).

A residential PV system may be divided into 2 or more arrays (for example, 1 array may be located on the east side of a gable roof running north–south and 1 on the west side). The PV arrays may have different orientations and slopes and be subject to different overshadowing effects. Consequently, where a residential PV system is installed across several locations on a roof, each array must be treated separately when calculating PV output. The hourly results for each array must then be combined to give a total hourly electrical production. If multiple arrays have the same orientation and slope and are not subject to any overshadowing, then they may be treated as a single system when calculating PV output.

The following subsections detail the calculation methods for each of the steps noted above.

3.11.2 Solar PV panel output calculation

Solar PV panel output calculations rely on the:

- geographic location of the dwelling
- amount of solar radiation present in the climate file
- angle and orientation of the panels.

Solar PV calculations are based on the Hay, Davies, Klucher, Reindl model laid out in *Solar engineering of thermal processes, 4th ed.*[26] Additional corrections for ensuring valid estimates are made based on information provided by CSIRO.

Unless otherwise specified, all angles are expressed in radians. For software, relevant user inputs should be made in degrees and then converted to radians using Equation 108, or a similar in-built function.

Equation 108: 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 uses a number of constant factors, or information taken from user inputs from the thermal shell:

T_{zn} – GMT timezone; derived from the postcode using the postcode list (part of existing NatHERS thermal documentation)

Φ – latitude of dwelling; derived from the postcode using the postcode list (part of existing NatHERS thermal documentation)

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

G_{SC} – solar constant; 1,367 (kW/m^2)

ρ_g – ground reflectance; 0.2

F_d – derating factor; 1.0.

The derating factor was used in an earlier version of the calculation method but has been replaced by specific derating calculations for losses, impacts of shading and so on. It is retained but fixed at 1.

User-defined values

The solar PV module uses several inputs from the user to describe the specifics of the solar PV system:

B – slope of solar panel (from horizontal)

γ_n – azimuth of solar panel (from north)

P_s – size of the solar array (kW)

NP – the number of phases across which the PV array is to be connected (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

[26] Duffie JA & Beckman WA (2013). Solar engineering of thermal processes, 4th edn, John Wiley & Sons, Hoboken, NJ.

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.

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 < 0.75 × P_s, then the system must issue a warning; for example, 'The inverter should be at least 75% of the capacity of the solar array – please check'.

Note 2: If EL_{pv} > NP × 5 and NP = 1, disallow this EL_{pv} value with the error, 'Single-phase installation cannot be greater than 5 kW'. If EL_{pv} > NP × 5 and NP = 2 or 3, then issue a warning, 'The PV export limit typically does not exceed 5 kW per phase – please check'.

Solar Panel Azimuth Correction

The reference book used, *Solar engineering of thermal processes*, is written for a northern hemisphere application, and assumes the azimuth of 0^0 faces toward the equator, i.e. south. Application to NatHERS therefore needs an adjustment to align with the azimuth provided on building plans. This is done using Equation 109:

Equation 109 Correction of solar panel azimuth

$$\gamma = \begin{cases} \gamma_n - 180, \gamma_n > 180 \\ \gamma_n + 180, \gamma_n \leq 180 \end{cases}$$

Where:

γ_n = azimuth of solar panel (from north) entered by user, in degrees

γ = Corrected azimuth of solar panel for use in this module, in degrees

Note that some values of γ may exceed 360^0. Since γ is applied as part of a trigonometric function (i.e. cos(γ) and sin(γ)), this does not influence the result (cos(90) = cos(450) = cos(810) etc.).

For use in the following equations, γ will need to be converted to Radians using Equation 108.

Solar time

Adjustments are made to correct for the distance between the dwelling and the weather station. Solar time, T_{Sol}, is calculated for each hour using Equation 110. Note that T_{Sol} should remain as a decimal, and not be converted to hours and minutes.

Equation 110: 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 111

L_{col} is defined by Equation 112

E is defined by Equation 113.

Equation 111: Calculation of L_{st}

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

Where T_{zn} is GMT timezone.

Equation 112: Calculation of L_{col}

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

Where L_{Loc} is longitude of the dwelling location.

Equation 113: 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 114.

Equation 114: Earth-to-Sun distance factor

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

Where:

B = Earth-to-Sun distance factor (radians)

n = day of year (1 Jan = 1, 2 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 Earth's rotational axis and is calculated for each day using Equation 115.

Equation 115: 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 (radians)

n = day of year (1 Jan = 1, 2 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 decimals, and not be converted to hours and minutes. Time of sunrise is calculated for each day using Equation 116.

Equation 116: 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 (hours)

δ = declination angle (radians)

Φ = latitude of dwelling (radians).

Time of sunset is calculated for each day using Equation 117.

Equation 117: 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 (hours)

δ = declination angle (radians)

Φ = latitude of dwelling (radians).

Hour angle

The hour angle gives the position of the Sun, east–west, compared to the local meridian. Morning values are negative, afternoon values are positive. It is calculated for each hour of the day. For some purposes, it is more appropriate to use the hour angle at the midpoint of the hour, rather than at the start.

Hour angle at the start of the hour is calculated using Equation 118.

Equation 118: Sun hour angle – start of hour

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

Where:

ω = hour angle (radians)

T_{sol} = solar time (hours).

Hour angle for the midpoint of the hour is calculated using Equation 119.

Equation 119: Sun hour angle – midpoint 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 (radian)

T_{sol} = solar time (hours).

Ratio of beam radiation

Solar radiation in the weather files is for horizontal surfaces. R_b is a geometric factor related to 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 120 and Equation 121.

Equation 120: Permitted range for ratio of beam radiation

$$0 \leq R_b \leq 40$$

Equation 121: Ratio of beam radiation

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

Where:

R_b = ratio of beam radiation from horizontal to tilted plane

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

$\cos\theta_z$ = 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, they are only relevant when the Sun is above the horizon. Equation 122 defines cos θ. Cos θ is calculated for each hour of the day.

Equation 122: Angle of the Sun above the horizon

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

Where:

δ = declination angle (radians)

Φ = latitude of dwelling (radians)

β = slope of solar panel (radians)

γ = azimuth of solar panel (radians)

ω_{mid} = hour angle for middle of the hour (radians)

T_{sol} = solar time

T_{rise} = time of sunrise (hours)

T_{set} = time of sunset (hours).

θ_z is the angle between a vertical line and the line to the Sun. When θ_z = 0°, the Sun is directly above the panels. When θ_z = 90°, the Sun is level with the panels on the horizontal plane. θ_z must be between 0° and 90°. This is tested by calculating cos $\theta_{z.i}$ using Equation 123, and then rearranging to solve for θ_z using Equation 124. The value of cos θ_z to be used in Equation 121 is then defined using Equation 125.

Equation 123: 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 (radians)

Φ = latitude of dwelling (radians)

ω_{mid} = hour angle for middle of the hour (radians).

Equation 124: Sun zenith angle

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

Equation 125: Cosine of the Sun zenith angle

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

Where θ_z is the Sun zenith angle and is expressed in degrees.

Extraterrestrial radiation

Extraterrestrial radiation on a horizontal surface is calculated using Equation 126 and Equation 127.

Equation 126: Extraterrestrial radiation on a horizontal surface

$$I_o \ge 0$$

Equation 127: 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 (Wh)

G_{sc} = global solar constant

n = day of year number

Φ = latitude of dwelling (radians)

δ = declination angle (radians)

ω_1 = hour angle (radians) at start of hour

ω_2 = hour angle (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 128. Note that, by definition, beam radiation requires line-of-sight from the Sun to the panel; so I_b is only > 0 between sunrise and sunset.

Equation 128: Beam portion of solar radiation

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

Where:

I_b = beam portion of solar radiation (W/m^2)

I_H = total solar radiation measured on the horizontal plane (W/m^2)

I_{dif} = Diffuse portion of solar radiation (W/m^2)

T_{sol} = solar time (hours)

T_{rise} = time of sunrise (hours)

T_{set} = time of sunset (hours).

Important note: The beam portion of the solar radiation is set equal to 0 if the PV array is shaded in that hour.

Anisotropy index

The anisotropy index, A_i, accounts for diffuse elements of extraterrestrial solar radiation on the tilted surface. It determines the part of the extraterrestrial diffuse radiation that should be treated as beam radiation. A_i is calculated using Equation 129.

Equation 129: 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 (kW/m^2)

I_o = extraterrestrial radiation (kW/m^2).

Total available solar radiation

Total available solar radiation on the PV panel is defined using Equation 130 and corrected using Equation 132.Total available solar radiation cannot be > G_{sc}. Values > G_{sc} only occur when the hour angle is very small – which inflates R_b and A_i – and should be ignored.

Equation 130: 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 (kW/m^2)

I_b = beam portion of solar radiation (kW/m^2)

I_{dif} = diffuse portion of solar radiation (kW/m^2)

I_H = total solar radiation measured on the horizontal plane (kW/m^2)

A_i = anisotropy index

R_b = ratio of beam radiation from horizontal to tilted plane

β = slope of solar panel (radians)

ρ_g = ground reflectance

f = modulating factor, calculated using Equation 131.

Equation 131: Modulating factor

$$f = \begin{cases} \sqrt{\frac{I_b}{I_H}}, I_H > 0 \\ 0, I_H \leq 0 \end{cases}$$

Equation 132: Realistic solar radiation on the solar PV panel

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

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 using Equation 133 and Equation 134.

Equation 133: Valid range for electricity generated by the solar panel

$$E_{Sol} \geq 0$$

Equation 134: Electricity generated by the solar panel

$$E_{sol} = \frac{I_T \times F_d \times P_s}{1{,}000}$$

Where:

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

I_T = realistic solar radiation on the solar PV panel (W/m^2)

F_d = derating factor

P_s = size of the solar array (kW).

3.11.3 Shading losses

Shading losses are not considered at this time. This will be reviewed in the future.

3.11.4 PV system losses

System losses include losses related to:

- ambient temperature
- soiling
- DC wiring
- conversion.

Total system losses are calculated using Equation 135.

Equation 135: 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 using Equation 136.

Equation 136: Ambient temperature-related PV losses

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

Where:

L_A = ambient temperature-related losses (%)

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

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

Note that in Equation 135, L_A is expressed on a scale of 0 to 1, while in Equation 136 it is expressed as a percentage.

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 it).

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 it).

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 it).

The system loss calculation should be applied to the hourly PV panel generation calculation (Equation 134) to derive the derated hourly PV panel generation by using Equation 137.

Equation 137: 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 (kWh)

E_{sol} = electricity generated by the solar panel before system losses for 1 hour (kWh) – see Equation 134

L_{TOT} = total PV system loss factor – see Equation 135.

3.11.5 Inverter limitations on available PV-generated electricity

While Equation 137 gives the derated output of the solar PV array for each hour of the year, this output must then be limited to the capacity of the associated inverter (Equation 138).

Equation 138: Electricity generated by the solar PV system with external constraints

$$E_{solD} \leq C_i$$

Where:

E_{solD} = Electricity generated by the solar panel for 1 hour (kWh)

C_i = total capacity of all installed inverters (kW).

3.11.6 Network limitations on export of PV-generated electricity

For each hour of the year, any solar PV generation that 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}) (Equation 139).

Equation 139: Maximum electricity that can be exported to the network

$$E_n \leq EL_{pv}$$

Where:

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

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

3.12 Battery storage

3.12.1 Overview

When 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).

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 use 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 onsite demand exceeds available supply from a PV system, 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).

3.12.2 Required inputs and default values

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

- Battery technology type – see Table 72 for various options
- B_{NC} = battery nominal storage capacity (kWh)
- B_{DD} = maximum depth of discharge – as a percentage of the nominal capacity of the battery; for example, if the battery is rated at 10 kWh and B_{DD} = 90%, then the usable capacity is 9.0 kWh
- B_{CE} = charge efficiency (%) – when charging, only B_{CE}% of the input energy is actually stored in the battery; the rest is lost from the system
- B_{DE} = discharge efficiency (%) – when discharging, only B_{DE}% of the energy discharged is in the form of available electrical power; the rest is lost from the system
- B_{CR} = battery C-rate – this is the maximum proportion of the battery's rated capacity that can be charged or discharged within 1 hour. This effectively limits the capacity of the battery to accept a charge or meet high hourly loads. Any shortfall is made up with imports from the grid. The charge and discharge C-rates are assumed to be the same.

Default values (all of which can be overridden by users) are provided in Table 72.

Table 72: 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	50	0.2	89.5	89.5	80	50
Zinc-bromine	100	0.25	87	87	75	50

Note: Lead-acid, zinc-bromine (and vanadium redox) batteries do not behave the same as lithium-ion batteries.

3.12.3 Calculation method

If a battery is present, then hourly energy accounting is required for:

- 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 onsite 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 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 dwelling's electrical load in that hour (E_{tot}), then the excess generation is stored in the battery (minus losses) until battery capacity is reached, after which any excess is exported to the grid (at the feed-in tariff rate). The capacity for a battery to accept charge in any given hour is limited by the battery's state of charge at that time and its C-rate (see next section 'Rules for battery operations (limitations)').
- **A deficit of electricity:** If, in a given hour, the output from the PV module is less than the dwelling's electrical load in that hour, then stored electricity from the battery (minus 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 by the maximum discharge rate of the battery (limited by its C-rate). Any shortfall in the battery's capacity to meet the load for that hour is made up by electricity imported from the grid.
- **Solar PV diverter hot water:** If a solar PV diverter water heater is included as part of the assessment, the water heater is charged first, then the battery is charged if there is still solar PV excess (i.e. the load required for the solar diverter water heater is considered as part of E_{tot}).

Rules for battery operation (limitations)

Equation 140: Rules for battery operation

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

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

$B_{CHARGE\text{-}EXT}$ 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 ≤ $B_{NC} \times B_{CR}$

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

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

$B_{DISCHARGE\text{-}BATT}$ must be ≤ $B_{NC} \times B_{CR}$

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

$B_{DISCHARGE\text{-}EXT}$ must be ≤ $B_{NC} \times B_{CR} \times B_{DE}$

Charging accounting

Equation 141: Rules for battery charge accounting

IF $(B_{NC} - B_{START}) / B_{CE} > B_{NC} \times B_{CR} / B_{CE}$ THEN

$B_{CHARGE\text{-}EXTMAX} = B_{NC} \times B_{CR} / B_{CE}$

ELSE

$B_{CHARGE\text{-}EXTMAX} = (B_{NC} - B_{START}) / B_{CE}$

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

$B_{CHARGE\text{-}BATT} = B_{CHARGE\text{-}EXTMAX} \times B_{CE}$ AND $PV_{EXPORT} = B_{PV} - B_{CHARGE\text{-}EXTMAX}$ (IF $PV_{EXPORT} < 0$ THEN $PV_{EXPORT} = 0$)

ELSE

$B_{CHARGE\text{-}BATT} = B_{PV} \times B_{CE}$

Discharging accounting

Equation 142: Rules for battery discharge accounting

IF $(B_{START} - B_{NC} \times (1 - B_{DD})) > B_{NC} \times B_{CR}$ THEN

$B_{DISCHARGE\text{-}EXTMAX} = B_{NC} \times B_{CR} \times B_{DE}$

ELSE

$B_{DISCHARGE\text{-}EXTMAX} = (B_{START} - B_{NC} \times (1 - B_{DD})) \times B_{DE}$

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

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

ELSE

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

Time step accounting

Equation 143: Rules for battery time step accounting

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

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

ELSE

$B_{END} = B_{START}$

At time step N, $B_{START\ (N)} = B_{END\ (N\text{-}1)}$

Where:

B_{START} = total energy in the battery at the start 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} = 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} = PV energy delivered to the grid (note network limits must be applied; i.e. IF $PV_{EXPORT} > C_i$ THEN $PV_{EXPORT} = C_i$)

$B_{DISCHARGE\text{-}EXTMAX}$ = 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 for B_{ED} but allowing for supply by any batteries

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

3.13 Plug loads and cooking loads

3.13.1 Annual loads

The assumed annual plug loads have been based on work undertaken previously for Sustainability Victoria and the ABCB. From this work, annual average total plug loads, cooktop loads (assumed to be gas) and oven loads (assumed to be electric) per number of occupants were derived. These are shown in Table 73. Linear regression was then used to determine the relevant factors (see Figure 4, Figure 5 and Figure 6).

Table 73: Annual plug load and cooking load by number of occupants

Number of occupants	Annual plug load, E_{PLUG} (MJ)	Annual cooktop load – gas, $E_{COOKTOP}$ (MJ)	Annual cooktop load – electric, $E_{COOKTOP}$ (MJ)	Annual cooktop load – induction, $E_{COOKTOP}$ (MJ)	Annual oven load – electric, E_{OVEN} (MJ)	Annual oven load – gas, E_{OVEN} (MJ)
1	7,441	1,067	691	475	569	1,133
2	7,899	1,333	864	594	711	1,417
3	8,353	1,600	1,037	713	853	1,700
4	8,801	1,867	1,210	832	995	1,983
5	9,245	2,133	1,382	950	1,138	2,267
6	9,686	2,400	1,555	1,069	1,280	2,550

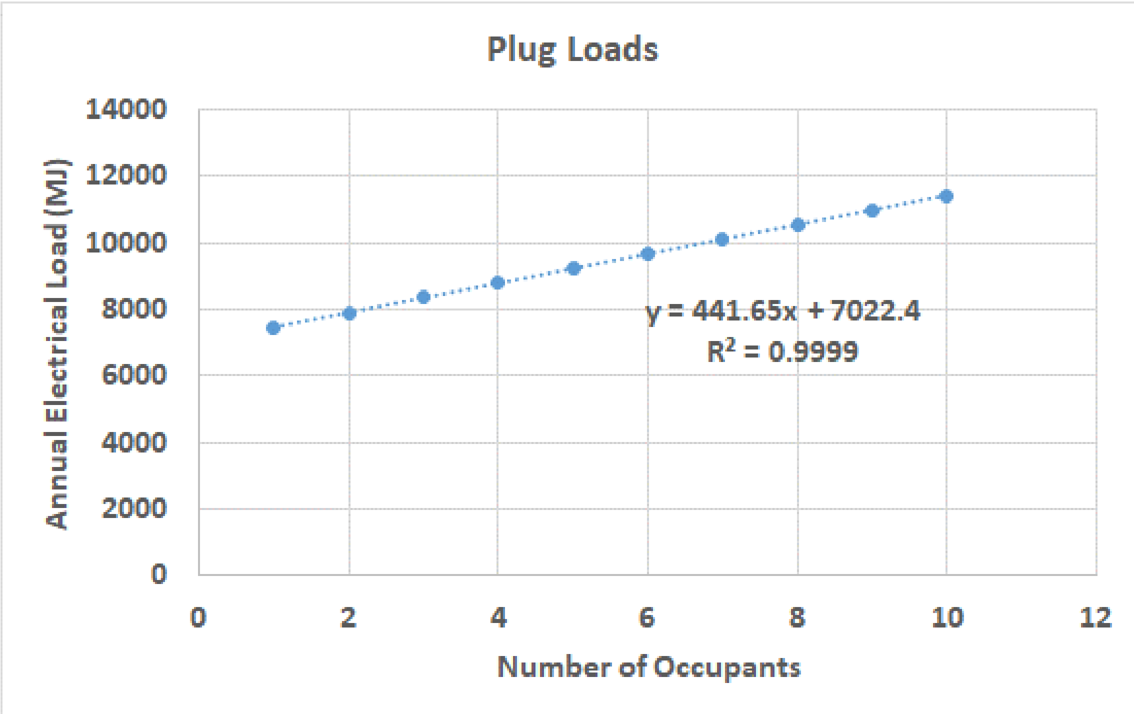

Figure 4: Annual plug loads by number of occupants

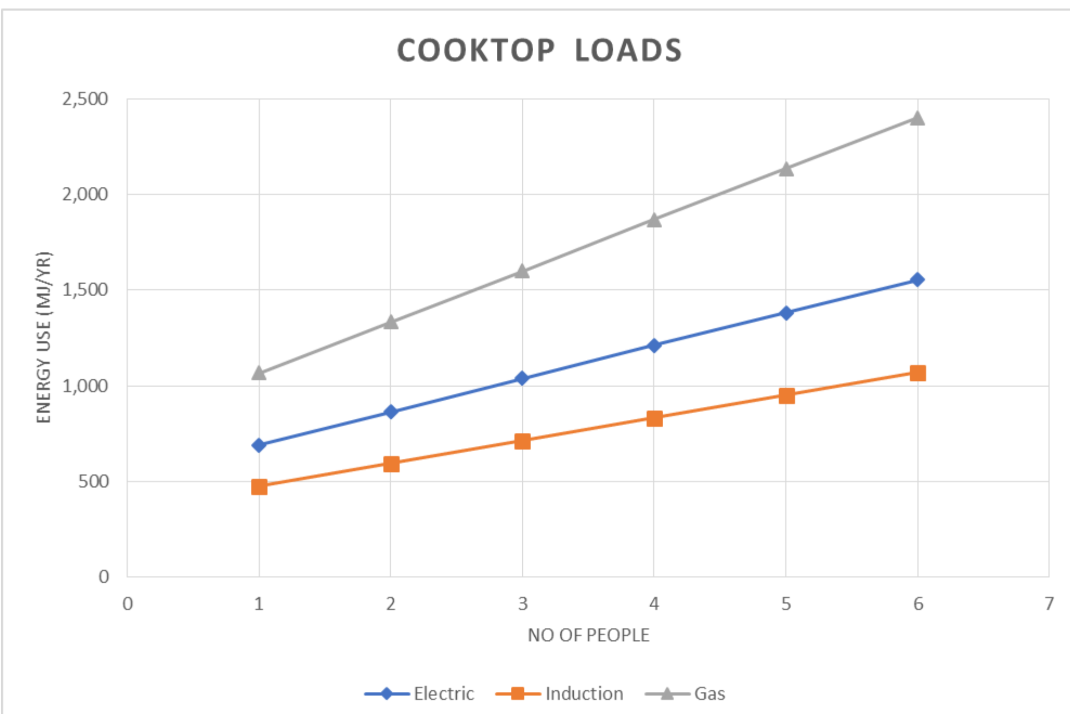

Figure 5: Annual cooktop loads by number of occupants

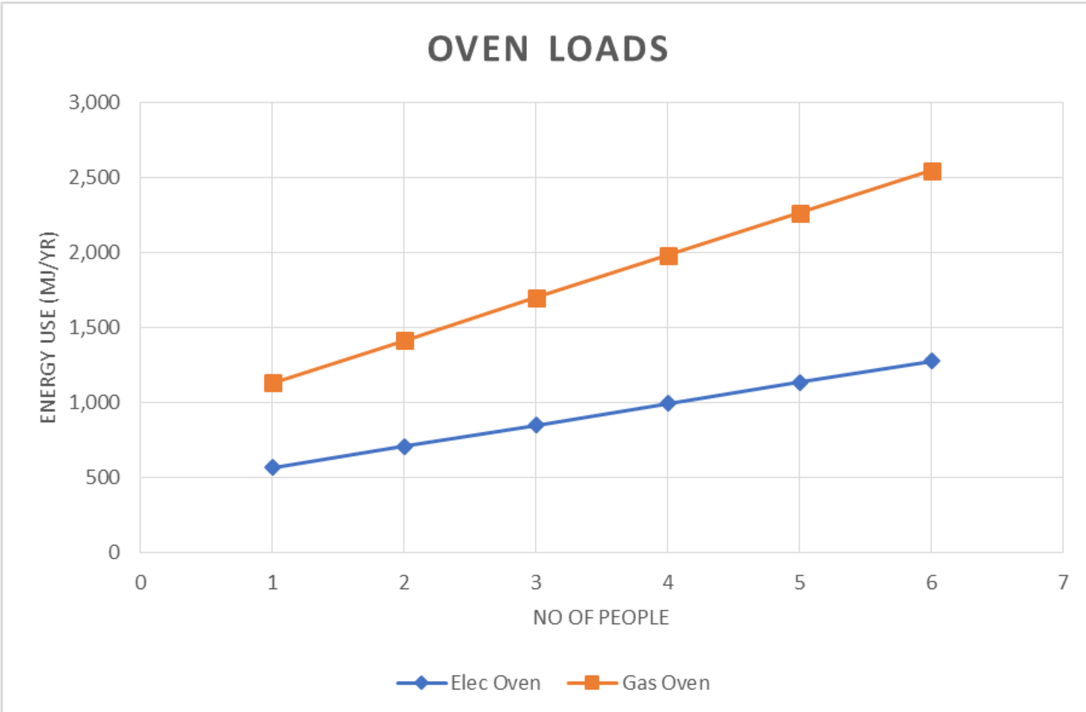

Figure 6: Annual oven loads by number of occupants

Plug loads

Annual plug loads are calculated using Equation 144.

Equation 144: Appliance annual plug loads as a function of occupants

$$E_{PLUG} = 7{,}022.4 + (N_{OCC} \times 441.65)$$

Where:

E_{PLUG} = total annual plug energy load (MJ/year)

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

Cooktop loads

Annual cooktop loads are calculated using Equation 145.

Equation 145: Cooktop annual loads as a function of occupants

$$E_{Cooktop} = C_c + (N_{Occ} \times F_c)$$

Where:

$E_{COOKTOP}$ = total annual cooktop energy load (MJ/year)

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

C_c = cooktop constant from Table 74 for relevant cooktop type

F_c = cooktop factor from Table 74 for relevant cooktop type.

Oven loads

Annual oven loads are calculated using Equation 146.

Equation 146: Oven annual loads as a function of occupants

$$E_{Oven} = C_O + (N_{Occ} \times F_O)$$

Where:

E_{OVEN} = total annual oven energy load (MJ/year)

N_{OCC} = number of occupants in the home (see Equation 2)

C_O = cooktop constant from Table 74 for relevant cooktop type

F_O = cooktop factor from Table 74 for relevant cooktop type.

Table 74: Cooking load factors

Quantity	Gas cooktop	Electric cooktop	Induction cooktop	Electric oven	Gas oven
Constant, C_x	800.13	518.47	356.47	426.53	849.87
Factor, F_x	266.67	172.77	118.77	142.23	283.37

Note: At present, NatHERS does not account for other cooking types such as wood-fired stoves. This may be revisited in the future.

3.13.2 Hourly loads

None of plug, cooktop or oven loads are evenly distributed across the day or across the seasons (although seasonal variation tends to be less marked). This means the annual load values must be broken down into hourly loads, based on the expected distribution of those loads through the year. This is important because it will allow:

- tools to reflect demand, feed-in, and occupancy time cycles
- the greatest flexibility to verify any requirements that may be established for NCC 2022.

Plug loads

Hourly loads for plug loads are calculated using Equation 147.

Equation 147: Appliance hourly plug loads

$$E_{PLUG.hr} = \frac{E_{PLUG} \times F_{PLUG.hr}}{100}$$

Where:

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

E_{PLUG} = total annual plug energy load (defined in Equation 144) (MJ/year)

$F_{PLUG.hr}$ = hourly plug-load factor for hour of day in month (see Table 75) for the weighted average of the all-day profile and work-day profile.

Note: The values in Table 75 allow for the number of days in each month and the sum of values in each month multiplied by the days in each month. This should sum to 1.000 (100%) across the whole year.

Cooktop loads

Hourly loads for cooktop loads are calculated using Equation 148.

Equation 148: Appliance hourly cooktop loads

$$E_{COOKTOP.hr} = \frac{E_{COOKTOP} \times F_{COOKING.hr}}{100}$$

Where:

$E_{COOKTOP.hr}$ = hourly energy load for hour of day in each month (MJ)

$E_{COOKTOP}$ = total annual cooktop energy load (defined in Equation 145) (MJ/year)

$F_{COOKING.hr}$ = hourly cooking load factor for hour of day in month (Table 75).

Note: The values in Table 75 allow for the number of days in each month and the sum of values in each month multiplied by the days in each month. This should sum to 1.000 (100%) across the whole year.

Oven loads

Hourly loads for oven loads are calculated using Equation 149.

Equation 149: Appliance hourly oven loads

$$E_{OVEN.hr} = \frac{E_{OVEN} \times F_{COOKING.hr}}{100}$$

Where:

$E_{OVEN.hr}$ = hourly energy load for hour of day in each month (MJ)

E_{OVEN} = total annual oven energy load (defined in Equation 146) (MJ/year)

$F_{COOKING.hr}$ = hourly cooking load factor for hour of day in month (Table 76).

Table 75: Plug-load hourly factor ($F_{PLUG.hr}$) – weighted average schedule

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.009182	0.009898	0.009316	0.009580	0.009574	0.010107	0.009982	0.009762	0.009698	0.009362	0.009570	0.009312
2	0.008274	0.008804	0.008275	0.008539	0.008454	0.008800	0.008728	0.008588	0.008579	0.008322	0.008451	0.008271
3	0.008061	0.008591	0.008061	0.008273	0.008187	0.008534	0.008407	0.008322	0.008393	0.008135	0.008264	0.008058
4	0.007927	0.008404	0.007928	0.008139	0.008001	0.008320	0.008194	0.008135	0.008180	0.008002	0.008051	0.007924
5	0.008007	0.008538	0.008008	0.008193	0.008134	0.008454	0.008327	0.008268	0.008259	0.008055	0.008131	0.008004
6	0.008194	0.008858	0.008462	0.008593	0.008587	0.009174	0.009101	0.008722	0.008766	0.008455	0.008504	0.008324
7	0.009235	0.010138	0.009743	0.010007	0.010054	0.010907	0.010916	0.010269	0.010311	0.009735	0.009864	0.009552
8	0.011291	0.012780	0.012306	0.012702	0.012935	0.014240	0.014492	0.013203	0.013322	0.012482	0.012609	0.011979
9	0.010782	0.012113	0.011585	0.011929	0.012133	0.013094	0.013265	0.012403	0.012389	0.011710	0.011917	0.011286
10	0.010569	0.011873	0.011424	0.011768	0.011973	0.012934	0.013025	0.012109	0.012096	0.011550	0.011677	0.011126
11	0.010435	0.011606	0.011157	0.011475	0.011627	0.012587	0.012758	0.011896	0.011883	0.011203	0.011410	0.010859
12	0.010088	0.011259	0.010810	0.011075	0.011200	0.012187	0.012331	0.011416	0.011536	0.010856	0.010984	0.010512
13	0.009928	0.010966	0.010570	0.010834	0.010987	0.011947	0.012037	0.011176	0.011243	0.010643	0.010690	0.010352
14	0.010008	0.011046	0.010650	0.010914	0.011067	0.012027	0.012117	0.011256	0.011323	0.010643	0.010770	0.010432
15	0.010008	0.011179	0.010730	0.010995	0.011200	0.012107	0.012197	0.011336	0.011403	0.010776	0.010850	0.010432
16	0.010008	0.011179	0.010730	0.010995	0.011200	0.012107	0.012278	0.011336	0.011403	0.010776	0.010850	0.010432
17	0.011504	0.013046	0.012786	0.013103	0.013415	0.014774	0.015106	0.013550	0.013722	0.012776	0.012903	0.012193
18	0.012358	0.014034	0.013640	0.013903	0.014215	0.015707	0.015960	0.014483	0.014574	0.013629	0.013756	0.013047
19	0.012892	0.014514	0.013907	0.014304	0.014615	0.016107	0.016307	0.014883	0.014921	0.014029	0.014156	0.013527
20	0.013212	0.014887	0.014361	0.014677	0.014935	0.016294	0.016441	0.015203	0.015187	0.014349	0.014609	0.013900
21	0.013319	0.015074	0.014415	0.014864	0.015122	0.016294	0.016494	0.015390	0.015240	0.014483	0.014795	0.014034
22	0.012492	0.013980	0.013373	0.013770	0.014028	0.015067	0.015213	0.014216	0.014148	0.013443	0.013702	0.013047
23	0.011264	0.012433	0.011772	0.012169	0.012295	0.013067	0.013131	0.012483	0.012416	0.011896	0.012076	0.011579
24	0.010356	0.011392	0.010864	0.011128	0.011255	0.011974	0.012037	0.011522	0.011377	0.010856	0.011117	0.010672

Notes:
1. Hour definition is hour ending at the specified clock hour (refer to section 3.1 regarding hour notation).
2. The values in this table 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 100% over a 12-month period.

Table 76: Cooking load hourly factor ($F_{COOKING.hr}$) – weighted average schedule (cooktops and ovens)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0.004297	0.005396	0.005195	0.005633	0.005708	0.006760	0.006285	0.006285	0.006163	0.005451	0.005633	0.004938
8	0.006575	0.008258	0.007949	0.008620	0.008734	0.010344	0.009617	0.009617	0.009431	0.008342	0.008620	0.007557
9	0.004455	0.005595	0.005386	0.005841	0.005918	0.007009	0.006517	0.006517	0.006390	0.005652	0.005841	0.005120
10	0.004455	0.005595	0.005386	0.005841	0.005918	0.007009	0.006517	0.006517	0.006390	0.005652	0.005841	0.005120
11	0.004455	0.005595	0.005386	0.005841	0.005918	0.007009	0.006517	0.006517	0.006390	0.005652	0.005841	0.005120
12	0.007261	0.009119	0.008778	0.009519	0.009645	0.011423	0.010621	0.010621	0.010415	0.009212	0.009519	0.008345
13	0.007261	0.009119	0.008778	0.009519	0.009645	0.011423	0.010621	0.010621	0.010415	0.009212	0.009519	0.008345
14	0.007261	0.009119	0.008778	0.009519	0.009645	0.011423	0.010621	0.010621	0.010415	0.009212	0.009519	0.008345
15	0.006718	0.008437	0.008122	0.008807	0.008924	0.010569	0.009827	0.009827	0.009636	0.008523	0.008807	0.007721
16	0.007261	0.009119	0.008778	0.009519	0.009645	0.011423	0.010621	0.010621	0.010415	0.009212	0.009519	0.008345
17	0.021961	0.027579	0.026549	0.028789	0.029171	0.034547	0.032121	0.032121	0.031499	0.027860	0.028789	0.025238
18	0.044118	0.055406	0.053337	0.057836	0.058604	0.069403	0.064531	0.064531	0.063280	0.055971	0.057836	0.050703
19	0.044118	0.055406	0.053337	0.057836	0.058604	0.069403	0.064531	0.064531	0.063280	0.055971	0.057836	0.050703
20	0.021961	0.027579	0.026549	0.028789	0.029171	0.034547	0.032121	0.032121	0.031499	0.027860	0.028789	0.025238
21	0.010943	0.013743	0.013230	0.014346	0.014536	0.017215	0.016006	0.016006	0.015696	0.013883	0.014346	0.012576
22	0.005518	0.006930	0.006671	0.007234	0.007330	0.008680	0.008071	0.008071	0.007915	0.007000	0.007234	0.006341
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0

Notes:
1. Hour definition is hour ending at the specified clock hour (refer to section 3.1 regarding hour notation).
2. The values in this table are used to allocate the share of annual cooktop or oven 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 (100%) over a 12-month period.

3.14 Energy value and societal cost

The 'energy value' of a home is calculated by multiplying the net hourly fuel loads by the societal cost of the relevant energy source and adding them together across the entire year. The societal cost of each energy source is the sum of the energy tariff (c/kWh for electricity and c/MJ for gas) and the cost of the carbon emissions associated with each fuel (c/kWh for electricity and c/MJ for gas). To calculate the societal cost of the electricity used, consumption must first be split into peak, shoulder, off-peak and controlled load components, as different electricity tariffs are used for each component.

This section provides a description of how to undertake the calculations for the benchmark energy value, and for the energy value of the home being assessed. It is based on a Whole of Home tool that is consistent with the calculation methods described in previous sections, and separately calculates the hourly energy consumption of the key end-uses in the house design being assessed. How these calculations are implemented in any tool will depend on the design of the tool.

In addition to the description, formula and data tables provided in this document, separate spreadsheets provide the large data table for the heating and cooling load adjustment factors, and the calculations for the societal energy costs of electricity, natural gas, LPG and wood.

As well as the energy end-use calculations that all NatHERS tools will have to undertake, the calculation of the benchmark and design energy value also requires access to:

- NatHERS star rating of the house design being assessed – 0.5 to 10.0, to 1 decimal place
- NatHERS climate zone of the house being assessed – 1 to 69
- state or territory of the house being assessed – to apply the correct tariffs
- total internal floor area (m^2) of the house design being assessed, including any garage.

3.14.1 Societal energy costs

The 'societal' cost of the different energy sources used is the sum of the retail energy cost (or tariff) for each energy source (c/kWh for electricity and c/MJ for gas and wood), plus the cost of the carbon emissions that result from using this energy (c/kWh for electricity and c/MJ for gas and wood).

Different societal costs are used for electricity consumption in the peak, off-peak and shoulder periods and for electricity that is used on a controlled tariff.[27] For every state and territory, the same societal energy costs will need to be used across all NatHERS tools, to ensure that they give consistent results.

The electricity, natural gas, LPG and wood costs can be obtained from market surveys to identify the average tariff in each state and territory. To calculate cost of carbon for each energy source, it is necessary to know the greenhouse emission coefficients for each energy source in each state and territory, and the carbon price ($/tonne) that will be used. The energy prices and carbon pricing and intensity for NatHERS assessments is included in Table 77 and Table 78.

[27] The terms peak, off-peak and shoulder refer to electricity that is consumed on the general electricity tariff during specified times of the day. The term 'controlled' tariff refers to special electricity tariffs that provide a cheaper rate for electricity that is consumed during certain off-peak periods (e.g. from 11 pm to 7 am the next morning). Off-peak electric storage, heat-pump water heaters, solar-electric water heaters, and in-slab electric heating might be operated on such a controlled tariff.

Table 77: Energy prices for NatHERS assessments

Cost	NSW	Vic	Qld	SA	WA	Tas	NT	ACT
Electricity cost – peak (c/kWh)	38.72	37.07	32.35	50.65	40.35	29.75	36.47	33.67
Electricity cost – shoulder (c/kWh)	24.89	23.83	20.80	32.56	25.94	19.13	23.45	21.65
Electricity cost – Off peak (c/kWh)	19.36	18.54	16.18	25.33	20.17	14.88	18.24	16.84
Electricity cost – Controlled (c/kWh)	12.99	19.27	15.63	19.79	11.84	13.29	26.05	14.62
PV export tariff (c/kWh)	9.00	12.00	10.00	11.00	7.00	9.50	26.00	9.00
Natural gas cost (c/MJ)	3.38	2.36	4.88	4.23	4.01	3.56	3.56	3.56
LPG cost (c/MJ)	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50
Wood cost (c/MJ)	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85

Table 78: Carbon pricing and intensity for NatHERS assessments

Factor	NSW	Vic	Qld	SA	WA	Tas	NT	ACT
Cost of carbon ($/tonne)	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
Electricity emission factor (kg/kWh)	0.9000	1.1196	0.9252	0.5328	0.7380	0.1728	0.7092	0.1750
Natural gas emission factor (kg/MJ)	0.06433	0.05543	0.06023	0.06193	0.05553	0.06433	0.06433	0.06433
LPG emission factor (kg/MJ)	0.06420	0.06420	0.06420	0.06420	0.06420	0.06420	0.06420	0.06420
Wood emission factor (kg/MJ)	0.00500	0.00500	0.00500	0.00500	0.00500	0.00500	0.00500	0.00500

The carbon emissions factors in Table 78 are sourced from *NCC 2022 update – Whole of Home component*, written by Energy Efficient Strategies. The figures in that report are ultimately sourced from the *National Greenhouse Accounts Factors 2019*.[28]

The societal cost of each energy source is calculated using this formula for the different fuels:

societal cost (electricity)

= energy cost (c/kWh) + [(cost of carbon ($/tonne) × emission factor (kg/kWh))/10]

societal cost (gas or wood)

= energy cost (c/MJ) + [(cost of carbon ($/tonne) × emission factor (kg/MJ))/10]

It is recommended that the NatHERS Whole of Home tools calculate the societal costs from first principles, using the agreed energy costs, cost of carbon and emissions coefficients. This will make it easier to update the societal costs from time to time, to account for changes in energy costs, the cost of

[28] dcceew.gov.au/climate-change/publications/national-greenhouse-accounts-factors-2019

carbon and the emissions coefficients.[29] A spreadsheet is available that calculates the societal energy costs from the input assumptions in Table 77 and Table 78. For these values, the calculated societal energy costs are shown in Table 79. Alternatively, tool developers could simply use a table of agreed societal energy costs for the calculations.

Table 79: Energy value (societal cost) of fuel for NatHERS assessments

Parameters	State or Territory							
	NSW	Vic	Qld	SA	WA	Tas	NT	ACT
Electricity – peak (c/kWh)	39.80	38.41	33.46	51.29	41.24	29.96	37.32	33.88
Electricity – shoulder (c/kWh)	25.97	25.17	21.91	33.20	26.83	19.34	24.30	21.86
Electricity – off peak (c/kWh)	20.44	19.88	17.29	25.97	21.06	15.09	19.09	17.05
Electricity – controlled load (c/kWh)	14.07	20.61	16.74	20.43	12.73	13.50	26.90	14.83
PV Export (c/kWh)	10.08	13.34	11.11	11.64	7.89	9.71	26.85	9.21
Natural gas (c/MJ)	3.46	2.43	4.95	4.30	4.08	3.74	3.74	3.64
LPG (c/MJ)	5.58	5.58	5.58	5.58	5.58	5.58	5.58	5.58
Wood (c/MJ)	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86

In general, the values in Table 79 match those quoted in *NCC 2022 update – Whole of Home component*; however, where errors have been discovered (e.g. using rounded values instead of raw figures for gas prices), these have been corrected. The differences are minor, but measurable, and generally have reduced the energy values of NatHERS assessments.

3.14.2 Time of use

Electricity prices vary with hour of use. As listed in Table 78 and Table 79, there are peak, off-peak, shoulder and controlled tariffs. Time-of-use designations are listed in Table 80.

[29] Energy costs and emissions intensities tend to change from year to year.

Table 80: Time-of-use designation

Nominal hour number	Period
1	Off peak
2	Off peak
3	Off peak
4	Off peak
5	Off peak
6	Off peak
7	Off peak
8	Off peak
9	Peak
10	Peak
11	Shoulder
12	Shoulder
13	Shoulder
14	Shoulder
15	Shoulder
16	Shoulder
17	Shoulder
18	Peak
19	Peak
20	Peak
21	Peak
22	Shoulder
23	Shoulder
24	Off peak

These hour designations differ from those listed in *NCC 2022 update – Whole of Home component*. When the NatHERS method was compared against the NCC Deemed to Satisfy provisions, the annual loads were matching but the energy values (societal costs) were not. Updating to the schedule in Table 80 allowed the energy values to align, and so has been adopted on the advice of consultants. It is noted that this has implications across the calculation method, and will be reviewed at a later stage.

3.15 Whole of Home rating

This section details the process of transforming the societal cost of the dwelling calculated in the previous section into the Whole of Home rating. This includes how the benchmark budget is calculated using the assessed dwelling, and how the difference between the benchmark and the assessed societal cost are used to generate ratings.

3.15.1 Energy load and energy balance

To complete the rating, the energy calculations from each module must be combined in different ways. To calculate the energy value of the assessed building, the overall energy balance for each fuel type is required. The energy balance shows in each hour whether the fuel is being imported to, or exported from, the building. Most fuel types in NatHERS at this stage will only be imports (e.g. gas and wood). The only fuel that can be exported at this stage is electricity.

The energy balance for a fuel type is the sum of the loads, minus any onsite generation that is being used to meet the loads. For this calculation, energy supplied by a battery is considered 'onsite generation' (after accounting for losses), as long as it has been charged by an onsite generation system. This is because electricity 'supplied' by the battery reduces the amount of electricity that needs to be imported.

To calculate the energy value of the benchmark dwelling, the energy loads for heating and cooling are required, as well as any non-regulated loads present in the assessment. These must be retained as loads, in addition to being combined in the energy balance. Note that the benchmark dwelling has specific loads for hot water and lighting, which are defined in section 3.10.2.

Note that homes with Type 1 PV Diverter hot water systems will have *both* imports and exports during an hour. These cannot be netted off against each other as this is a key difference between Type 1 systems, which do not modulate input power and therefore cannot use all available solar PV onsite, and Type 2 and 3 systems which can modulate input power. See section 3.8.5 for further details.

3.15.2 The benchmark dwelling

NatHERS Whole of Home ratings are based on how the energy value of the assessed home compares with the energy value of a benchmark dwelling.

The 'energy value' of the benchmark dwelling is based on a:

- 7.0-star NatHERS rating
- 3-star (2019 GEMS) ducted reverse-cycle air conditioner for heating and cooling the conditioned zones
- 5-star gas instantaneous water heater
- lighting power density of 4 W/m^2.

The same plug and cooking loads as the assessed home are also applied. The benchmark dwelling for the assessment uses the assessed dwelling model to determine the loads. This means the same floorplan, climate zone, orientation and so on.

3.15.3 Calculating the benchmark electricity consumption

The annual electricity consumption (or import) of the heating and cooling, lighting, plug and cooking loads must be calculated, and then segmented into the peak, shoulder and off-peak components,[30] so that the appropriate societal energy costs can be applied. As the benchmark dwelling does not include any solar PV, this may be done on an annual basis instead of hourly, as long as the accuracy requirements of the software accreditation protocol are still met.

3.15.4 Benchmark heating and cooling electricity consumption

To calculate the energy consumption of the ducted reverse-cycle air conditioner, it is necessary to first calculate the total annual heating and cooling loads[31] in the 'conditioned areas' of the dwelling – this refers to all areas of the dwelling that are defined as conditioned zones in the NatHERS thermal assessment. The benchmark dwelling is assumed to be in the same climate zone and have the same floor area and general design as the dwelling being assessed, but has a NatHERS rating of 7.0 stars.

To estimate the total annual heating and cooling loads of an equivalent 7.0-star dwelling, the dwelling is benchmarked with itself and adjust the total annual heating and cooling load of the design being assessed back to what it would be if the dwelling had a 7.0-star rating. This can be done using Equation 150.

Equation 150: Whole of Home adjustment factor for thermal load

$$Adjustment\ Factor = \frac{E_{Ther.Rat}}{E_{7-star}}$$

Where:

$E_{Ther.Rat}$ = adjusted annual energy load for the assessed dwelling (MJ/m^2)

$E_{7\text{-}star}$ = adjusted annual energy load for a 7.0-star dwelling in the climate zone for the assessed dwelling (MJ/m^2).

Alternatively, adjustment factors that are based on the ratio of the NatHERS star bands (MJ/m^2) for ratings from 0.5 to 10 stars and the NatHERS star band for a 7.0-star dwelling have been developed for all climate zones and are provided in a separate spreadsheet.

Calculation of the total annual benchmark heating and cooling electricity consumption follows 5 steps:

1. Sum the hourly heating and cooling loads for the conditioned zones for each hour of the year to produce the hourly combined heating and cooling load (MJ).
2. Calculate the total annual combined heating and cooling load (MJ) for each hour of the day (1 to 24), as well as the total annual combined heating and cooling load (MJ).

[30] The controlled load component of the electricity consumption is not relevant to the benchmark dwelling, as the air conditioner and lighting are assumed to operate on a general electricity tariff. 'Controlled load' refers to appliances that run on the cheaper off-peak electricity overnight (e.g. off-peak electric water heating).

[31] This is the heating and cooling energy input (MJ) that is required to maintain the necessary comfort conditions in the dwelling being assessed. The hourly heating and cooling load data for the conditioned living and conditioned other zones will be available to the tools from the NatHERS assessment. The energy consumption is calculated by dividing the heating and cooling loads by the conversion efficiency of the heater and cooler.

3. Calculate the total annual combined heating and cooling load (MJ) in the peak, off-peak and shoulder periods, and calculate the percentage of the total annual consumption that occurs in each period. An example for steps 2 and 3 is provided in the following 2 tables.

Example 1

Period	Hour	Combined heating and cooling load (MJ)
Off peak	1	0.6
Off peak	2	5.1
Off peak	3	0.8
Off peak	4	0.5
Off peak	5	0.3
Off peak	6	0.3
Off peak	7	0.3
Off peak	8	3,987.7
Peak	9	1,762.5
Peak	10	1,356.8
Shoulder	11	838.1
Shoulder	12	671.7
Shoulder	13	631.5
Shoulder	14	645.1
Shoulder	15	683.5
Shoulder	16	765.4
Shoulder	17	683.2
Peak	18	627.5
Peak	19	891.3
Peak	20	771.3
Peak	21	557.6
Shoulder	22	704.9
Shoulder	23	784.4
Off peak	24	1.3
	Total	**16,372**

Period	Combined heating and cooling load	
	MJ	%
Peak	5,967.0	36.4
Shoulder	6,407.8	39.1
Off peak	3,996.9	24.4
Total	**16,371.7**	**100.0**

4. Obtain the adjustment factor for the house design being assessed from the look-up table – this will be provided as a separate spreadsheet table, with values for all climate zones and for NatHERS ratings from 0.5 to 10 stars in 0.1-star increments. Use this factor to estimate the total annual heating/cooling load for the 7-star benchmark dwelling, as shown in Equation 151.

Equation 151: Benchmark total annual heating and cooling load

$$Benchmark\ total\ heating\ and\ cooling\ load\ (\mathrm{MJ/year}) = \frac{Total\ heating\ and\ cooling\ load\ of\ house\ design\ (\mathrm{MJ/year})}{adjustment\ factor}$$

Example 2

NatHERS rating 7.2 stars

Climate zone 60

Total heating and cooling load of house design 16,372 MJ/year

Adjustment factor 0.9394

Benchmark total annual heating and cooling load = 16,372 / 0.9394 = 17,428 MJ/year

5. Calculate the annual energy consumption of the benchmark ducted reverse-cycle air conditioner used for heating and cooling. This has a 3-star rating (2019 GEMS) for both heating and cooling and is assumed to have 15% duct losses. A 3-star rating corresponds to a coefficient of performance (CoP) for heating of 4.5, and an energy efficiency ratio (EER) for cooling of 4.5. The duct losses result in a net CoP = EER = 3.825. As the CoP and EER are the same, the total benchmark heating and cooling energy consumption can be simply calculated from the benchmark total heating and cooling load by dividing it by 3.825. Using CoP and EER, and the fact that 1 kWh = 3.6 MJ, the benchmark heating and cooling electricity in kWh can be calculated.

   Example 3

   Benchmark total heating and cooling load = 17,428 MJ/year

   Benchmark heating and cooling electricity (kWh) = 17,428/ (3.825 × 3.6) = 1,265 kWh/year

   This annual electricity consumption is then segmented into the peak, off-peak and shoulder periods, using the percentages calculated in step 3. (See section 3.10.5 for example).

3.15.5 Benchmark lighting electricity consumption

The benchmark dwelling is assumed to have a lighting power density of 4 W/m^2. The lighting is assumed to operate for an average of 1.6 hours per day over the year, a total of 584 hours per year.

Calculation of the benchmark lighting electricity consumption follows 2 steps.

1. Calculate the total installed lighting load (kW) by multiplying the total internal floor area of the dwelling (m^2) by 4 W/m^2 and dividing by 1,000 to convert to kW. This is then multiplied by 584 hours to calculate the annual electricity consumption in kWh. This can be simplified using Equation 152

Equation 152: Benchmark annual lighting electricity

$$Benchmark\ lighting\ electricity\ (\mathrm{kWh}) = Total\ internal\ floor\ area\ (\mathrm{m}^2) \times 2.336$$

2. Determine the percentage of the lighting electricity consumption that occurs during the peak, off-peak and shoulder periods. The percentages can be calculated from the hourly lighting electricity consumption of the dwelling design being assessed. As with heating and cooling, first calculate the total annual lighting electricity consumption in each hour of the day (1 to 24), calculate the total annual electricity consumption in the peak, off-peak and shoulder periods, then calculate the percentage of total annual consumption in each of these periods.

   Example 4

   Total internal floor area (excluding garage) 153.9 m^2

   Benchmark lighting electricity (kWh/year) = 153.9 × 2.336 = 356.5 kWh/year

Table 81: Peak, shoulder and off-peak distribution of lighting electricity consumption for example dwelling

Period	Lighting electricity consumption	
	MJ	**%**
Peak	559	43.2
Shoulder	458	35.4
Off peak	277	21.4
Total	**1,294**	**100.0**

3.15.6 Plug and cooking loads

For plug and electric cooking loads, energy value is calculated in the same way as lighting. These are non-regulated, and must be retained separately from the regulated loads for the purposes of setting the rating scale.

Table 82 provides an example that assumes an electric cooktop and electric oven.

Table 82: Peak, shoulder and off-peak plug, cooktop and oven loads for example dwelling

Period	Plug-load electrical		Cooktop electrical load		Oven electrical load		Total
	MJ	**%**	**MJ**	**%**	**MJ**	**%**	**MJ**
Peak	2,840.3	33.8	731.9	69.2	602.3	69.2	**4,174.5**
Shoulder	3,206.8	38.2	261.6	24.7	215.3	24.7	**3,683.7**
Off peak	2,354.2	28.0	64.4	6.1	53.0	6.1	**2,471.6**
Total	**8,401.3**	**100.0**	**1,057.9**	**100.0**	**870.6**	**100.0**	**10,329.8**

3.15.7 Calculating the benchmark hot water gas consumption

The benchmark dwelling is assumed to have a 5-star gas instantaneous water heater, and an assumed number of occupants based on the internal floor area of the dwelling. As the NatHERS Whole of Home tools are already designed to calculate the annual water heating energy consumption for various water heater types and efficiency levels, it should be straight forward to obtain this from the water heating module of the tool. It will simply be the annual gas consumption of the 5-star gas instantaneous water heater option for the assumed number of occupants (based on the total internal floor area, excluding garage), and for the water heating zone that the house design is located in (based on the postcode).

Energy value for gas cooking is calculated in the same way.

Example

Total internal floor area (excluding garage)	153.9 m^2
Assumed number of occupants	3.15 people
Postcode	3058
Water heating zone:	4
Annual gas use of 5-star gas instant	13,418 MJ

3.15.8 Calculating the benchmark hot water electricity consumption

Gas instantaneous water heaters have a small auxiliary electrical load in addition to the main gas use (see section 3.8). This electrical load is included as part of the electrical load for the benchmark dwelling.

3.15.9 Calculating the benchmark energy value

The benchmark energy value is the total annual electricity and gas consumption of the heating and cooling, water heating and lighting of the benchmark dwelling, multiplied by the relevant societal energy costs.

3.15.10 The energy value of the benchmark dwelling

The annual electricity and gas consumptions calculated for the benchmark house are multiplied by the relevant societal energy cost to calculate the energy value of each energy source. These are then added to calculate the overall benchmark energy value.

Example

The example in Table 83 and Table 84 is for a house located in Victoria, and uses the benchmark heating and cooling, lighting, water heating, cooking and plug-load energy consumption data from the example 2 and example 3 section 3.10.4 and example 4 section 3.10.5.

Table 83: Peak, shoulder and off-peak regulated and non-regulated benchmark electricity consumption for the example dwelling

	Heating cooling		Lighting		Total regulated	Total non-regulated
Period	**%**	**kWh**	**%**	**kWh**	**kWh**	**kWh**
Peak	53.3	674	33.4	155	830	1,160
Shoulder	41.9	530	36.6	127	657	1,023
Off peak	4.8	61	30.1	77	138	687
Total		**1,265**		**360**	**1,625**	**2,869**

Table 84: Example energy value of a benchmark dwelling

Energy source	Regulated energy (kWh or MJ)	Non-regulated (plug + cooking)	Societal energy cost (c/kWh or c/MJ)	Regulated energy value	Non-regulated energy value	Total energy value
Electricity – peak (kWh)	813	1,160	38.38	$318.38	$445.05	$763.43
Electricity – shoulder (kWh)	682	1,023	25.14	$165.25	$257.24	$422.49
Electricity – off peak (kWh)	186	687	19.85	$27.32	$136.28	$163.61
Natural gas (MJ)	13,418	0	2.43	$326.06	$0.00	$326.06
Total	**n/a**	**n/a**	**n/a**	**$837.01**	**$838.57**	**$1,675.58**

n/a = not applicable

3.15.11 Total benchmark electricity consumption

This is the sum of the total annual heating and cooling and lighting electricity consumption, segmented into the peak, shoulder and off-peak periods. This can be easily calculated using the segmented consumption calculated for the heating and cooling and lighting.

Table 84 provides an example of the total regulated and non-regulated benchmark electricity consumption segmented into peak, shoulder and off-peak periods.

3.15.12 Calculating the energy value of the dwelling being assessed

The ‘energy value’ of the dwelling design being assessed is based on the total energy consumption of the heating and cooling, water heating, lighting and any pool equipment[32] multiplied by the relevant societal cost of energy.

The calculation is based on the actual NatHERS star rating of the dwelling design, and the appliances (type and efficiency level) specified for the dwelling. The ‘energy value’ of these fixed appliances can be offset by a rooftop PV system. The calculation of this offset is based on the annual mains electricity offset provided by the PV system (or PV self-consumption) and the annual export of PV electricity back into the electricity grid, multiplied by the relevant societal electricity cost. If a storage battery is used in conjunction with the PV system, this will reduce the PV export and increase the mains electricity offset; it is important that this is taken into account.

The NatHERS Whole of Home tools have been designed to calculate:

- the hourly energy consumption of the fixed appliances
- the PV export and mains electricity consumption
- all that is necessary to calculate the total annual electricity, natural gas, LPG and wood consumption of the fixed end-uses
- the total annual mains electricity offset and export of the rooftop PV system.

[32] Inclusion of pool and spa heating will be considered once this module is complete, but at present the module only includes pump and cleaning equipment.

The electricity consumption of the fixed end-uses must be segmented into peak, off-peak, shoulder and controlled load. This is also the case for the mains electricity offset provided by the rooftop PV system. The total annual general electricity consumption of the fixed appliances and the mains electricity offset of the PV system first must be separated into the hours of the day (1 to 24) and then into the peak, off-peak and shoulder periods, as for the benchmark heating and cooling and lighting energy consumption. The electricity consumption for any appliances operated on a controlled load tariff[33] should be kept separate from this.

It is important to remember that all energy consumption for the fixed end-uses should be included in the calculations, including any auxiliary electricity consumption for gas heating, and gas instantaneous and gas-boosted solar water heaters. Energy sources that may be used by the fixed appliances include:

- heating – electricity, natural gas, LPG, wood
- cooling – electricity
- water heating – electricity, natural gas, LPG, wood
- pool equipment – electricity (natural gas to be considered when pool heating module is complete).

The way in which these calculations are undertaken will vary depending on the way a particular tool has been designed. However, for the calculation of the design energy value, the electricity of the fixed appliances must be segmented into controlled load and peak, off-peak and shoulder periods, and the mains electricity offset provided by any PV system must be segmented into peak, off-peak and shoulder periods. Only annual totals are required for natural gas, LPG, wood and PV export.

These results are then multiplied by the relevant societal energy costs to calculate the energy value. The energy values of all the fixed appliances are added to calculate the total energy value, and the energy value of the mains electricity offset of the PV is added to the PV export to calculate the total PV offset. The net energy value of the dwelling design is the energy value of the fixed end-uses minus the energy value of the PV offset.

Table 85 provides an example of the energy value for a dwelling with the following characteristics:

- 178.1 m^2 (153.9 m^2 excluding garage) single-storey Class 1, 7.2 star dwelling located in Victoria
- location – climate zone 60, postcode 3058
- heating – 5.1-star gas ducted heater for all conditioned areas
- cooling – refrigerative room air conditioner; 2-star (conditioned living), 3-star (conditioned other)
- water heating – heat pump run on a peak (general) tariff
- lighting – 4 W/m^2
- cooking – gas cooktop, electric oven
- pool equipment – none
- PV system – 2 kW, north facing.

[33] This includes any off-peak electric water heating (whether electric storage, heat pump or solar-electric) and any in-slab electric heating.

Table 85: Example energy value of an assessed dwelling

Parameter	Regulated annual use or offset (kWh or MJ)	Non-regulated annual use or offset (kWh or MJ)	Social cost of energy (c/kWh or c/MJ)	Regulated energy value ($)	Non-regulated energy value ($)	Total ($)
Electricity – peak (kWh)	347	1,160	38.38	133.18	445.05	578.23
Electricity – shoulder (kWh)	386.7	1,023	25.14	97.22	257.24	354.46
Electricity – off peak (kWh)	148.6	687	19.85	29.50	136.28	165.78
Electricity – controlled (kWh)	0	0	20.58	0.00	0.00	0.00
Natural gas (MJ)	33,267	0	2.43	808.39	0.00	808.39
LPG (MJ)	0	0	5.58	0.00	0.00	0.00
Wood (MJ)	0	0	1.86	0.00	0.00	0.00
Subtotal – energy use	**n/a**	**n/a**	**n/a**	**1,068.28**	**838.57**	**1,906.85**
PV offset – peak (kWh)	364.8	0	38.38	140.01	0.00	140.01
PV offset – shoulder (kWh)	849.8	0	25.14	213.64	0.00	213.64
PV offset – off peak (kWh)	2.3	0	19.85	0.46	0.00	0.46
PV export (kWh)	1,642.9	0	13.31	218.67	0.00	218.67
Subtotal – PV offset	**n/a**	**n/a**	**n/a**	**572.78**	**0.00**	**572.78**
Net total (energy – PV offset)	**n/a**	**n/a**	**n/a**	**495.50**	**838.57**	**1,334.08**

n/a = not applicable

3.15.13 Calculating the rating

The rating is calculated using the energy value of the benchmark dwelling as a reference. The rating is on scale of 0 to 150 (Figure 7), where:

- 50 – the score of the benchmark dwelling (Benchmark 1), made up of 100% of regulated loads + the plug and cooking loads
- 60 – the score with 70% of the regulated loads for Benchmark 1 + the plug and cooking loads (Benchmark 2)
- 100 – the score of a dwelling with net zero societal cost
- 150 – the maximum rating awarded under NatHERS
- 0 – the worst performance rating of existing houses, to ensure that existing houses have a path for progression up the scale if renovations or upgrades are implemented, so that they are not ‘stuck’ at the lower end after improvements.

Figure 7: Example rating scale showing benchmarks 1 to 5

Using these points, the rating scale is broken up into homes that are:

- < 50 (energy values higher than Benchmark 1)
- from 50 to 60, inclusive of 50 and 60 (energy values ≤ Benchmark 1, but not < Benchmark 2)
- > 60 (energy values lower than Benchmark 2).

Calculating the breakpoints

To set up the rating scale, the energy value for the dwelling at Benchmark 1 must be known (rating of 50). The value of the plug loads and cooking must also be known, so that Benchmark 2 can be correctly calculated.

Equation 153: Energy value for rating of 50

$$E.V_{50} = Benchmark\ Regulated + Plug\ and\ Cooking$$

Equation 154: Energy value for rating of 60

$$E.V_{60} = (0.7 \times Benchmark\ Regulated) + Plug\ and\ Cooking$$

Equation 155: Energy value for rating of 100

$$E.V_{100} = 0$$

Equation 156: Energy value for rating of 0

$$E.V_0 = (W.F \times Benchmark\ Regulated) + Plug\ and\ Cooking$$

Where:

$E.V_{50}$ = maximum energy value for a Whole of Home performance rating of 50

$E.V_{60}$ = maximum energy value for a Whole of Home performance rating of 60

$E.V_{100}$ = maximum energy value for a Whole of Home performance rating of 100

$E.V_0$ = minimum energy value for a Whole of Home performance rating of 0

Benchmark Regulated = energy value (societal cost) of the heating, cooling, hot water and lighting for a 7-star equivalent of the assessed thermal shell with 3-star ducted heating and cooling, 5-star gas instantaneous hot water and 4 W/m^2 lighting; loads calculated as per the relevant module above.

Plug and Cooking = energy value of plug loads and cooking loads for the assessed dwelling; the benchmark dwelling uses the same plug and cooking loads as the assessed dwelling; if the assessed dwelling is to have gas cooktop and electric oven, the benchmark dwelling has gas cooktop and electric oven, and so on

W.F = 'worst factor' Table 86); indicates how high the energy value is for the worst reasonable expectation of the assessed dwelling.

'Worst factor' is based on a 1-star thermal shell rating, electric heating and hot water that use peak rate electricity and ducted 1.5-star reverse-cycle cooling. This must be looked up based on the NatHERS climate zone and the state or territory for the assessed dwelling.

Analysis was conducted on the need to differentiate the worst case across solar zones (hot water) within a NatHERS and state/territory combination (e.g. climate zone (CZ) 66, Ballarat, Victoria, crosses solar zones 3 and 4). While the benchmark requires using the solar zone, the worst factor does not change significantly and was deemed an unnecessary complication. This only affects dwellings that would score 49 or lower.

Table 86: Rating breakpoint worst factor

CZ number	CZ name	State/territory	Worst factor
1	Darwin	NT	2.769
2	Port Hedland	WA	2.543
3	Longreach	NT	3.004
3	Longreach	Qld	2.425
4	Carnarvon	WA	1.956
5	Townsville	Qld	3.234
6	Alice Springs	NT	2.024
6	Alice Springs	Qld	3.421
7	Rockhampton	Qld	2.301
8	Moree	NSW	1.805
8	Moree	Qld	2.604
8	Moree	SA	2.497
9	Amberley	NSW	3.536
9	Amberley	Qld	3.932
10	Brisbane	NSW	3.081
10	Brisbane	Qld	3.518
11	Coffs Harbour	NSW	2.715
12	Geraldton	WA	3.450
13	Perth	WA	2.910
14	Armidale	NSW	3.613
14	Armidale	Qld	3.794
15	Williamtown	NSW	4.267
16	Adelaide	SA	3.151
17	Sydney (RO)	NSW	3.609
18	Nowra	NSW	3.905
19	Charleville	NSW	3.198
19	Charleville	Qld	3.989
20	Wagga	NSW	3.304
20	Wagga	Vic	2.537
21	Melbourne (RO)	Vic	2.854
22	East Sale	Vic	2.265
23	Launceston (Ti Tree bend)	Tas	2.082
24	Canberra	ACT	2.382
24	Canberra	NSW	3.373
24	Canberra	Vic	1.933
25	Cabramurra	NSW	1.987
25	Cabramurra	Tas	3.434
25	Cabramurra	Vic	3.076

Table 86 (continued): Rating breakpoint worst factor

CZ number	CZ name	State/territory	Worst factor
26	Hobart	Tas	2.489
27	Mildura	NSW	3.144
27	Mildura	SA	3.003
27	Mildura	Vic	3.170
28	Richmond	NSW	3.228
29	Weipa	Qld	2.974
30	Wyndham	NT	3.222
30	Wyndham	WA	3.346
31	Willis Island	Qld	4.061
31	Willis Island	WA	3.552
32	Cairns	Qld	3.338
33	Broome	WA	2.299
34	Learmonth	WA	3.119
35	MacKay	Qld	3.154
36	Gladstone	Qld	3.381
37	Halls Creek	NT	3.034
37	Halls Creek	WA	2.985
38	Tennant Creek	NT	2.559
38	Tennant Creek	Qld	3.367
39	Mt Isa	Qld	3.844
40	Newman	WA	3.949
41	Giles	WA	4.028
42	Meekathara	WA	4.018
43	Oodnadatta	NT	3.936
43	Oodnadatta	SA	4.273
44	Kalgoorlie	WA	4.233
45	Woomera	SA	3.897
46	Cobar	NSW	4.186
47	Bickley	WA	3.115
48	Dubbo	NSW	3.329
49	Katanning	WA	3.682
50	Oakey	NSW	3.477
50	Oakey	Qld	2.796
51	Forrest	WA	2.629
52	Swanbourne	WA	3.149
53	Ceduna	SA	2.438
54	Mandurah	WA	3.025
55	Esperance	WA	3.611

Table 86 (continued): Rating breakpoint worst factor

CZ number	CZ name	State/territory	Worst factor
56	Mascot	NSW	4.071
57	Manjimup	WA	4.457
58	Albany	WA	4.176
59	Mt Lofty	SA	3.590
60	Tullamarine	Vic	2.841
61	Mt Gambier	SA	2.062
61	Mt Gambier	Vic	3.466
62	Moorabbin	Vic	2.724
63	Warrnambool	Vic	3.049
64	Cape Otway	Vic	3.091
65	Orange	NSW	4.548
66	Ballarat	NSW	3.804
66	Ballarat	Vic	3.975
67	Low Head	Tas	3.482
68	Launceston (Airport)	Tas	3.976
69	Thredbo Village	NSW	3.437
69	Thredbo Village	Tas	3.522
69	Thredbo Village	Vic	3.224

Note that it is not necessary to reconstruct different rating scales for locations with a specific heat-pump zone. The worst factor is based on an electric water heater and the performance does not change for a location that is in water heater zone HP5.

The 4 breakpoints are used to generate the rating scale. The relevant portion of the rating scale depends on where the assessed dwelling energy value is relative to $E.V_{50}$ and $E.V_{60}$.

Translating the energy value into the rating

The process for calculating the rating is:

1. Calculate $E.V_{50}$, $E.V_{60}$ and the energy value of the assessed building, $E.V_{Assessment}$.
2. Determine relevant equation and calculate relevant breakpoints.
3. Calculate rating.

Table 87 provides the relevant rating function for each situation, depending on where $E.V_{Assessment}$ is compared with $E.V_{50}$ and $E.V_{60}$.

Table 87: Logic for choosing rating equation

Condition	Required breakpoint	Rating function
$E.V_{Assessment} > E.V_{50}$	$E.V_{0}$	Equation 157
$E.V_{50} \geq E.V_{Assessment} \geq E.V_{60}$	Nil	Equation 158
$E.V_{Assessment} < E.V_{60}$	$E.V_{100}$	Equation 159

Equation 157 shows the calculation for when $E.V_{Assessment}$ is > $E.V_{50}$. The $E.V_0$ breakpoint must be known for this calculation.

Equation 157: $E.V_{Assessment}$ is > $E.V_{50}$

$$(E.V_{Assessment} - E.V_{50}) \times \frac{-50}{E.V_0 - E.V_{50}} + 50$$

Equation 158 shows the calculation for when $E.V_{Assessment}$ is ≤ $E.V_{50}$ and ≤ $E.V_{60}$.

Equation 158: $E.V_{Assessment}$ is ≤ $E.V_{50}$ and ≤ $E.V_{60}$

$$(E.V_{Assessment} - E.V_{60}) \times \frac{-10}{E.V_{50} - E.V_{60}} + 60$$

Equation 159 shows the calculation for when the $E.V_{Assessment}$ is < $E.V_{60}$. The $E.V_{100}$ breakpoint must be known for this calculation.

Equation 159: $E.V_{Assessment}$ is < $E.V_{60}$

$$E.V_{Assessment} \times \frac{-40}{E.V_{60}} + 100$$

NatHERS Whole of Home ratings must be between 0 and 150. There are no negative NatHERS ratings. Dwellings that would rate below 0 are given a rating of 0.

Whole of Home ratings cannot exceed 150. Dwellings that would rate above 150 are awarded 150.

Whole of Home ratings are rounded down to the nearest whole number (i.e. 50.9 is 50, 60.1 is 60 and so on).

Example 1

Using the values from the earlier example throughout section 3.15, we find

$E.V_{Assessment}$ = 1,334.08

Benchmark regulated = 837.01

Plug and cooking = 838.57

Therefore, calculate $E.V_{50}$ using Equation 153:

$E.V_{50}$ = 1,675.58

Calculate $E.V_{60}$ using Equation 154: Energy value for rating of 60Equation 154:

$$E.V_{60} = 0.7 \times 837.01 + 838.57$$
$$= 585.91 + 838.57$$
$$= 1{,}424.48$$

$E.V_{Assessment}$ is < $E.V_{60}$, therefore, calculate rating using Equation 159:

$$Rating = E.V_{Assessment} \times \frac{-40}{E.V_{60}} + 100$$
$$= 1{,}334.08 \times \frac{-40}{1{,}424.48} + 100$$
$$= 1{,}334.08 \times -0.0281 + 100$$
$$= 62.51$$
$$= 62$$

Example 2

$E.V_{Assessment}$ = 1,700

Benchmark regulated = 1,500

Plug and cooking = 500

Therefore, calculate $E.V_{50}$ using Equation 153:

$E.V_{50}$ = 2,000

Calculate $E.V_{60}$ using Equation 154:

$$E.V_{60} = 0.7 \times 1{,}500 + 500$$
$$= 1{,}050 + 500$$
$$= 1{,}550$$

$E.V_{Assessment}$ is between $E.V_{50}$ and $E.V_{60}$; therefore, calculate rating using Equation 158:

$$Rating = (E.V_{Assessment} - E.V_{60}) \times \frac{-10}{E.V_{50} - E.V_{60}} + 60$$
$$= (1{,}700 - 1{,}550) \times \frac{-10}{2{,}000 - 1{,}550} + 60$$
$$= 150 \times \frac{-1}{45} + 60$$
$$= 56.66$$
$$= 56$$

Appendix A – Cooling thermostat settings by NatHERS climate zone for Whole of Home rating, ZERL zones and evaporative cooler suitability

Appendix A data table is provided in a MS Excel format at Whole of Home National Calculations Method | Nationwide House Energy Rating Scheme (NatHERS).

Evaporative coolers are most suitable for climates with a high-to-moderate cooling load and where the relative humidity is lower for periods when cooling is most likely to be required. An in-depth analysis has been undertaken for each of the 69 NatHERS climate zones, and a preliminary assessment of the suitability of evaporative coolers has been undertaken, based on internationally recognised operating conditions in which evaporative coolers are likely to be most effective.

A separate document is available that sets out the underlying analysis used to develop these preliminary assessments. Note that these assessments are based on direct-cooling evaporative systems.

Indirect-cooling evaporative systems may be suitable in climates assessed as marginal.

A total of 7 possible assessments, based on quantitative criteria for each hour in a standard year, have been made as follows to provide preliminary guidance to assessors:

- high cooling – NOT suitable for evaporative
- high cooling – MARGINAL (significant periods where there is moderate to high relative humidity)
- high cooling – suitable for evaporative
- moderate cooling – NOT suitable for evaporative
- moderate cooling – MARGINAL (significant periods where there is moderate to high relative humidity)
- moderate cooling – suitable for evaporative
- LOW COOLING – need for any active cooling should be carefully considered.

Before selection, the specific installation and local climate should always be assessed by a qualified professional.

Appendix B – Water heater performance coefficients for annual energy by climate zone for Whole of Home rating

Appendix B data table is provided in a MS Excel format at Whole of Home National Calculations Method | Nationwide House Energy Rating Scheme (NatHERS).

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 coefficients specific to each type of system and each climate zone. The application of coefficients *a*, *b*, *c* and *d* is shown in Equation 27, which is repeated below for convenience:

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

The annual hot water demand energy $E_{Annual\text{-}output}$ (energy output), which is the input parameter for this equation, is defined in Equation 26. Coefficients are set out in this appendix.

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

XXX-Y-ZZ

Where:

XXX is a 3-letter code to identify the water heater type – see Table 30

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 gives the performance level for the water heater type – see Table 30.

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

Note: For solar thermal electric boost systems that are intended to operate on controlled tariffs (such as off peak), the supplier should confirm that the specific water heater has been configured for use with this type of energisation profile and the STCs earned are for this specific configuration. The coefficients in Appendix B will then be valid. See 'Water heater hourly energy use' in section 3.8.4 for more details.

Appendix C – Water heater performance coefficients for monthly share of energy by climate zone for Whole of Home rating

Appendix C data table is provided in a MS Excel format at [Whole of Home National Calculations Method | Nationwide House Energy Rating Scheme (NatHERS)].

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 coefficients specific to 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 shown in Equation 28, which is repeated below for convenience:

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

Where $E_{Annual\text{-}output}$ (hot water demand) is defined in Equation 26.

Specific 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 28 for solar thermal electric should be equal to 1.0000.

For solar thermal gas boost systems, 2 sets of coefficients are provided to separately estimate the share of gas (STG) and electricity (STX) in each month (noting that the total annual purchased energy estimated from Equation 27 is gas plus electrical energy). The sum of values for each of the 12 months from Equation 28 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_{month}, b_{month} and c_{month} will be 0, 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 3-code to identify the water heater type – see Table 30

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 3-letter abbreviation for each month, consisting of the first 3 letters (e.g. JAN = January, NOV = November).

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

Appendix D – Water heater performance coefficients for hourly share of energy by climate zone for Whole of Home rating

Appendix D data table is provided in a MS Excel format at [Whole of Home National Calculations Method | Nationwide House Energy Rating Scheme (NatHERS)](#).

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 27 and coefficients in Appendix B. The monthly and daily energy are then determined in accordance with Equation 28 and Equation 29 using coefficients from Appendix C. The share of daily energy is then determined for 4 separate components (*A*, *B*, *C* and *D*) using a third-order polynomial with coefficients specific to each component, as defined in Equation 31 to Equation 34 (reproduced below):

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

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

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

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

In summary:

- Component A applies to Hours 0% (i.e. hours of 0% hot water demand = hours 1–7, 10, 11, 13, 15, 20–24)
- Component B applies to Hours 10% (i.e. hours of 10% hot water demand = hours 12, 14)
- Component C applies to Hours 12.5% (i.e. hours of 12.5% hot water demand = hours 16, 17, 18, 19)
- Component D applies to Hours 15% (i.e. hours of 15% hot water demand = hours 8, 9).

The following equation should be used to validate the values for the 4 components (Equation 35, reproduced below):

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

Appendix E – NatHERS 7-star energy loads

Appendix E data table is provided in a MS Excel format at Whole of Home National Calculations Method | Nationwide House Energy Rating Scheme (NatHERS).

Appendix F – Postcode list

The postcode list contains over 2,600 rows of data, and so is provided as a spreadsheet. Please contact the NatHERS administrator if you require a copy.

Appendix F data table is provided in a MS Excel format at Whole of Home National Calculations Method | Nationwide House Energy Rating Scheme (NatHERS).