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Solar and Heat Pump Water Heater Performance Rating
AS/NZS 4234:2021 revision – why, how, and what does it achieve?

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Introduction

Solar and heat pump water heater performance rating methods are specified in Australian and New Zealand standard AS/NZS 4234 *Heated water systems – Calculation of energy consumption* produced by Australian and New Zealand standards committee CS-028 [1].

Direct testing of solar and heat pump water heating systems under outdoor conditions is possible. However due to transient outdoor conditions and seasonal effects, outdoor testing requires a test period of many months and the tests must be repeated for every system configuration offered by a supplier. The procedure defined in AS/NZS 4234 overcomes the time and cost limitations of direct outdoor testing by using component performance data determined through standards such as AS/NZS 2535.1 [2], AS/NZS 2712 [3], AS/NZS 4692.1 [4], AS/NZS 5125.1 [5], AS/NZS 5263.1 [6] as inputs to an annual simulation model of hot water systems.

Standard AS/NZS 4234 defines how to quantify the annual purchased energy consumption of water heaters under various operating conditions using computational time series software such as TRNSYS. The simulated consumed energy can then be compared to reference gas and electric water heaters under the same thermal load and hence energy savings can be calculated.

The standard is extensively used by Australian and New Zealand governments for compliance to product minimum performance requirements and also to calculate various energy abatement trading certificates such as the Renewable Energy Certificate scheme (Small Technology Certificates) managed by the Australian Government Clean Energy Regulator, the Victorian Energy Efficiency Certificates managed by the Victorian government Essential Services Commission and other state government greenhouse gas abatement schemes.

In 2018 Standards Australia initiated a project to revise the standard. The objectives of the revision included: -

1. New modelling methodology test specification required to calculate energy consumptions of emerging technologies such as: -
    a. PV direct and indirect water heating.
    b. Variable capacity air source heat pumps.
    c. Instantaneous electric water heaters (also operating as in-line solar boosters)
    d. Solar thermal water heaters with supplementary boosting from air sourced heat pumps.
2. Revisions and extensions of existing AS/NZS 4234 listed technologies.
3. Revisions to the Australian climatic weather files.
4. Revisions to the thermal load consumed by the reference gas water heaters.
5. Addition of a method of performance evaluation for larger commercial liquid heating systems
6. A requirement by Standards Australian that reference to proprietary software was to be removed from all standards.

Standards Australia committee CS28 managed the development and drafting of the revision and the standard was published in 2021. The major changes to the standard are outlined in the following sections.

PV water heating.

Direct PV water heaters where PV generation is dedicated for water heating was included in the revision. However, with the advent of PV diverters and grid interactive water heaters that aim to maximise onsite PV self-consumption and hence reduce grid electricity energy consumption, new methodologies were required to simulate these water heaters.

Indirect PV water heaters which allow PV output to be switched between onsite loads including water heating and export are growing in popularity with producers such as Catchpower [7] and Solahart [8] marketing a range of products with varying degrees of heater control sophistication. These systems include export/import current clamps from the premises to the grid and aim to modulate the electrical consumption of the water heater such that PV export to the grid is minimised when thermal energy storage in the water heater is possible.

Modifications were required to the simulation model to facilitate modelling of PV water heating. The modifications included: -

1. Changes to the modelling of hot water tank boosting to include allowance for water heater element power to modulate in response to the excess power available from the local PV array (after local electrical load is satisfied)
2. Introduction of dynamically adjustable thermostat temperatures so advanced controllers can vary thermal energy storage capacity to match excess PV output throughout the annual simulation.
3. Extension of Legionella control modelling software so that advanced controllers that use weekly Legionella sanitation (AS 3498 [9] Legionella control section 7.1 (j).i) can be modelled throughout the annual simulation.

Modelling of PV water heaters requires simulation models of a PV array, wiring and inverter and water heating element controller. Modelling of the PV array assumed a MPPT in all instances. Losses for panel mismatch and panel degradation have a default setting of 7%. This can be reduced to 3% when microinverters or panel optimizers are utilized. Wiring system losses of 2% were also specified. Inverter efficiencies are included with reference given to the California Energy Commission methodology [10] , however inverter output is deemed to be 0 W where the PV input is less than 5% of the rated inverter capacity as inverters have poor power conversion efficiency for low power input.

To determine the available PV power for water heating, the general domestic electrical consumption also must be determined (all other electrical loads not including hot water heating). A daily profile of such consumption is set as a priority load for the PV generated power with only the excess PV power being available for water heating. A daily household electricity use profile was generated from publicly available data from Ausgrid (Sydney) [11]. This data set was filtered to only consider houses that had a controlled load (assumed for water heating) to ensure the hot water heating load was not measured as part of the general domestic electrical consumption. The average electrical consumption for each 30-minute period of the day was then used to generate the specified daily household electricity demand profile. To account for seasonal variations in household consumption a seasonal electrical energy load multiplier was produced (see AS/NZS 4234:2021 tables A.7.2 and B.7.2 [1]). Considering a significant portion of the domestic electrical consumption is based on space heating & cooling, the seasonal load multiplier also is a function of climatic region. Finally, an electrical load scaling factor was used to connect the electrical consumption to the thermal loads for different household sizes. The scaling factors used were simply assumed to be the same as the hot water thermal load scaling factors with the medium load denoted as the "average" electrical load.

The final electrical adjustment to determine the PV electrical power available at the water heater were losses due to microprocessors control of the water heater and modulation losses through rapid switching devices such as MOSFETs used to modulate the power into the water heater. The modulation loss was deemed to be 10% of the modulated load.

Variable capacity air source heat pumps

Variable capacity heat pump water heaters may be powered indirectly from a PV array and controlled so as to minimise grid power use. There has been considerable commercial interest in the application of variable capacity heat pumps in commercial applications however variable capacity heat pumps are not common in domestic water heating applications.

Variable speed heat pump technology has been prevalent for many years in space heating/cooling using inverters and DC motor driven compressors. It is known that the relationship between COP and power consumption for a given thermal load depends on the heat pump capacity (normally measured at different compressor speeds). Compressor efficiency curves indicate an optimum condition at the capacity (or speed) that the heat pump is designed to operate at. If the compressor speed varies from that optimum condition, then the heat pump COP and power consumption will be less ideal than those at the optimum condition.

The standards committee determined that a new performance characterisation methodology was required for modelling variable capacity heat pump water heaters. AS/NZS 4234 specifies multiple characterisation tests to be carried out at different compressor speeds using the same methodology as specified for single speed heat pumps in AS/NZS 5125 [5]. Testing was undertaken on a commercial heat pump to determine COP and Power adjustment factors at different compressor speeds that formed the basis of the default Power and COP adjustment factors in the revised standard. The calculated COP and Power used within the existing HP performance calculations are adjusted by the relative speed adjustment factors. It was recognised that not all heat pumps would have the same adjustment factors (conservative default values were selected) so AS/NZS 4234 also details test methods using AS/NZS 5125 with the heat pump operating at least four additional variable capacity conditions, allowing the user to effectively generate their own unique Power and COP adjustment factors through additional measurement.

Instantaneous electric water heaters (also operating as in line solar boosters)

Whilst the use of an instantaneous electric water heater as an inline solar booster currently is rare, given the rising popularity of instantaneous electric water heaters and the move to electrification, instantaneous electric water heaters were added to AS/NZS 4234. The parameters that define instantaneous gas water heaters were used as a basis of defining a new characterisation method for instantaneous electric booster water heaters. The thermal efficiency of such devices is relatively high as immersion elements are used. The losses are minimal when considering the magnitude of the energy being consumed and thermally delivered. A default thermal efficiency of 97% can be used or alternatively be substantiated using EN 50193-1 [12] test results. The heat output is simply the rated electrical capacity of the water heater times the efficiency. The start-up thermal capacity is energy required to raise the stored volume of water in the water heater by 45K. Standby and operational electrical energies are considered as any electrical consumption that does not directly heat the water flowing through the water heater.

Solar thermal water heaters with supplementary boosting from air sourced heat pumps.

There are a number of solar water heaters on the market that utilize an air source heat pump (ASHP) as the booster. These water heaters are very efficient due to the combination of the solar input and the boosting using the COP advantage of the ASHP. The challenge with the simulation methodology for this system was to model multiple flows into/out of the tank. The standard tank model used in modelling has only two flows into/out of the tank (one being the collector loop and the other being the load delivery). A third energy flow was required for water pumped from the tank to a separate ASHP and back. A heat exchanger was utilized for the heat pump water circulating loop with the heat exchanger surface area set large with very minimal thermal resistance to simulate the third water flow to/from the water heater.

Revisions to the Australian climatic weather files

Revisions to the Australian climatic weather files were considered given AS/NZS 4234:2008 referenced climate files with some data originating in the 1970's. The committee recognised that human induced global warming is evident in the period from 1970's to current time, hence it was necessary to update the climatic data utilized in the simulations. Updated climatic files were made available by Exemplary Energy Partners [13] and are provided with the release of AS/NZS 4234. In general, there was a slight improvement of performance for solar thermal products but very little change for ASHP's due to the revised climatic data, with the impact seen most prominently in Australian climatic zone 4.

Revisions to the efficiency of the reference gas water heater

The reference gas storage water heater was revised to change the thermal efficiency from a 3 star to 4 star water heater as reflective of the Minimum Energy Performance Standards (MEPS) regulated through Equipment Energy Efficiency (E3) [14] with references to Australian/New Zealand Standard AS/NZS 5263.1 [6] or Australian/New Zealand Standard AS/NZS 4552.2 [15]. The 3 star reference water heater no longer meets the minimum thermal performance for a gas storage water heater to be sold in Australia. For gas boosted solar water heater, the energy savings was reduced by approximately 10%.

Removal of reference to proprietary software.

Standard Australia now requires that references to proprietary software be removed from all Australian standards . Reference to TRNSYS as the simulation tool was therefore removed in AS/NZS 4234. A new miscellaneous publication MP104 [16] was released at the same time as AS/NZS 4234 that details how to use the standard with TRNSYS 15 [17] including the TRNAUS extension [18]. Changes to TRNAUS included the following:

1. Changes to type 160 to allow element power and thermostat control temperatures to vary throughout the simulations.
2. Changes to type 178 to allow compliance with AS 3498 Legionella control section 7.1 (j).i.

As AS/NZS 4234 does not stipulate TRNSYS as the modelling software, there had to be safeguard added to the standard to ensure the accuracy of any other modelling package used to prove compliance with AS/NZS 4234 has the same modelling accuracy as TRNSYS. To prove compliance, several example systems were analysed in TRNSYS utilizing the methods stipulated in MP104 and these results were tabulated in AS/NZS 4234. The parameters used in these assessments are listed in a Supplementary Material document that accompanies the standard. Users of AS/NZS 4234:2021 wishing to use an alternative model, must prove that the annual energy purchased and energy gained from solar sources (including ASHP) are within defined tolerances (0.5% lower and 3% higher) of those derived from the TRNSYS simulations that follow MP104. Users who employ the methods stipulated in MP104 therefore logically comply with the simulation accuracy requirement in AS/NZS 4234. Whilst this approach is laborious, the committee wanted to avoid is a situation where users would seek alternate simulated results from multiple software packages to inflate the simulated performance. It is recommended that regulators who reference the standard should also reference MP104 to be used as the calculation method. Whilst this will currently limit the software selection to TRNSYS with the TRNAUS extension until any additional MP documents are developed for alternative software, it will maintain a consistency of performance evaluation.

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