E3 Equipment Energy Efficiency

Australian Government

New Zealand Government

Hot Water Systems Discussion Paper: Comparative Technology Method for Evaluating the Performance of Hot Water Systems

A joint initiative of Australia, State and Territory and New Zealand Governments

Contents

1. Introduction

1.1 Overview of Discussion Paper

Hot water systems are a priority group of products for the 'Equipment Energy Efficiency' (E3) program due to their estimated 25% contribution to residential energy consumption.[1]

To promote the adoption of energy efficient and low running cost water heating technologies in trans-Tasman homes, the Australian and New Zealand governments and jurisdictions, have already deployed a range of policy and regulatory actions[2] including:

- Renewable energy and energy efficiency certificate schemes that support uptake of energy efficient water heaters.
- Building regulations that specify low carbon water heating systems be installed in new homes to reduce greenhouse emissions, energy consumption and household running costs.
- Minimum Energy Performance Standards (MEPS) under the E3 program for certain trans-Tasman water heating appliance technologies.

Future options for governments to consider include:

- Enabling government energy efficiency certificate schemes to support market development for low carbon water heating options that may be targeted differently in different jurisdictions.
- Facilitating improved decision making at point of purchase by provision of advice to consumers, (either directly and/or through purchasing channels), on water heating energy costs and greenhouse emissions specifically tailored to the consumer's particular situation, and for the range of water heating products that they can choose from.

To facilitate these options, it would be beneficial to establish a single uniform trans-Tasman database covering all water heating products. The database would hold data on the performance of water heating systems across all climate zones in Australia and New Zealand, including a range of hot water consumption profiles required in different households.

A central repository of hot water systems information would minimise the burden on industry in providing the data required for proposed policy actions and potential future information programs across the range of jurisdictions covered by E3.

1.2 Purpose of this Discussion Paper

This purpose of this document is to provide a basis for consultation with stakeholders such as the water heater supply industry, Government agencies and consumer groups. This discussion document will facilitate feedback on the proposed method for evaluating the performance of hot

[1] Residential consumption range is 23-28% and equates to 85PJ/yr in Australia and 16PJ/yr in NZ in 2014.
[2] Some of these actions are yet to be developed. Additional consultation will be undertaken as part of that development.

water systems that can be used as the basis to support E3 programs and a trans-Tasman water heater database.

This document addresses the methodology and modelling approaches considered appropriate for each of the main hot water system technologies, confirmation of the robustness of the methodology and modelling approach proposed, and provides background commentary on the development of the methodology.

1.3 Making a submission

Written submissions on the issues raised in this paper should be provided by e-mail by 1 March 2021. Submissions should include the subject line 'Hot Water CTM'.

Questions are provided at the end of each section. Stakeholders are encouraged to work through these questions while reviewing the paper.

Submissions can be sent to:

Australian Government Department of Industry, Science, Energy and Resources
E: EnergyRating@industry.gov.au

Energy Efficiency and Conservation Authority (EECA) of New Zealand
E: star@eeca.govt.nz

1.4 Purpose and basis of the Comparative Technology Method

It is proposed that a Comparative Technology Method (CTM) be used to provide a means to measure and compare the efficiency of combinations of residential hot water technologies installed in locations throughout Australia and New Zealand delivering hot water loads to representative households of differing sizes.

A single uniform database of water heaters will require a robust and consistent performance evaluation methodology to support the provision of comparative hot water system performance data that can usefully compare system performance across technology types. This performance data can be used as the agreed basis of water heater system performance for a range of Government incentives and regulatory programs as well as providing the basis of a proposed application-based consumer comparison tool.

The CTM will be based on a clear set of principles (Refer Section 4) to consistently evaluate the performance of water heaters and proposes a method that will deliver on these principles. It will also enable improvements in the CTM should test measurement approaches change in the future, as well as the addition of new technologies where appropriate.

The proposed CTM will use existing test method inputs initially, which will help to keep industry costs to a minimum. This will provide initial data that can be used for modelling water heater performance (using AS/NZS 4234:2021) and support the early development of the proposed comparison tool.

Current test methods are fit for this purpose, but it is expected that improvements will be made over time to refine them. Such improvements could include:

- Providing test data to allow the calculated annual energy consumption to be validated
- Tests to demonstrate improved performance for innovative products with better control systems
- Gas instantaneous water heater performance at less than maximum flow rate and with elevated inlet temperature
- Including the impact of retained heat between draws on gas instantaneous water heater performance
- Storage water heater recovery rate after major draw-down (maximum heating rate)
- Storage water heater reheating from warm rather than cold (e.g. after standing period with no draws)
- Any special controls to meet Legionella requirements and,
- Draw profiles that might affect stratification/mixing of storage tank.

1)	**Is the proposed basis of the CTM reasonable? And, if not, what basis should be used instead?**

1.5 The Function of the CTM compared with MEPS (Minimum Energy Performance Standards) and Labelling

MEPS for water heaters started with electric storage water heaters in Australia in 1999, and in NZ in 2002. MEPS for small electric water heaters were made more stringent in 2005. Different requirements were applied in each country, due to market differences. In 2013, changes were proposed to move Australia and New Zealand to a single method of test and MEPS level, but this work ceased in 2014, in accordance with E3 program prioritisation. Gas water heaters have been required to comply with MEPS requirements since 2011 in Australia and 2013 in New Zealand. However, as MEPS is the lowest limit for a product to be allowed on sale it must be based on a rigorous test that is readily repeatable and be measured to give a precise[3] value.

There is currently no mandatory Government-led energy labelling for any hot water technologies in NZ or Australia. Gas water heaters have been subject to an industry-based energy rating label in Australia since 1987, which is part of the mandatory certification requirements for gas appliances. In the 2000s, the industry compliance standards transitioned to Australian Standards.

The CTM for water heaters is intended to be the basis of providing specific information to a purchaser based on their particular load and climate zone. As such, it will be more informative for householders at the time of purchase and to the wider intermediaries who influence householders' decisions than a traditional label.

Consequently, the CTM will leverage the benefits of the existing measurements of performance to provide credible information directly relevant to the purchaser's situation. It will be able to be used by purchasers, suppliers and installers to inform their purchase decisions.

[3] Precision is the closeness of multiple measurements of the same parameter to each other.

As a CTM will provide performance information when delivering an estimated load (based on a household's estimated hot water use), it is not required to be as precise as a MEPS test (which is designed to precisely measure performance against a set minimum). However, it needs to provide an accurate[4] evaluation of comparative performance. The CTM also needs to be able to take into account a number of factors often best accounted for in a computer simulation.

[4] Accuracy is closeness of the measurements to a true value.

2 Background

A new E3 hot water workstream began in 2018. The objectives of this work included:

- Reduced household energy use from water heating
- Reduced greenhouse gas emissions from water heating
- More informed consumer water heater purchasing decisions.

In Australia, the E3 program is managed by the Greenhouse and Energy Minimum Standards (GEMS) Regulator in conjunction with the Energy Efficiency Advisory Team (EEAT). In NZ, the E3 program is managed by the Energy Efficiency and Conservation Authority (EECA).

A five-year trans-Tasman policy framework[5] and roadmap was produced in late 2018 and formed the basis of a stakeholder consultation process with trans-Tasman industry, consumer groups and Government agencies between November 2018 and January 2019.

Options proposed included the provision of improved information to purchasers, a review of current minimum energy performance (MEPS) levels and extension of MEPS to include additional water heating technologies.

While there was some industry resistance to product labelling and potential changes to MEPS and development of new test methods, there was recognition that, for success, system performance information needs:

- To be specific to the householder's situation and be tailored to:
  - Provide the metric(s) that are important to a purchaser based on household hot water usage and regional characteristics, be it running costs based on their particular energy tariff, or local greenhouse impacts, or both.
  - Estimate the energy performance of the water heating system, based on local climatic conditions.
  - Allow for new technology to be added over time as new products are developed, and.
  - Allow users to adjust for the impact of actions that they have taken already, e.g. to allow for them to include PV supplied direct to the water heater or through diverters.
- To use currently available data as much as possible so that it:
  - Does not require much, if any, additional testing, thereby avoiding effort, cost and delays: and,
  - Does not need to be delayed for new measurement standards to be produced.

In particular, it was agreed that it is important to know typical hot water draw-off profiles and that this should be pursued as a priority task.

Responses from that consultation process have helped guide the development of this CTM consultation document.

[5] A Policy Framework for Hot Water Systems in Australia & New Zealand see: https://www.energyrating.gov.au/document/policy-framework-hot-water-systems-australia-new-zealand

The two key objectives from the current E3 Hot Water Systems work program relate to proposing a comparative technology method for all in-scope technologies, and the development of a comparative performance tool to enhance informed consumer purchasing decisions.

Both objectives will require a comprehensive database of all available water heater technologies including product specifications and performance metrics along with a comparative technology method (CTM) applicable to all technologies and energy sources.

Realistic evaluation methodologies will also require an understanding of typical household draw-off profiles (pattern and amount of hot water use) across NZ and Australia. The NSW Department of Planning, Industry and Environment (DPIE) has just begun a household hot water monitoring project that will collect data on hot water usage in 200 homes across NZ and Australia. This is described further in Section 9.

3 Scope

Water heater system types in scope for the Comparative Technology Method (CTM) include the following main categories of water heaters:

- Electric storage water heaters (ESWH)
- Electric instantaneous water heaters
- Gas instantaneous water heaters
- Gas storage water heaters
- Solar water heaters including, both thermal collectors and photovoltaic (PV) powered
- Heat pump water heaters (HPWH), grid powered and/or PV powered.

There are numerous possible combinations of these main technology types with various energy sources and technical variations. All combinations of water heater system types considered within the scope of this work are shown in Figure 1. It has been assumed that the types of water heaters currently in use in Australia and NZ, as shown in Figure 1, will continue to be common choices by homeowners.

2)	**Is the scope of water heaters proposed to be included within the CTM appropriate or is it too broad, or not sufficiently broad?**

Figure 1 - Permutations of Technology and Energy Source

4 Comparative Technology Method Principles

The following principles define an effective CTM:

1. The method should allow the calculation of annual purchased energy for a range of water heater types/products based on a function or model linking annual purchased energy to hot water load taking into account:
    a. Location (climate),
    b. Hot water consumption end use pattern and,
    c. The characteristics of the water heating technology.

    The method used for each type of water heater should be appropriate to the complexity of the water heater and provide a "level playing field", so no technology is inherently advantaged or disadvantaged.

2. The method should be sufficiently rigorous to provide clear performance estimation without unnecessary complexity. This should minimise the opportunity for "gaming" the system and maximise the confidence in the results for equipment suppliers, regulators, installers and consumers. Sufficiently rigorous means that the performance calculated will be sufficient to allocate the water heater into different performance levels and provide useful estimated running costs for different situations.
3. The method should utilise existing international and trans-Tasman test method results and available data as much as practicable and be capable of accepting results from improved testing as it becomes available. This will minimise the costs for trans-Tasman equipment suppliers to utilise the CTM and allow for quick take up. The CTM should minimise:
    a. Requiring additional laboratory capacity and needing to upgrade equipment and train staff
    b. Manufacturers needing to understand the new requirements and incurring additional expenses testing products to a new method
    c. Disruptive misalignment with building codes which could require extensive delays waiting for building/plumbing code update cycles.
4. The performance calculations should take into account the climate conditions and key factors representative of the trans-Tasman water heater installations so that purchasers can have a reliable estimate of the annual purchased energy needed to provide hot water for households in different locations in Australia and New Zealand.
5. The method should be software neutral so that the modelling could be carried out using any comprehensive modelling environment.
6. Water draw shall be defined as energy added to the cold water to provide hot water (in MJ) rather than the volume of hot water. If a water heater runs out of capacity and can no longer provide water above a useful floor temperature required for the draw off demand, then the heater can be considered as unsuitable for that load amount and pattern.

3)	Are these principles fair and reasonable and what, if any, alterations, additions or deletions should be considered?

5 How will the CTM be used for the benefit of hot water systems purchasers?

The CTM will be used to provide comparative information primarily during a purchase decision. Consequently, the 'Comparison' will be from the perspective of a specific, not generic user, as would be the case in a 'label' type output.

The performance of the product will be modelled at three separate loads for each climate zone and a performance equation curve fitted to those points. The equation will provide a function relating the energy purchased (electricity, gas or both) to the amount of hot water used. Separate equations will be developed for each climate zone.

These equations will be the key output data from the database for each product.

A purchaser, or intermediary advising the purchaser, will be able to put into a tool the specific householder details including:

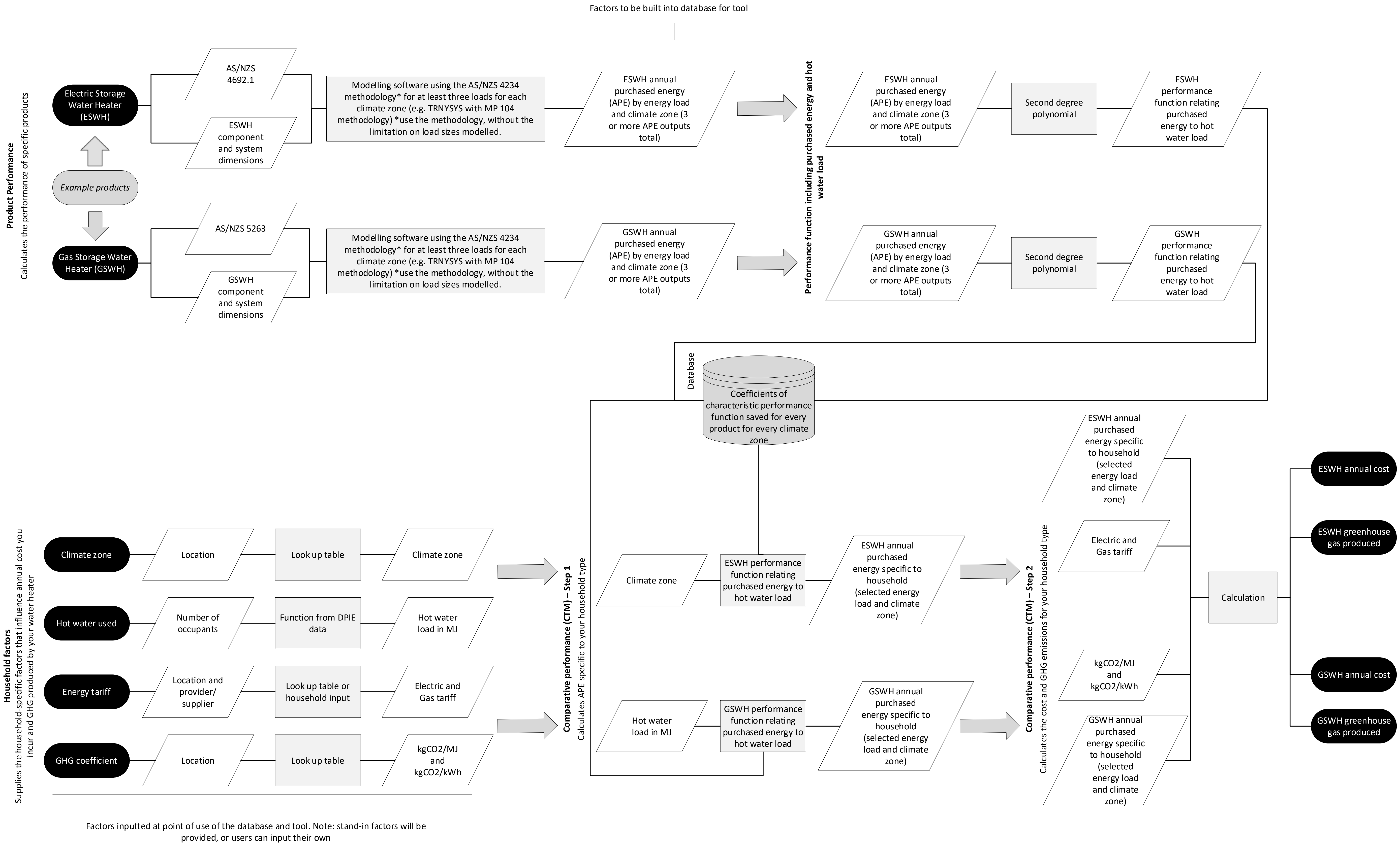
- Location which will give climate zone, and (potentially), generic tariff data, (i.e. if the user doesn't put in specific data from their energy bills)
- Household details that will be fed into an equation that will come from the DPIE (NSW) hot water consumption monitoring to provide the estimated hot water load for that household
- Which type(s) of appliances they are interested in, or a list of models that they may have been quoted.

The tool will then choose the relevant (product, climate) performance equation(s) from the database, and input the calculated hot water load to produce the estimated amount of gas or electricity or both that will need to be purchased to supply that amount of hot water to that household.

The purchased energy can then be used to calculate the energy costs, using tariff information, or greenhouse gas emissions (GHG), using fuel GHG coefficients. The energy consumed, the energy cost or the GHG produced will be the comparative information available to the purchaser to inform their decision. The tool may also have an option for the user to put in purchase and installation costs based on any quotes that they have so that they get a more complete cost comparison.

A diagram illustrating how the CTM will produce comparative outputs is provided below:

Figure 2: Use of the CTM to Provide Comparative Outputs



6 Proposed Method

Evaluating performance across the range of water heater types for the range of hot water consumption and climates under consideration would not be feasible using a simple laboratory test and extrapolation to different loads and climate situations.

This is especially the case for complex products such as heat pump water heaters (HPWHs) and solar water heaters where local weather conditions significantly impact performance. Consequently, simulation of performance with input of realistic climate data is used internationally to provide estimated annual performance of water heaters.

In a report by Ecotope[6] regarding energy use by heat pump water heaters for the Northwest Energy Efficiency Alliance in the USA they state: "To accurately estimate heat pump water heater energy use across houses in the Northwest, it is necessary to understand their behaviour well enough to predict performance under a wide variety of operating conditions and installation scenarios. The operating conditions span a range of ambient air temperatures, inlet water temperatures, and occupant hot water use patterns. Installation scenarios span the range from conceptually simple garage locations to complex configurations .... Consequently, to assess all possible operating conditions and installation configurations, we turn to software simulations, supported by field measurements".

The proposed method to evaluate water heater performance across the multiple technologies used in water heating across Australia and New Zealand in a range of different households is to base it on the methodology used in AS/NZS 4234 *Heated water systems - Calculation of energy consumption.*

The strength of this method is that it is a Component Test System Simulation (CTSS) evaluation that allows calculations to be done for different climate zones and for different loads and can be readily adapted to cover the expanded range of hot water technologies under consideration.

The AS/NZS 4234 standard is currently being revised and the public comment draft includes a new method to interpolate performance between a range of loads, which is a significant benefit when assessing system efficiency with variable hot water demand. The draft standard also moves the reference to modelling software to an associated miscellaneous publication, MP104 *Modelling of heated water systems in accordance with AS/NZS 4234-2021 using TRNSYS.*

On balance, the methodology within AS/NZS 4234-2021 is an ideal starting point for the CTM – whilst acknowledging that the method may need to be modified and strengthened to make it sufficiently robust to meet all the objectives of the current E3 Hot Water Systems work program.

A similar approach is used in Australia by the Clean Energy Regulator and the Victorian Energy Upgrades program to assign deemed savings to solar and heat pump water heaters. In these cases, they use the AS/NZS 4243-2008 Standard but require some additional constraints to maximise consistency.

AS/NZS 4234-2008 is used and supported by both industry and government in Australia and NZ and a similar method is also used in the United States of America by the Solar Ratings and Certification Council. The CTM method proposed in this document builds on AS/NZS 4234, adding a method to

[6] Pages 10, 11 and 12 of https://neea.org/img/uploads/heat-pump-water-heater-saving-validation-study.pdf

evaluate purchased energy across a range of loads and a method to turn the purchased energy into costs or GHG.

For each technology, a modelling approach of "simple" or "complex" is proposed.

Simple Method

A simple method will consist of a characteristic equation linking performance to hot water load. The equation will be developed by correlation of model output with climate data, hot water consumption etc., and may have different coefficients for different climate zones. The simple equation may include parameters derived from testing and an analysis of annual performance using the characteristic equation in the complex model simulation of annual performance. The correlation equation would be specific to each water heater type or in some situations may be limited to subtypes.

For example - A simple modelling approach may be suitable for instantaneous gas water heaters except for heat loss between load events. More complex transient modelling will be required if load events are within two heat loss time constants[7]. As the time constant could be of the order of one hour, heat loss will have some effect for most load patterns.

Complex Method

A method that uses a Component Test System Simulation (CTSS) such as AS/NZS 4234 provides a suitable approach for complex water heaters[8] with a minimum of adjustment to the Standard's methodology.

This method uses component test results generally from tests specified in other standard methods to develop a computer simulation model using the TRNSYS[9] modelling environment and a number of standard templates.

This method is used for solar and heat pump water heaters (see Appendix 1: Overview of AS/NZS 4234:2021).

The standard method calls up four different loads in each climate zone. The loads are defined as the amount of energy needed to be added to the water by the system to provide the required quantity of hot water. Note that loads are defined as an amount of energy rather than a volume of hot water as the majority of the uses of hot water are defined by energy (i.e. a set outlet temperature and a volume or flow rate of hot water) rather than a volume of hot water. The loads vary by climate zone to take into account the additional energy required to heat colder water and the additional volume of water that is likely to be used by householders in cooler climates.

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[7] A time which represents the speed with which a particular system can respond to change, typically equal to the time taken for a specified parameter to vary by a factor of $1 - 1/e$ (approximately 0.6321)

[8] Complex systems include: solar water heaters, heat pump water heaters and 'simple' technologies with complex control systems.

[9] TRNSYS is specified in the current version of AS/NZS 4234. Standards committee CS-028 is undertaking a project to update that standard which will include removing the specification of TRNSYS. A Miscellaneous Publication (MP104) will be prepared by CS-028 to define the way that TRNSYS can be used with the revised standard.

In AS/NZS 4234 there is a method to define which load is suitable for a particular product, but there is no requirement to evaluate performance for different loads[10].

Relationship between household details and estimated hot water loads

A comprehensive monitoring project, managed and funded by DPIE in NSW (refer Section 9), is about to begin to monitor hot water loads across Australia and New Zealand.

The results of this monitoring project will include defining a relationship between hot water load and household size, demographics and other factors for a range of representative climate zones across the two countries. This will provide the hot water load input to the CTM.

4)	**Is the proposal to use a method based on AS/NZS 4234:2021 and SA/SNZ MP 104 reasonable? Should any modifications be required?**

[10] The revision of AS/NZS 4234:2021 will include a method to interpolate performance over a wide range of hot water consumption if each water heater is evaluated under a range of loads.

7 Modelling Environment

The proposed methodology is to be software neutral. This is consistent with AS/NZS 4234-2021 which will be software neutral after the current revision and will no longer refer to TRNSYS. AS/NZS 4234-2021 will refer to an associated miscellaneous publication, MP104 *Modelling of heated water systems in accordance with AS/NZS 4234 using TRNSYS*, that will specify the application of AS/NZS 4234-2021 using the TRNSYS modelling package.

There remains an option for software providers to prepare similar miscellaneous publications to cover other modelling environments using a verification procedure specified in AS/NZS 4234-2021.

It is proposed to align the CTM evaluation method with the revised AS/NZS 4234-2021 standard and the Clean Energy Regulator and VEU requirements as much as possible so as to avoid industry confusion and duplication of effort resulting from different requirements for different uses.

AS/NZS 4234-2021 is general enough to cover any comprehensive modelling environment to simulate water heaters.

It is proposed that TRNSYS[11] will be used as the reference modelling environment as its models are openly documented and well accepted. Other software models can be used however, they will need to provide evidence that the simulations of all water heater types using that software will give results that are within 3% of the TRNSYS model results, or task test results, if available, for each water heater type.

MP104 will also provide templates to facilitate auditing of the modelling files. If other modelling environments and templates are covered by additional miscellaneous publications, they can be called up if regulators have confidence that the results will be consistent.

There are two ways to verify modelling outputs – match with other simulated data (i.e. results from TRNSYS modelling); or match with real measured data. Measured data may seem better, however getting sufficient accurately reported measured data is likely to be difficult, time consuming and labour intensive for some technologies. A comprehensive model of an instantaneous gas water heater has been developed using TRNSYS and initial analysis indicates a very good fit to existing laboratory test data[12].

As laboratory time is expensive, any additional testing should only be required where justified by the need for additional data certainty, to avoid barriers to entry of new or improved products.

Solar water heaters would require approximately 6 weeks of testing (for example using AS 2984) so this will be infeasible. Fortunately, at the time of developing the CTSS standard in early 1990s extensive comparisons were made between the measured and simulated annual performance of

[11] TRNSYS (Transient System Simulation Program) - a flexible based software environment used to simulate the behaviour of transient systems. TRNSYS was developed by the University of Wisconsin in the 1970s and has subsequently been added to by other modellers so that it now covers a range of water heating technologies as well as Solar PV and building performance. TRNSYS is used in the calculation of STCs for water heaters for the Australian Renewable Energy Target as well as the Victorian Energy Upgrades program.

[12] Morrison G.L. “Annual performance rating of instantaneous gas water heaters” 15 April 2020

solar and heat pump water heaters[13]. This comprehensive verification of the AS/NZS 4234 modelling against AS 2984 test results makes it unnecessary to have additional testing for solar water heaters.

5)	**Is the proposal to use a software neutral modelling environment reasonable?**

[13] [1] Simulation of the Long-Term Performance of Thermosyphon Solar Water Heaters Solar Energy V33,515-526, 1984 https://www.dropbox.com/s/ce69s98nownla5o/simulation_long_term84.pdf?dl=0
[2] Solar Domestic Water Heater Design Sensitivity Study Report 1986/FMT/2 (Kensington, University of New South Wales) https://www.dropbox.com/s/f8heleamwc86w0o/design2.pdf?dl=0
[3] System Modelling and Operation Characteristics of Thermosyphon Solar Water Heaters Solar Energy V34, 389-405, 1985 https://www.dropbox.com/s/6cpc0f0llxomdfo/thermosyphon_braun_morr.pdf?dl=0
[4] Correlation of Solar Water Heater Test Data Solar Energy V39,135-142 1987 https://www.dropbox.com/s/0lo5x1tcgw9g4q1/correlation87.pdf?dl=0
[5] Simulation of packaged solar heat-pump water heaters Solar Energy V53,249-257, 1994 https://www.dropbox.com/s/u1htn61vx8t276b/Packaged%20HP.pdf?dl=0

8 CTM Procedure

The CTM procedure will be based on the revised AS/NZS 4234:2021 and SA/SNZ MP 104[14] once published. The following proposed procedure is based on current understanding of the public comment draft of the standard, but as the standard may change from that in the public comment document, this procedure is not a final document and may change over time.

The following section is a draft of a stand-alone procedure that will be available to guide water heater suppliers to model their water heaters' performance using the CTM:

This procedure provides instructions for modelling of water heating products to calculate the annual purchased energy when applying for products to be included in the trans-Tasman water heating database Register of Products.

The Procedure

The products covered by this guide are:

- Electric storage water heaters (ESWH)
- Electric instantaneous water heaters
- Gas instantaneous water heaters
- Gas storage water heaters
- Solar water heaters including, both thermal collectors and photovoltaic panel (PV) powered
- Heat pump water heaters (HPWH), grid powered and/or PV powered.

8.1 Modelling Requirements

8.1.1 TRNSYS Modelling

Modelling shall be conducted in accordance with AS/NZS 4234:2021 (*Heated water systems – Calculation of energy consumption*) using the TRNSYS program in accordance with SA/SNZ MP 104.

The modelling is to be carried out for all trans-Tasman climates zones relevant to the market for each product.

The boosting regime modelled must be consistent with the way the product will be installed. The modelling shall show compliance with the Legionella control requirements specified in AS 3498-2009 for Australia and Section G12/AS2 of the New Zealand Building Code for New Zealand.

To model thermosiphon SWHs and thermosiphon sidearm heat exchangers, use extension package TRNAUS.

The product is to be modelled for at least three loads in each zone so that a performance curve can be developed over the range of loads as specified in Appendix F of AS/NZS 4234:2021 "Calculation of performance at other hot water loads".

[14] The CTM procedure refers to TRNSYS files. If any alternative modelling software is validated, then the relevant modelling files would need to be substituted for the listed TRNSYS files.

Note that for solar and heat pump water heaters some loads used may be higher than the load chosen to comply with Section 3.5 “Domestic hot water load selection” of AS/NZS 4234:2021. Also, If the output does not achieve the water temperature minimum limit specified in Section 3.6.3 “Minimum delivery temperature”, then the maximum load that meets the temperature requirement shall be reported for each climate zone. This is required to ensure that the system can deliver the selected loads above the minimum temperature limit in the middle of winter in each climate.

8.1.2 Presentation of results

Results shall be presented in the current version of the Water Heater Product Application Form available at the database website.

The curve of energy consumed vs. load for each climate zone model shall be provided.

8.1.3 Documents required

The following documents must be provided:

- All test reports that produce parameter values used in the modelling must be provided.
- TRNSYS .dck, .lst and .out files
- Report on the fitting of the curve of load vs energy consumption for each zone modelled
- To allow calculation of running costs for time-of-use tariffs, modelling results of purchased energy may be reported by tariff periods.

8.2 For solar water heaters

8.2.1 Key model parameters

For solar water heaters the calculation of energy consumption shall use the collector inclination and orientation as below:

- For Australia - Collector inclination=25°, azimuth=0° North (as per the “North Orientation” in AS/NZS 4234:2021 Table A3).
- For New Zealand - inclination=35°, azimuth=0° North for both Zone 5 and Zone 6.

8.2.2 Boosting regime

The boosting regime modelled must be consistent with the way the product will be installed.

8.2.3 Off-peak boosting

Electric boosted solar water heaters intended to be installed with off peak boosting should be sized to minimise boosting required during peak times. The model shall separately report the total energy supplied in each boost period (peak and off peak) throughout the modelling calculation.

8.2.4 Off-peak electric boost availability times

For off-peak electric boost availability times, refer to the AS/NZS 4234:2021 “night rate”.

8.2.5 Off-peak electric boost systems with one element

Off-peak electric boost systems with one element may be set to allow the booster to be energised with a 'one shot' boost if the delivered water temperature falls below a set threshold, with the control reverting to regular operation after one boost cycle. This feature may only operate once per day.

8.2.6 Continuous boosting

For electric boosted solar water heaters and heat pumps that are to be installed on continuous boosting tariff, the system should be modelled with the boost control in continuous mode. If so, the results must note that the modelling assumed a continuous tariff.

8.2.7 Variable thermostats

Products with variable thermostats which facilitate user override are acceptable. The thermostat setting used in the model must meet the following conditions:

- The model setting is within the range of settings available for the actual product; and
- The model achieves the following related Standards requirements:
    - Minimum delivery temperature of 45°C; and
    - The product must control for Legionella complying with the Legionella control requirements specified in AS 3498-2009 for Australia and Section G12/AS2 of the New Zealand Building Code for New Zealand.

8.2.8 User over-ride of time-limited boosting and one-shot boosting

The concept of time limited boosting used in off-peak electric water heaters has been adopted in solar with gas boosting storage water heaters. If the time clock or controller settings are adjustable by the user then there may be a significant reduction of solar contribution. User adjustment of the boost control could occur during periods of bad weather or when there is a short-term high demand.

8.2.9 Automatic resetting controls

The modelling methodology accounts for the potential user adjustment of auxiliary boosting by requiring that the controls automatically reset to the conditions used for the rating analysis within 24 hours of any user adjustment of the controller.

Both gas and electric products that allow user over-ride of an auxiliary booster control that automatically resets within 24 hours should be modelled using a 'one-shot' boosting option that is initiated when the delivery temperature drops to a level where the product would fail the minimum delivery temperature requirement. This feature may only operate once per day. The one-shot threshold temperature should be 45°C or higher depending on the product design.

8.2.10 Permanent user over-ride controls off-peak boosting

Products that allow the user to reset the boost controller and that do not automatically reset to the operating conditions used during the rating calculation should be modelled with the boost control in continuous mode.

8.2.11 Mid-winter load delivery

The system must report the minimum delivery temperature under each modelled load as specified in AS/NZS 4234:2021. The purpose of this requirement is to ensure the consumer has sufficient hot water through periods of low solar gain.

8.3 For heat pump water heaters

Use the TRNSYS templates available with SA/SNZ MP 104.

8.4 For gas instantaneous water heater heaters

The model shall use the TRNSYS deck template from AS/NZS 4234:2021 or the revised template for transient modelling to model the performance of the water heater. The template is available from the database website.

If the Transient modelling template is used to account for the impact of retained heat between draws on gas instantaneous water heater performance, the heat loss coefficient of the heater shall be the value found from a heat loss test to be provided.

8.5 For gas storage water heaters

The model shall be based on the TRNSYS template deck in SA/SNZ MP 104.

8.6 For electric storage water heaters

The model shall be based on the TRNSYS template deck in SA/SNZ MP 104.

8.7 For electric instantaneous water heaters

The model shall use the TRNSYS deck template from AS/NZS 4234:2021 or the revised template for transient modelling to model the performance of the water heater. The template is available from the database website

If the transient modelling template is used to account for the impact of retained heat between draws on the instantaneous water heater performance, the heat loss coefficient of the heater shall be the value found from a heat loss test to be provided.

8.9 For direct PV powered electric storage water heaters

The model shall be based on the TRNSYS template deck in SA/SNZ MP 104.

For solar PV powered water heaters, the calculation of energy consumption shall use the PV panel inclination and orientation as below:

- For Australia - Collector inclination=25°, azimuth=0° North (as per the “North Orientation” in AS/NZS 4234:2021 Table A3).
- For New Zealand - inclination=35°, azimuth=0° North for both Zone 5 and Zone 6.

8.10 For direct PV powered heat pump water heaters

The model shall be based on the TRNSYS template deck in SA/SNZ MP 104.

For solar PV powered water heaters, the calculation of energy consumption shall use the PV panel inclination and orientation as below:

- For Australia - Collector inclination=25°, azimuth=0° North (as per the “North Orientation” in AS/NZS 4234:202x Table A3).
- For New Zealand - inclination=35°, azimuth=0° North for both Zone 5 and Zone 6

9 Draw Off Profiles

Testing and modelling for all hot water systems should ideally be based on realistic typical household water heating quantities rather than the current methods used for gas water heaters and electric storage water heaters that are largely unrelated to actual household usage.

Sustainable Energy Transformation (SET) carried out research[15] into information available on household hot water draw-off quantities and profiles in Australia and NZ, as well as investigating a range of international studies. This work identified that there is no single source of draw-off profile data that can be utilised as a basis for testing or modelling.

However, that study also concluded, through TRNSYS modelling, that for a given total hot water draw, the draw off pattern[16] didn't have a large impact on the efficiency of the water heater.

The research was able to identify key factors that impact on household hot water draw-off quantities. The key determining factor is the number of occupants (or the number of bedrooms if occupancy data is not available). The relationship between number of occupants and water used is almost linear. The volume of water used per occupant decreases slightly with increasing occupant numbers suggesting that here is a base load for some appliances when only one occupant and then an approximately steady additional quantity used per additional occupant.

Other factors that impact hot water use include:

- Climate
- Seasonality
- Water heater type
- Householder attitudes to water and energy use

Given the lack of information on draw-off profiles and the importance of this information to the overall project, the NSW Department of Planning, Industry and Environment (DPIE) has embarked on a project to install hot water monitoring equipment in a sample of 200 homes throughout Australia and NZ. This project aims to capture data that is as representative as possible of various climate zones, water heater types and household sizes within the constraints of the project budget. Seasonality is a factor in hot water use, so the monitoring project was originally planned to run for at least 12 months and will begin generating data from December 2020. With the recent changes in householders spending more time at home due to Covid-19, the monitoring may be extended into 2022.

The output of this work will lead to the development of a number of typical household draw-off profiles. Of particular interest for understanding energy consumption of instantaneous water heaters will be the typical number of hot water draws, as the initial hot water use requires the instantaneous water heater heat exchanger to also be heated. The study will also provide statistical information on mean daily household water use that can be analysed to determine the impact of a

[15] Understanding Which Factors Influence a Proposed Household Hot Water Draw-Off Profile Study – June 2019

[16] The variation of hot water used at different times throughout a representative day as a percentage of the total hot water use amount. Based on a range of different patterns used in standardised tests in Australia, New Zealand, EU and USA

range of factors such as household size, climate zone, water heater type etc. By measuring hot water consumption over at least a 12-month period, the study will also illustrate seasonal variation in hot water use.

This information can then be used as the basis of test methods and modelling as well as being incorporated into the proposed water heater comparison tool.

In the meantime, good progress can be made in developing the CTM in the absence of the DPIE data and this information can be incorporated as it becomes available.

10 Other Markets

The USA and European Union (EU) have considerably different markets for water heaters. They also have different approaches to energy labelling of water heaters both between these two regions and in comparison with Australia and NZ.

The EU provides a comprehensive but complex label and has ten separate tapping profiles that could be used, although three tapping profiles cover the most likely uses.

The EU system is based on nominal primary energy consumption rather than secondary energy which is the basis for the USA approach. Primary energy is used in the label to facilitate comparison of products that use electricity and gas. Primary sources of energy can be used directly, as they appear in the natural environment e.g. natural gas, while secondary sources of energy derive from the transformation of primary energy sources e.g. electricity generated from the combustion of coal or gas.

The USA provides a Uniform Energy Factor (UEF), which is analogous to efficiency and which is available to purchasers through a web listing. Different water heater types are required to meet different minimum UEF values to be allowed to be sold.

The UEF can be based on one of four loads which in 2015 replaced a single large load with only 6 draw-offs. There are some concerns from Industry that the 2015 National Appliance Energy Conservation Act (NAECA) requirements are too onerous, and this is leading to additional costs for consumers. In particular larger electric storage water heaters will need to have heat pump heating to displace some of the energy used in a resistance element, in order to meet the minimum UEF. This has led to some unforeseen outcomes such as where multiple small lower efficiency water heaters are installed rather than a single high efficiency unit.

There is no international consensus on which metric is most useful in labelling. The EU uses a nominal primary energy approach, and the USA uses costs. The use of primary energy in the EU is to allow a more appropriate method of comparison between electric and gas fuelled water heaters as the combustion losses occur on different sides of the meter with these two fuels. This attempt at a more comprehensive comparison has some unresolved issues but is generally well received across the range of EU countries despite the diversity of primary sources for electricity across the EU.

11 Exclusions

Consideration has been given to additional emerging and low volume water heating technologies. The purpose of doing so has been to ensure that the broadest practicable range of technology types are included in this work. Emerging technologies that may become more common in future are also to be considered to ensure, as far as practicable, that technologies are not excluded from consideration. Balancing that approach has been a consideration of not investing a disproportionate amount of time and effort into including technologies that are unlikely to become popular in the short to medium term or where the details of the operation of the technology are not yet sufficiently specified in order to be able to develop a suitable approach. However, the proposed method, database and consumer tool will be designed to be flexible enough to add in new technology as required.

The technologies currently excluded are:

- Large tank water heaters with solar thermal preheat section and high temperature PV/grid heated section with a control objective of minimising grid usage.
- Demand response enabled water heaters. The water heater will be included but, as demand response will not affect performance, no efficiency allowance for the inclusion of demand response will be made (i.e. demand response capable units are expected to assist with load shifting and their impact on consumer costs will be reflected in the consumer tool calculations).
- Combi technology for non-hot water purposes. To include these technologies will require estimated consumption of heat by the non-hot water end uses. This is possible but will not be done at this stage.
- Water preheating using heat recovery from fuel cells or PV panels.
- Gas-fired absorption heat pump water heater.

6)	**Are any of the above exclusions inappropriate and if so, what would be the rationale for their inclusion?**

Appendix 1. Overview of AS/NZS 4234 Heated water systems - Calculation of energy consumption

AS/NZS 4234:2021 *Heated water systems - Calculation of energy consumption* is a component test system simulation (CTSS) method to calculate the purchased energy required to provide a specific amount of hot water in a specific climate.

The current AS/NZS 4234:2008 *Heated water systems - Calculation of energy consumption* methodology is summarised below.

Components of the system are characterised by the use of test results from standardised tests in other standards:

- **Electric storage heated water systems** and **tanks used for solar or heat pump water heaters** are tested to assess the heat loss from the tanks under set conditions using standard AS/NZS 4692.1:2005 *Electric water heaters - Part 1: Energy consumption, performance and general requirements*. This heat loss characteristic is based on a set temperature difference and a fully heated tank. Modelling takes into account the temperature surrounding the tank, the volume of the tank that is heated and the temperature of that water. This is done by modelling temperature stratification in the tank and accounting for the variation of heat loss from different sections of the tank due to the variation of insulation thickness around the tank.
- **Gas storage water heaters** are evaluated using AS/NZS 4552:2005 *Gas Water Heaters for hot water supply and/or central heating*[17] to characterise the maintenance rate and the thermal efficiency of the water heater. This can also be used for solar water heaters with gas boosting into the tank. Stratification is also included in the model in a similar manner to electric tanks and the model also accounts for changing temperature differences in realistic operation.
- **Instantaneous (continuous flow) gas water heaters** are also characterised using the tests in AS/NZS 5263 *Gas appliances*. The characteristic is used to define the thermal efficiency. The starting losses due to initial heating of the cold water (or the wasted heat left in the water at the end of a draw) is also measured. The number of draws is used to calculate the energy used as start-up losses. These water heaters are also used as inline boosters for solar water heaters, so the performance with varying temperature input water is calculated in the model. However, the burner efficiency is assumed to be independent of the inlet temperature.
- **Heat pump water heating** units are characterised using AS/NZS 5125.1 *Heat pump water heaters - Performance assessment - Part 1: Air source heat pump water heaters*. This method characterises the performance of the heat pump over a range of temperatures (air, water, wet bulb and dew point) and develops characteristic equations relating the COP and the power consumed to the air and water

[17] AS/NZS 4552 has been superseded by AS/NZS 5263.1.2:2016 *Gas appliances - Gas fired water heaters for hot water supply and/or central heating*. However, AS/NZS 4234:2008 standard still refers to the previous version.

temperatures. It also includes a low temperature test to characterise the performance impact at periods when frosting of the heat exchanger may reduce performance of the heat pump.

- **Solar collector** performance is characterised by the testing method in AS/NZS 2535.1:2007 *Test methods for solar collectors - Thermal performance of glazed liquid heating collectors including pressure drop* (similar to and interchangeable with ISO 9806:2017 or EN 12975-2:2006). The method tests the output of the solar collector under a range of different heating fluid temperatures to provide a characteristic equation that relates performance to the difference between the fluid temperature and the air temperature and the solar irradiance.

The method in AS/NZS 4234 prescribes the way that the components are connected in the model including piping lengths and insulation in a representative installation so that comparative results are based on realistic situations.

The standard provides a standardised annual task performance calculation methodology based on different climate zones in Australia and NZ and four different hot water loads which vary by climate zone. The hot water loads are based on energy added to the cold water and delivered at a particular time of day and season. The four loads for Australia are approximately peak volumes of 300, 200, 120 and 80 litres per day.

The modelling is done in the TRNSYS modelling environment and standardised TRNSYS modules for the different components are supplied with the standard. The 2021 revision of AS/NZS 4234 will remove the references to TRNSYS in the main standard and move specifications for using the TRNSYS software modules to a Miscellaneous Publication SA/SNZ MP 104 - *Modelling of heated water systems in accordance with AS/NZS 4234:2021, using TRNSYS.*

The output of the modelling includes the amount of purchased energy required to provide the load and also the energy savings % of that product compared to a reference water heater that uses the same fuel type as may be used for boosting a solar or heat pump water heater e.g. gas for solar gas water heater or electricity for solar electric or heat pump water heater.

The standard requires the evaluation of the performance when providing only one load. If the product cannot supply that load without running out of hot water (output below 45°C) or for solar and heat pump water heaters without providing a reasonable level of saving (specified as 60% compared to the conventional base water heater), then the water heater performance is evaluated at a lower load. Four representative loads are specified.

The 2021 revision will also include solar PV water heaters that are electric resistance or heat pump water heaters either directly connected to the PV or use ‘excess’ PV power through a diverter switch. To understand how much ‘excess’ PV power is likely to be available a method to calculate the likely consumption of electricity by a household (other than water heating) is provided. This estimated consumption of electricity in the rest of the household will introduce an additional potential source of error in the analysis. However, it is a real product and needs to be included in the method. As additional information becomes available it may be revised over time.

The 2021 revision will also include, in an informative appendix, a method to interpolate between the amount of energy needed for different hot water loads that will allow estimation of performance for a particular load without needing to undertake an individual simulation for each particular load.