E3 Equipment Energy Efficiency

Product Profile: Heat Pump Water Heaters

Air-Source Heat Pump Water Heaters in Australia and New Zealand

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A joint initiative of Australian, State and Territory and New Zealand Governments.

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Executive summary

Background

Water heating in Australia and New Zealand is a major contributor to electricity use in the residential sector. In Australia this leads to significant impacts on greenhouse gas emissions. Heat pump water heaters offer a means of using electricity to heat water more efficiently. They have been available for many decades, but the uptake of the technology in Australia and New Zealand has been limited until recently.

Heat pump water heaters use refrigeration technology to extract heat from the ambient air and transfer it to a tank of water to supply household hot water. They can extract heat from a range of renewable ambient heat sources including air, water or the earth. This product profile deals only with 'air-source' heat pump water heater (HPWH) technology. The technology has a key energy efficiency advantage over traditional electric resistance water heaters as it is capable of supplying two to three times as much heat energy as the electricity it consumes. However, the actual energy efficiency varies widely from model to model.

As sales of HPWHs increase, so does the importance of achieving a satisfactory level of energy efficiency, together with an acceptable level of product performance. There is no consistent information on these factors available to the public, nor are there Minimum Energy Performance Standards (MEPS) for HPWHs in Australia or New Zealand at present. MEPS can remove the least efficient products from the market, resulting in lower average household energy use and reduced greenhouse gas emissions. HPWHs are exempt from the tank heat loss MEPS that apply to electric storage water heaters, provided they meet certain criteria for 'renewable energy' contribution under Australian Standard AS4234.

This product profile explores a range of issues, and is intended to support informed consideration of the potential for measures to improve the energy efficiency and performance of heat pump water heaters sold in Australia and New Zealand. At present there are no mandatory energy efficiency regulations that apply to a HPWH. It should be noted that no decision to implement mandatory regulations would be taken without further consultation and Ministerial approval.

The heat pump water heater market

At present there are at least 18 brands and 80 models of HPWH on the Australian market, and at least 9 brands and 25 models on the New Zealand market. The great majority of units sold are integral or split systems, where the compressor and the water tank are sold together. In New Zealand there is a wide range of 'stand-alone' heat pumps that can be retrofitted to an existing water tank.

The demand for HPWHs has been boosted as a result of most Australian jurisdictions imposing building regulations on greenhouse gas intensity for water heaters in new homes. In the replacement market, purchasers usually make decisions under time and cost pressure, and often delegate the decision to an intermediary such as a plumber. The decision is highly sensitive to replacement times and capital costs. When replacing electric storage water heaters, purchasers often choose like-for-like or the cheapest option, usually another electric resistance water heater. They generally only consider alternatives such as heat pumps if they are forced to (e.g. if electric water heaters are no longer available) or the capital cost differential is narrow.

In recent years the Australian HPWH market has increased in response to the availability of Small-scale Technology Certificates (STCs) as part of the Commonwealth Small-scale Renewable Energy Scheme, and cash rebates offered by the Commonwealth and some states and territories. Annual sales increased from about 5,000 in 2006 to a peak of 65,000 in 2009 largely due to high rebate values and jurisdictions implementing greenhouse gas intensity limits on new homes. The market has since reduced to about 20,000 in 2010 as the rebates have wound down.

An important determinant of future market demand is the extent to which Australian states and territories implement the phase-out of greenhouse intensive water heaters in existing houses as agreed by the Ministerial Council on Energy (MCE) in 2010. With current levels of implementation, sales are projected to increase slowly to about 40,000 per year by 2032. If the Australian phase-out is implemented completely in all participating jurisdictions, a large segment of the electric storage water heater replacement market would be diverted to HPWHs, and sales would be projected to reach around 100,000 per year by the end of the decade. The New Zealand HPWH market is around 500 units per year, despite the recent availability of grants from Energy Efficiency and Conservation Authority (EECA) and is not expected to increase significantly in the near future.

Sales in Australia and New Zealand may rise if consumer familiarity with and confidence in the technology increases, the energy efficiency improves, noise issues are addressed, their relative purchase costs decline, electricity prices increase or tariff structures which are more favourable to HPWH operation are introduced.

The water heater market is subject to a range of market failures, including lack of information and split incentives, in which there is conflict between the interests of householders and intermediaries such as builders and plumbers who are influential in water heater choice. In these circumstances, government intervention in the market has the potential to improve the overall welfare of the community if the intervention is aimed at correcting or reducing the impact of market failure.

Product performance, testing and consumer information

The relative complexity of HPWHs compared with other water heating technologies means there is a wide range of design approaches, and a wide range in the energy efficiency and performance of models on the market.

From a consumer perspective, it is critical that a HPWH is not only energy efficient, but also meets consumer needs in other ways. While the scope for greater energy efficiency is the main subject of this product profile, without measures to ensure 'fitness for purpose' there is a risk that increases in energy efficiency may be achieved in ways that compromise the overall performance of the product. For example, greater apparent energy efficiency could be achieved with a slower heat up time; or more powerful compressors could heat water faster but may be noisy.

Some products may not operate satisfactorily in cold climates or may rely on electric resistance elements for supplementary heating in such conditions. Additionally, some models are unable to provide adequate performance under off-peak tariffs. As a consequence, they may rely on more expensive continuous tariffs.

The risk of purchasing a HPWH which does not perform well could undermine consumer confidence in the HPWH market. It is therefore important that any proposed measures to increase the energy efficiency of HPWHs and to enable purchasers to compare the performance of models should take the full range of performance criteria into account, to avoid unintended consequences. Currently, such information is not available in a uniform or reliable manner.

In order to obtain accurate information on performance, 13 distinct HPWH models sold in Australia and New Zealand were tested by independent laboratories. These models constituted approximately 80% of Australian HPWH sales in 2010. The results raised concerns that the information available to consumers generally overstates product performance with regard to energy efficiency, energy savings and noise. The test results also called into question the adequacy of the information available to consumers on the suitability of models for operation under frost conditions and in cold climates.

While access to reliable and comparable information on the performance of HPWHs is likely to help engaged consumers, the nature of the water heater market means that most consumers are not actively engaged in the purchase decision, so establishing minimum standards may be required if energy efficiency is to be increased.

Electric storage water heaters must meet MEPS based on maximum tank standing heat losses, as measured in accordance with the standard *AS/NZS 4692.2: 2005 Electric water heaters - energy consumption, performance and general requirements*. Although HPWHs often have similar tanks, they are exempt from meeting these heat loss MEPS requirements, provided that they achieve other aspects of energy performance. A product profile on Electric Storage Water Heaters will be available for consideration in mid 2012 as part of the process to review the existing MEPS for this technology. The option to remove the exemption for HPWHs will be among the issues discussed in the Electric Storage Water Heater profile.

One means of measuring and communicating the energy efficiency of a HPWH would be a single metric that fairly reflects actual use. This is the intended objective of the standard *AS/NZS 4234:2008 Heated water systems – Calculation of energy consumption*, which uses the results of physical tests and other inputs to simulate water heater performance over an entire year, under a range of standard draw off patterns and daily and seasonal variations in climate. However, results from AS/NZS 4234 have proven difficult to verify, as it requires extensive testing, modelling and the use of proprietary information which cannot be easily independently verified.

The AS/NZS 4234 simulation results conducted for this product profile were, generally speaking, inconsistent with the performance claims published by suppliers, even where those were also said to be based on the supplier's own simulations using the standard.

Given the concerns regarding the reliability and repeatability of information based on AS/NZS 4234 modelling results, consideration was given to an assessment approach based on physical testing alone. It appears that coefficient of performance (COP), heat up times and other data derived from physical tests to the standard *AS/NZS 5125:2010 Heat pump water heaters – product performance assessment*, and standing heat loss tests to AS/NZS 4692 indicate the main factors that will influence energy efficiency and useability.

Apart from energy efficiency, physical testing can provide comparative measures of other aspects of performance not adequately reflected by the limited metrics produced by AS/NZS 4234, including:

- heat up times;
- tank heat loss;
- noise;
- variation in energy efficiency under different test conditions;
- performance under frosting; and
- characteristics that may increase running costs at low temperatures (e.g. reliance on electric resistance elements rather than heat pump operation).

Only a minority of the 13 models tested satisfactorily on all of these criteria.

Conclusions

Considering the range of performance issues and potential market failure, consumers are likely to benefit from strategies to improve the energy efficiency and performance of heat pump water heaters, and from measures to improve the quality of information available for individual models.

The following strategies are proposed for consideration by stakeholders:

1. Establish a system of mandatory product testing and registration, based on AS/NZS 5125, as well as noise testing to ISO 3741. As HPWH suppliers already conduct physical tests to AS/NZS 5125 and governments already maintain registers of other appliances, the additional costs should be relatively minor in comparison with the potential public benefits.
2. Introduce MEPS and functional performance requirements, including addressing cold temperature performance and noise issues, with proposed notification of the requirements no later than mid 2013 and requirements to take effect by mid 2014. There are likely to be significant benefits from ensuring that all models are fit-for-purpose and achieve MEPS.
3. Enable public access to the registered data, with models identified. This will provide potential purchasers, competing suppliers and regulators with an overview of the range of products and performance levels on the market.
4. Develop energy labelling standards, either as a mandatory requirement or initially for voluntary use by suppliers.
5. Develop a roadmap of potential future increases in minimum performance criteria.

Consultations on this product profile

This product profile is an investigation of the energy efficiency and performance of heat pump water heaters, the product market in Australia and New Zealand, the effect of any current standards and regulations, and possible opportunities for improving energy efficiency and performance in the interests of consumers.

Readers are invited to comment on a number of aspects in this document, particularly market data and modelling assumptions, to assist with the formulation of preferred policy options. While we welcome comments on all aspects of the product profile, responses to the key questions on page 8 would be of particular assistance.

Written comments should be sent via e-mail, and should be received by **10 August, 2012**. Comments can be sent to:

Australia:

Subject: Heat pump water heater product profile

energyrating@climatechange.gov.au

New Zealand:

Subject: Heat pump water heater product profile

regs@eeca.govt.nz

What happens after consultation on the product profile?

The material in this product profile, as well as written submissions and/or issues raised at stakeholder consultation meetings, will be considered in helping governments decide whether to proceed with developing options to improve the energy efficiency and performance of heat pump water heaters, the reliability of the information available to consumers, and what options may be available.

If the preferred options involve regulation (e.g. MEPS and/or labelling), a Regulatory Impact Statement (RIS) will be prepared to analyse the costs, benefits, and other impacts of the proposal. This will be subject to the usual consultation processes, and the final decisions will be made by the Select Council on Climate Change in Australia and by the New Zealand Cabinet.

Key questions

1. What do you think would be the best way for governments to facilitate an increase in the average energy efficiency of heat pump water heaters?
2. What aspects of heat pump water heater performance (in addition to energy efficiency) do you think are important (e.g. reheat time, noise, ability to operate in a range of climates, service life, and any others)?
3. What do you think are the key measures to ensure heat pump water heaters offer satisfactory performance to consumers on all relevant criteria?
4. Can you provide improvements to the market data presented for Australia and New Zealand, and in particular, the estimates of current and projected sales of heat pump water heaters? Please provide data.
5. Do you believe consumers can make accurate comparisons of heat pump water heater energy efficiency, cold temperature performance, running costs and noise?
6. Are there any issues to consider if product testing and registration was introduced and based on AS/NZS 5125? Please provide detail.
7. If mandatory noise testing was introduced it is suggested that ISO 3741 *Acoustics - Determination of sound power levels and sound energy levels of noise sources using sound pressure - Precision methods for reverberation test rooms* could be used. Do you have any concerns with using this standard ? Please provide detail if there are concerns including solutions to address.
8. Do you think that there is a case for minimum energy performance standards?

9. If MEPS was introduced it is suggested that AS/NZS 5125 is used to provide physical measures of performance. Do you have concerns with the proposed measures of performance? If so, can you provide improved alternative measures of HPWH performance from physical test results for:
    a. Normal operation energy efficiency (Proposal: Time weighted COP from 45°C to maximum, at Test Condition 1);
    b. Cold temperature operation energy efficiency (Proposal: Time weighted COP from 45°C to maximum, at Low Temperature Test Condition);
    c. Normal operation rate of reheating (Proposal: litres per hour from 45°C to maximum, at Test Condition 1); and
    d. Cold temperature rate of reheating (Proposal: litres per hour from 45°C to maximum, at Low Temperature Test Condition);
10. What impact do you think implementing MEPS would have on the industry and consumers in Australia and New Zealand?
11. Do you think there is a case for the physical labelling of products with their performance? If so, should this be mandatory or voluntary?
12. What impact do you think these measures (MEPS and labelling) would have on competition, product costs and consumer choice?
13. Do you think there is a case for mandatory noise testing and maximum noise limits?
14. Are there any additional measures which the Equipment Energy Efficiency (E3) Program could consider to increase the energy efficiency of heat pump water heaters?

1. Heat Pump Water Heaters

Background

This report profiles heat pump water heaters in Australia and New Zealand, explores options to improve their energy efficiency and seeks stakeholder input and feedback on those options.

The product profile has been commissioned by the Equipment Energy Efficiency (E3) Program, which comprises representatives of government agencies that promote energy efficiency in the Commonwealth, state, territory and New Zealand governments. The E3 Program develops, amongst other things, minimum energy performance standards (MEPS) and energy labelling for appliances and equipment, with the aim of improving the energy efficiency of products sold in Australia and New Zealand.

Australia and New Zealand have individual strategies for improving energy efficiency, including water heating: the National Strategy on Energy Efficiency and National Hot Water Strategic Framework in Australia, and the New Zealand Energy Efficiency and Conservation Strategy. These strategies note the substantial reductions in energy use, energy costs and greenhouse gas emissions that can be made by improving the efficiency of technologies such as domestic water heaters, including heat pump water heaters (HPWHs). Increasing energy efficiency also improves energy security by reducing energy demand, and defers the need for more expensive additional energy supply by making better use of existing energy infrastructure.

The purpose of this product profile is:

1. to examine the technology and assess the range of HPWH energy efficiency and performance in the Australian and New Zealand market; and
2. to consider measures to improve the energy efficiency and performance of HPWHs.

This product profile covers detailed descriptions of HPWHs, their attributes and market profile, performance as measured by independent tests, and opportunities for improving their energy efficiency.

Energy use in water heating

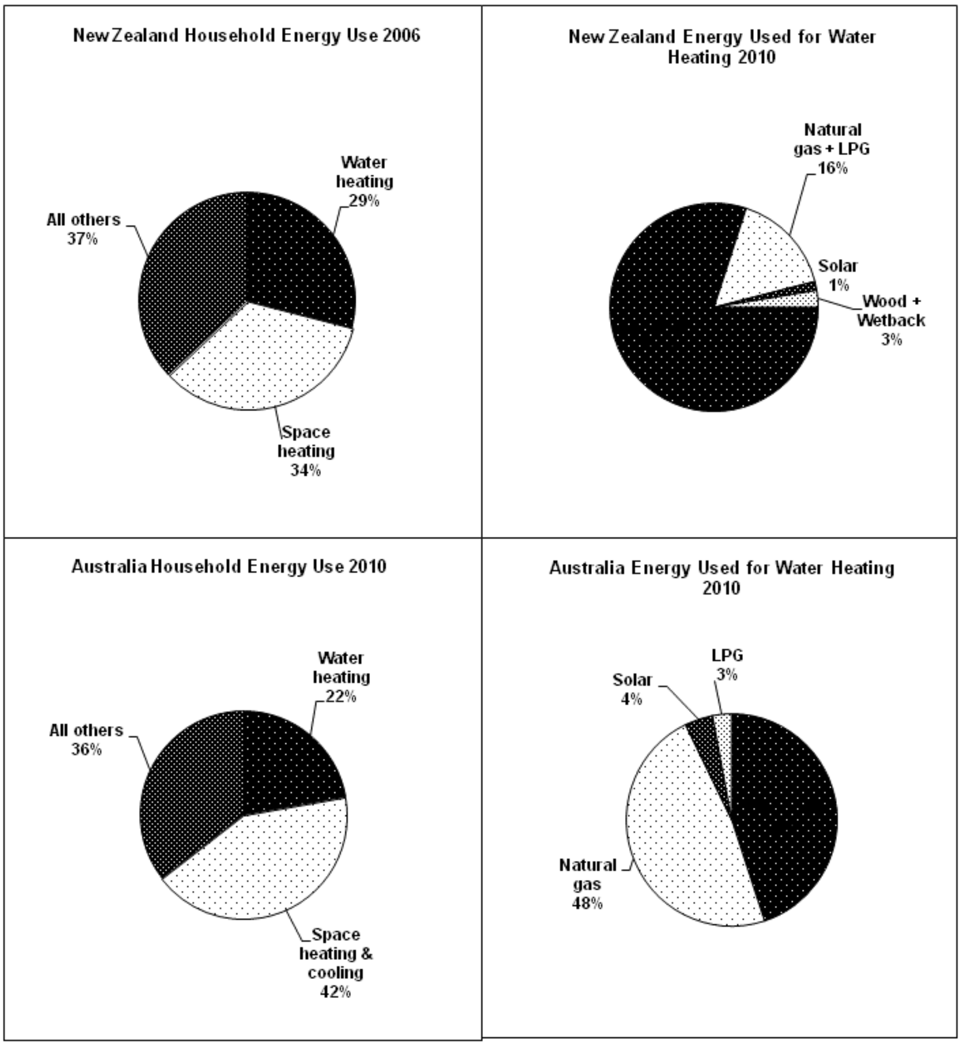
In both Australia and New Zealand, water heating accounts for the second largest segment of household energy use, after space heating and cooling. In Australia, about 48% of the energy used for water heating comes from natural gas, 45% from electricity, 3% from Liquefied Petroleum Gas (LPG) and 4% from solar. In New Zealand, electricity supplies 80% of water heating energy, natural gas provides 16% and solar energy provides 1.4%.

Electricity can be used to heat water in many different ways. The most common type is electric resistance heating, where all the energy supplied is electricity and the water is heated by an immersed electric element. In solar-electric water heaters, the majority of the energy transferred to the water is solar energy, but in most climates there is also a need for a resistance element to supply hot water when solar availability is low.

Electricity is the most greenhouse intensive form of delivered energy in Australia, so while electricity accounts for less than half of household water heating energy, it accounts for about 80% of the emissions from water heating. New Zealand electricity is considerably less greenhouse intensive, as nearly three quarters of electricity in 2010 was generated from renewable energy.[1]

[1] The average emissions intensity of electricity supply in Australia in 2010 was 295 kg CO_2-e/GJ, and natural gas 58 kg CO_2-e/GJ (GWA 2010). The average emissions intensity of electricity supply in New Zealand in 2010 was 38 kg CO_2-e/GJ, and natural gas 54 kg CO_2-e/GJ (EECA 2012).

Figure 1 Water heating share of residential energy use



How heat pump water heaters operate

In essence, heat pump water heaters operate on the same principle as air conditioners and refrigerators. They use fluids with certain thermodynamic properties (called 'refrigerant fluids') to transfer heat from one zone to another. Electricity is used to compress and pump the refrigerant fluid around a circuit of pipes. The fluid expands, gasifies and absorbs heat in an 'evaporator', and on the other side of the cycle it liquefies and gives out that heat in a condenser (see Figure 2).

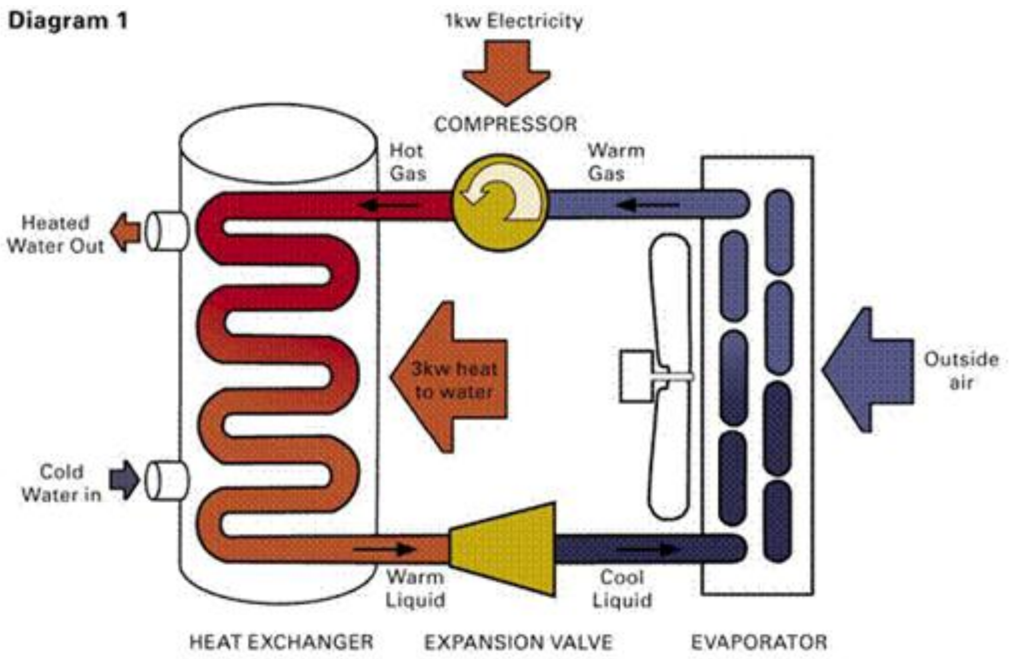
Heat can be absorbed from any medium – from the air, from a convenient body of water or from the ground. It can be transferred to any medium as well – into water, air or (if desired), the ground. Designs are generally optimised to work best with a particular heat source; hence they may be described as 'air-source' or 'water source' heat pumps. This product profile deals with air-source heat pump water heaters only, since this is the type most commonly used in the Australian and New Zealand household heating markets.

The extraction of heat from the ambient air will leave the environment fractionally cooler, but when that energy is concentrated in a relatively small volume of water (e.g. a 250 litre tank) it will, over a period, raise its temperature above that of the heat source, to a level that is useful for domestic hot water supply– typically 50-65°C. The properties of the commonly used refrigerant fluids prevent the attainment of higher temperatures through heat pumping alone, because the efficiency of the heat transfer process falls as the temperature differential between the ambient heat source and the stored water increases.

However, the ambient environment provides a virtually unlimited and free source of heat. Although the ambient heat source is effectively inexhaustible, it cannot be accessed without using electricity – unlike many designs of solar water heater, which can function much of the time (all of the time, in some climates) without the use of any electricity or fuel at all. The heat pump consumes electricity for moving this heat, and in general more energy is transferred into the water than the quantity of electrical energy used. This is a completely different principle from the common electric resistance water heater, where the electricity supplied is directly converted to heat via a resistance element. (Another difference is that an electric resistance water heater can reach much higher temperatures).

It should be noted that some HPWHs do use electric resistance elements for supplementary heating in periods of high hot water use or cold ambient temperatures.

Figure 2 Example of heat pump water heater operation



The ratio of the quantity of energy transferred to the heated water to the quantity of electrical energy consumed is called the Coefficient of Performance (COP). Electric resistance water heaters would have a COP just below 1.0 (although with electric resistance technology this is usually described as near-100% 'efficiency'). By contrast a HPWH can have a COP well above 1. For example, a COP of 3 means that 3 kWh of heat energy is transferred to the water for every 1 kWh of electricity used by the heat pump (referred to as 300% 'efficient').

Appendix 1 describes the different types of HPWHs and how their performance is tested.

Advantages and disadvantages of heat pumps

Compared with other options, HPWHs have the following advantages:

- HPWHs have the potential to supply more heat energy than the electrical energy they consume;
- They can often be located in the same position as a pre-existing external water heater, so external changeover installations are often relatively simple (although less so when replacing an internal water heater);
- They can often operate on a standard power outlet, so do not require special wiring or three-phase supply, as many electric resistance water heaters do;
- There is no requirement for roof-mounted collector panels, so HPWHs are useable where the construction or orientation of the roof is not suitable for solar collectors, or collectors are not wanted for aesthetic reasons; and
- They provide a low greenhouse gas emission water heating option in areas without a natural gas supply.

Disadvantages include:

- The capital cost is significantly higher than electric resistance or gas water heaters;
- The performance of HPWHs is reduced in colder ambient air temperatures, with lower energy efficiency and slower rates of water heating;
- The operation of a HPWH produces some noise which, if too loud, may annoy some householders or their neighbours;
- HPWHs are more complex than electric resistance water heaters and some models can have issues with durability and reliability ; and
- They can require a more expensive continuous electricity tariff to operate effectively.

Energy efficiency and greenhouse gas emissions

The main advantage of a HPWH compared with an electric resistance water heater is its potential for supplying more heat energy than the electrical energy it consumes, due to the concentration of ambient energy. A properly designed and installed HPWH should use about 50% to 65% less electricity in actual operation than a water heater which uses electric resistance heating only to supply the same amount of hot water. A reduction in electricity use can result in reductions in both running costs and greenhouse gas emissions compared with an electric resistance water heater.

Hot water use varies widely, but the typical annual energy use of an electric resistance water heater is around 4,000 kWh. A 60% reduction represents a saving of 2,400 kWh/yr. Under an extended hours tariff (e.g. about 14c/kWh for 18 hrs supply per day) the running cost saving would be over A$330 per year. Furthermore, the difference between a 50% reduction and a 60% reduction would be 400 kWh, or $56 per year. At New Zealand electricity tariffs (25c/kWh) the running cost saving would be over NZ$600 per year.

Cold temperature performance

The energy efficiency and rate of water heating of HPWH technology is particularly sensitive to ambient air temperatures because their performance is dependent on concentrating the heat from the ambient air and transferring it into water. The lower the amount of heat in the ambient air, the harder it is to concentrate. HPWHs can be designed to operate at very low ambient temperatures – some refrigerant fluids can extract heat from air at temperatures well below 0°C.

If cold air temperature is accompanied by high humidity the evaporator surfaces can 'frost' or ice up. The ice will form an insulating barrier that inhibits heat transfer. Frosting often begins well above 0°C ambient air temperature.

To address this problem, some designs incorporate de-icing functions, including reversing the refrigerant flow from the stored hot water to the evaporator until the ice melts off; others incorporate de-icing resistance elements in the evaporator. Another issue is that models with poor cold temperature performance often rely on in-tank electric resistance boosting. This results in the unit operating as an electric resistance water heater rather than as a heat pump while the frost conditions persist, and sometimes well after de-icing is complete.

A HPWH that has high energy efficiency, a fast rate of water heating in cold temperatures and a well-insulated storage tank is likely to also perform well in higher ambient air temperatures. An additional benefit is that the HPWH performs better under off-peak or restricted hours electricity supply conditions, when tariffs are lower. Further information on the influence of climate on heat pump water heater performance is provided in Appendix 1.

Noise

As the heating process depends on the operation of moving parts (electric motors, compressors and fans), there is some noise associated with HPWHs. An electric resistance water heater, by contrast, has no moving parts and makes no noise. Although some HPWH models are quiet, consumer and local council concerns about excessive noise may be reducing the market acceptance of HPWHs and so limiting the choice of low emission hot water technologies for the Australian/NZ consumer. Noise complaints by owners and neighbours are reasonably common[2]. Additionally, councils, local and state governments have differing rules and restrictions on noise (see Appendix 1), and there is anecdotal evidence that such restrictions are limiting the number of dwellings that are able to install HPWHs.

[2] About 15% of the HPWH reviews in one on-line forum mentioned noise (EnergyConsult 2011).

The noise problems that can arise from poor fan or compressor design can be exacerbated if the HPWH is installed too close to the owner's or neighbours' living room and bedroom windows.

While some HPWH suppliers publish noise levels on websites or brochures, they rarely state how these are measured or under what standard. This makes independent verification of the claims very difficult and consumers are unable to compare noise levels between different products. The lack of consistent information on noise is further hindering consumers' ability to make an informed choice on a quieter model of HPWH.

Durability

Perceptions of lower durability and reliability may be reducing the uptake of heat pump water heaters. Rotating parts (compressors and fans) are subject to more wear than non-moving parts and there have been recalls of heat pump models in Australia due to the risk of compressor failure[3]. While some suppliers offer the same warranties for HPWHs as for their other water heater product lines, most limit the warranty on the refrigeration unit, the most expensive component of the water heater, to as little as one year. The issue of compressor warranty and reliability was also identified in submissions to the *Consultation Regulation Impact Statement for Phasing out Greenhouse Intensive Water Heaters in Australian Homes 2010*.

One of the 13 heat pump water heaters purchased for testing for this product profile was found to perform very poorly due to a low charge of refrigerant gas, which compromised its energy efficiency. It is unclear if the fault is common, or if a consumer would notice this fault once a product is installed. The test results were not included in the calculation of mean and average values, but are shown in some diagrams to illustrate the extent to which faults can affect performance. A product testing regime which identifies faulty models would raise the overall reliability and durability of the HPWHs on the market.

The safety and durability of the heat exchangers is also an issue in some jurisdictions. The New Zealand Building Code requires measures such as twin-wall heat exchangers to reduce any risk of refrigerant leaking into potable water. However twin wall designs are inherently less efficient, due to the need to transfer heat across an additional medium. There may be other acceptable solutions that carry a lower energy efficiency penalty.

Tariffs

Like all other types of water heater using electricity, HPWHs can in theory be connected to either a more costly continuous tariff or a cheaper restricted hours (off-peak) tariff. HPWHs are more sensitive to restricted tariffs than electric resistance or solar-electric water heaters due to their lower energy transfer rates and their inability to collect ambient energy when de-energised (unlike solar water heaters).

Many HPWHs are installed on the continuous tariff because installers advise the owners that the units will not operate satisfactorily on off-peak (or the owners decide that for themselves). Sometimes the shift is from the cheapest restricted hours tariff to an intermediate-price extended hours tariff. If a HPWH is able to operate satisfactorily on a cheaper tariff, then the energy savings that come from replacing an electric water heater with a HPWH will be matched by the cost savings, and not eroded by having to switch to a more expensive tariff.

[3] http://www.justice.qld.gov.au/fair-and-safe-work/electrical-safety/electrical-product-recalls?queries_year_query_posted=1&queries_year_query=&queries_type_query_posted=1&queries_type_query=heaters&current_result_page=1&results_per_page=0&submitted_search_category=&mode=

2. The Heat Pump Water Heater Market

Regulations and other measures

The heat pump water heater market needs to be understood in relation to the regulations and financial support programs which influence it.

At present there are no mandatory energy efficiency regulations that apply to a heat pump water heater as a complete product. The only mandatory energy efficiency regulations that potentially apply to the product are standing tank heat loss limits, which in Australia were first adopted for unvented (mains pressure) electric storage water heaters in 1999, and extended to vented (low pressure) and heat exchange water heaters in 2005. In New Zealand, heat loss limits were applied to vented water heaters in 1988 and to unvented water heaters in 1989.

In Australia and New Zealand, storage tanks used as a component of HPWHs are exempt from standing tank heat loss requirements if resistance heating provides less than 50% of the annual energy supplied, as calculated using AS/NZS 4234[4]. A separate product profile, for electric storage water heaters, will be assessing if this exemption is still appropriate.

Building codes

New construction

All Australian states and territories other than Tasmania (TAS) and the Northern Territory (NT) have rules restricting the use of greenhouse intensive water heaters in new Class 1 buildings (i.e. detached, terrace, row and town houses), either through their own regulations or by reference to the relevant clauses in the National Construction Code. These rules have largely eliminated electric resistance water heaters from the new home market in favour of HPWH, solar, natural gas and LPG.

The BASIX rating scheme, introduced in New South Wales (NSW) in 2004, allows the use of electric resistance water heaters but imposes such a high rating penalty that builders must compensate with much stricter (and more costly) levels of thermal performance or more energy efficient lighting or fixed appliances. BASIX has resulted in an increase in the heat pump share of the NSW water heater market, to about 12% of new homes built from 2005 to 2008 (BASIX 2011).

The New Zealand Building Code requires that hot water systems comply with *NZS 4305 Energy efficiency – domestic type hot water systems,* which specifies maximum heat losses for all types of water heater, up to 700 litres capacity.

Existing buildings

South Australia (SA) and Queensland (QLD) have had regulations (metropolitan and nearby areas for SA and gas reticulated areas for QLD) restricting the replacement of electric resistance water heaters since 2008 and 2010 respectively. At the end of 2010, the Ministerial Council on Energy agreed to adopt measures to phase out greenhouse gas intensive water heaters for existing houses in all jurisdictions except Tasmania.[5] The measures require changes to state and territory plumbing regulations to be implemented. Since the 2010 MCE decision, no jurisdiction has implemented new regulations to implement the phase-out. If the phase-out is completely implemented as agreed, the water heater replacement market in Class 1 homes will be restricted to heat pump, solar, natural gas, LPG and wood-fired water heaters.

[4] http://www.energyrating.gov.au/products-themes/water-heating/electric-water-heaters/meps-and-labelling/ Calculation is for Climate Zone 3 with an energy delivery of 22.5 MJ/day for an electric boosting element and the energisation profile specified by the manufacturer.
[5] http://www.ret.gov.au/Documents/mce/_documents/2010%20bulletins/24th_Meeting_Communique_10Dec2010.pdf

Financial measures

Small-scale Technology Certificates

In Australia, the *Renewable Energy (Electricity) Act 2000,* which is administered by the Clean Energy Regulator (CER), established national targets for the quantity of electricity to be generated from renewable energy sources. The scheme, which commenced in 2001, requires electricity retailers and other liable parties to contribute to the achievement of the target by creating or acquiring numbers of Renewable Energy Certificates (RECs) – later renamed Small-scale Technology Certificates (STCs) – based on their energy sales or use. STCs can be created by any installation of eligible water heaters, whether in new construction or as replacements in existing buildings. Although it is voluntary to register a product for STCs, the commercial benefit has resulted in the majority of HPWHs being registered.

The financial value of STCs has been used to offset the purchase costs of HPWHs to consumers. A typical residential HPWH creates around 20 to 30 STCs. The price of STCs in the clearing house is fixed at $40, but prices on the open market have consistently been below the $40 price since STCs were introduced.[6] While the market price of STCs varies with market supply and demand, at a price of $30 per STCs they would contribute $600 to $900 to the purchase of each HPWH.

Rebates and other financial support

Commonwealth of Australia

In July 2007 the Commonwealth Government began to offer means tested rebates of $1,000 to householders replacing electric resistance water heaters with a solar or heat pump water heater in existing privately owned homes. In February 2009 the government introduced its *Energy Efficient Homes* package[7], which offered a rebate of $1,600, payable after installation, for a solar or heat pump water heater replacing an electric resistance water heater. All models eligible to create 20 or more STCs were eligible to receive rebates.

The amounts were progressively reduced, as indicated in Table 1. The scheme will close on 30 June 2012, with systems purchased or ordered after 28 February 2012 no longer eligible. Between the introduction and end of rebates, the Commonwealth contributed in excess of $320 million to over 250,000 water heater installations.[8]

Table 1 Commonwealth government water heater rebate amounts ($AUD)

Water Heater Type	3 February 2009 – September 2009	September 2009 – February 2010	February 2010 – June 2012
Solar-electric, solar-gas,	$1,600	$1,600	$1,000
Heat pump	$1,600	$1,000	$600

Australian states and territories

Several states and territories offer, or have offered, cash rebates for householders who replace an electric resistance water heater with a solar, heat pump and in some cases a gas water heater. (A few also offer rebates for water heater installations in new construction, but only for restricted types and/or to low income groups).

In October 2007 the NSW Government began offering rebates, from $600 for a HPWH or solar water heater eligible for at least 20 STCs, and up to $1,200 for models eligible for 43 or more STCs. The eligibility conditions and amounts were stable until January 2010, when the amounts were equalised at $300 for all types, and there were minor adjustments to the eligibility and payment criteria. The program finished in June 2011.[9] By that time over 154,000 rebates had been paid, of which nearly 31% (48,000) were for HPWHs.[10]

Sustainability Victoria has offered rebates for solar water heaters since 2000. HPWHs were later added to the eligibility list. At present, rebates of between $300 and $600 are available for HPWHs installed in areas without gas reticulation, the amount depending on whether the installation is in a regional or metropolitan area, the size of the tank and the energy savings calculated using AS/NZS 4234. About 36,000 rebates were paid between 2000

[6] http://www.cleanenergycouncil.org.au/cec.html STCs were trading below $30 in April 2012.
[7] http://www.environment.gov.au/energyefficiency/index.html The *Energy Efficent Homes* package also offered the alternative option of free ceiling insulation up to a value of $1,600.
[8] http://www.climatechange.gov.au/government/initiatives/solar-hot-water.aspx In 2012 the Federal Government announced a new program to help local councils install solar and HPWHs in community faclities.
[9] http://www.environment.nsw.gov.au/rebates/index.htm
[10] GWA estimate, based on NSW Climate Change Fund quarterly bulletins. 53% were solar-electric, 3% solar-gas and 13% gas.

and the end of 2011.[11] The majority of rebates paid have been for gas-boosted solar water heaters replacing conventional gas water heaters. Only a relatively small number of HPWHs have received a rebate. The replacement of an electric water heater with a HPWH, solar-electric, gas or solar-gas unit is also an eligible activity under the Victorian Energy Efficiency Target (VEET) scheme. .Since 2002 the SA Government has offered incentives to eligible low-income households for the installation of solar, heat pump and gas water heaters in new and existing dwellings. The scheme is due to end in June 2013. In the period July 2006 to March 2009, just before the Commonwealth rebate started, the rate of take-ups averaged about 2,300 per year, of which about 9% were HPWHs. Since April 2010, the QLD Government has offered $600 toward the purchase of solar or HPWHs ($1,000 for eligible low income households). There were 19,500 take-ups in 2010/11, but the ratio of HPWHs is not known[12].

The Australian Capital Territory (ACT) Government offers $500 rebates for HPWHs if they are replacing an existing electric resistance water heater, and provided the household has also spent $2,000 or more on energy efficiency measures, following an energy audit. The rate of take-up is not known. Western Australia (WA) has a solar water heater rebate scheme, but HPWHs are not eligible. There are no rebates in Tasmania or the NT.

New Zealand

The New Zealand Government had in place a scheme to promote the uptake of heat pump water heaters through rebates. It was administered by the Energy Efficiency and Conservation Authority (EECA). A pilot scheme offering a $1,000 grant was run throughout 2009, and from 14 February 2011 EECA offered $575 for qualifying installations (Table 2).13 The program has recently ended, applying to HPWHs purchased up to 14 June 2012. These grants subsidised the installation of new units that meet certain minimum criteria including testing to the relevant AS/NZS standards.

Table 2 New Zealand grant categories and amounts ($NZD)

Water Heater Type	2005 – September 2009	2009	February 2011 – June 2012
Solar-electric, solar-gas,	$1,000	$1,000, $500	$1,000, $500
Heat pump	NA	$1,000	$575

[11] *Review of Sustainability Victoria's Strategic Direction*, 2011
[12] http://www.deedi.qld.gov.au/documents/Corporate-Publications/DEEDI_Annual_Report_2010-11.pdf
[13] A list of qualifying models is at http://www.energywise.govt.nz/node/18233

The market

Australia

At present there are 18 brands and about 80 separate models of HPWHs registered with the CER as eligible for STCs (Table 3). As this is a voluntary scheme, it is possible that are additional models, not registered with the CER. It is estimated that the products of the GWA Group Limited and Rheem Australia Pty Ltd constitute over 60% of total sales[14].

Table 3 HPWH suppliers and brands, Australia and New Zealand

Supplier	Heat pump brands	Available in:	Country of Manufacture or Assembly
Aquafire Industries Ltd	Aquafire	New Zealand	China
Azzurro	Azzurro Solar	New Zealand	China
Chromagen Pty Ltd	Chromagen	Australia	China
Conergy Australia	Conergy	Australia	Germany
Econergy Limited	Econergy	New Zealand	Assembled in New Zealand
Efficient Heating N.Z. Limited	Exceed	New Zealand	China
GWA Group Limited	Dux , Radiant, Ecosmart	Australia	Mixture of imported and Australian manufactured components. Assembled in Australia
Hot Water Heat Pumps Ltd	Performance Plus	New Zealand	Mixture of imported and New Zealand manufactured components. Assembled in New Zealand.
Ochsner	Ochsner	Australia	Germany
Peter Sachs Industries Pty Ltd[(a)]	Saxon	Australia	China
Quantum Energy Limited	Quantum	Australia, New Zealand	China
Parex Industries Ltd	Stiebel Eltron	New Zealand	Germany, China
Rheem Australia Pty Ltd	Rheem, Edwards, Everhot, Solahart, Accent Air	Australia	Mixture of imported and Australian manufactured components. Assembled in Australia
Rheem N.Z Ltd,	Rheem	New Zealand	Mixture of imported and Australian manufactured components. Assembled in Australia
Sanden	Sanden, Edson	Australia	Japan
Siddons Solarstream Pty Ltd	Siddons Solarstream	Australia	Assembled in Australia
Stiebel Eltron	Stiebel Eltron	Australia	Germany
Sustainable Direct Solutions Pty Ltd	Taitronics	Australia	Thailand

(a) Currently in liquidation

Figure 3 also shows the sum of Commonwealth and state rebates available to HPWH purchasers in NSW, which accounted for over 60% of the national HPWH market in 2009. There is a close correlation between the magnitude of the rebates and the installations that claimed STCs which is assumed to represent the majority of the Australian installations. Data for calendar years 2011 and 2012 are not yet available, but it is likely that the installations declined following the cessation of the NSW and Commonwealth rebates.

[14] Derived from data provided by ORER.

Figure 3 HPWH Installations by Year, Australia

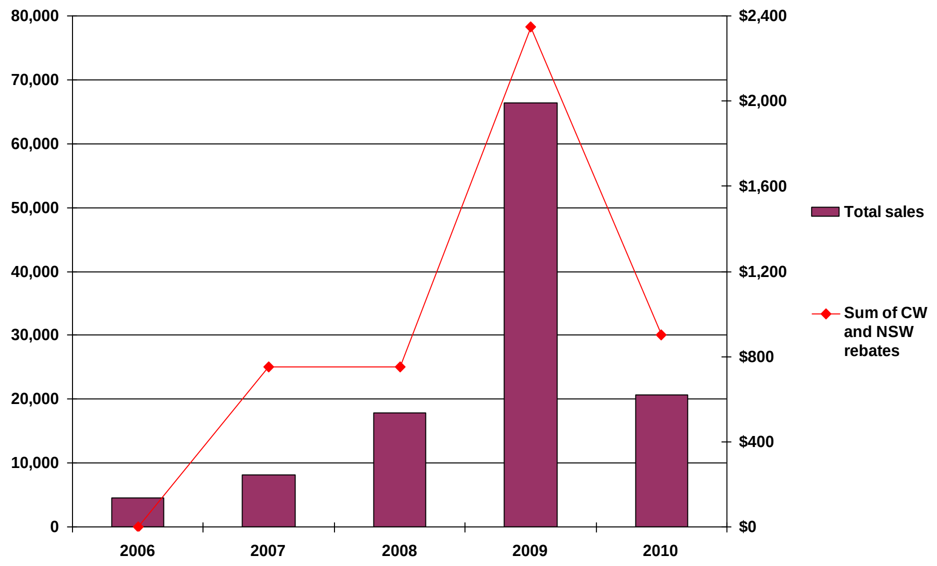
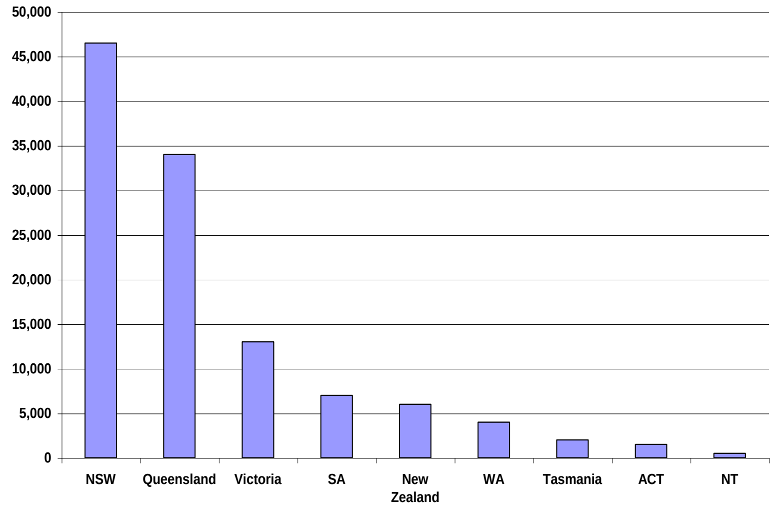


Figure 4 Estimated stock of HPWH in residential use (2010)



The installed stock of HPWHs can be estimated by summing the installations since 2005. Although a small number of HPWHs would have been in use before then, the great majority of units in use today are less than 5 years old, so end of service life failures would have little impact on the current stock. Estimated stock in each state and territory at the end of 2010 is shown in Figure 4. It is estimated that NSW and QLD have 76% of the Australian stock of HPWHs, even though they have 52% of the total number of Australian dwellings. The higher rate of HPWH installations in these states is due to a number of factors, including:

- A lower share of households with access to reticulated natural gas than in Victoria, SA and WA, hence less competition from gas in the low greenhouse emissions water heater market;
- Favourable financial incentives (especially NSW);
- In NSW, the effects of the BASIX requirements for new dwellings; and
- Large populations living in climate zones where HPWHs perform well.

The rebate effect on Australian HPWH demand is now reduced, with the cessation of the Commonwealth and NSW schemes. The main determinants of market demand are the take-up of HPWHs in new construction and whether individual states and territories implement the MCE agreed phase-out of greenhouse intensive water heaters in existing houses.

With current regulatory settings, sales are projected to increase from around 20,000 per year to about 40,000 by 2030 (Figure 5). In the absence of market stimulation from a phase-out of electric resistance water heaters, the main driver of the HPWH market would be new dwelling construction (Figure 6). If the phase-out is implemented completely in all relevant jurisdictions, a large segment of the electric resistance water heater replacement market would be diverted to HPWHs, and sales would be projected to reach around 100,000 per year by 2020. Note that the projected surge in sales to pre-2012 houses around 2019 reflects the expectation that most of the HPWHs installed in 2009 will have reached the end of their service lives, and about half would be replaced with new HPWHs. The post-2022 increase in sales to homes built after 2012 reflects the expectation that all their original HPWHs would be replaced by new HPWHs as they reach the end of their service life.

Sales in Australia and New Zealand would also increase if consumer confidence in the technology increases, noise issues are addressed, the energy efficiency increases, the relative costs decline, electricity prices increase or tariff structures more favourable to the operating patterns of HPWHs are introduced.

Figure 5 Projected HPWH sales by Australian jurisdiction, with current regulatory settings

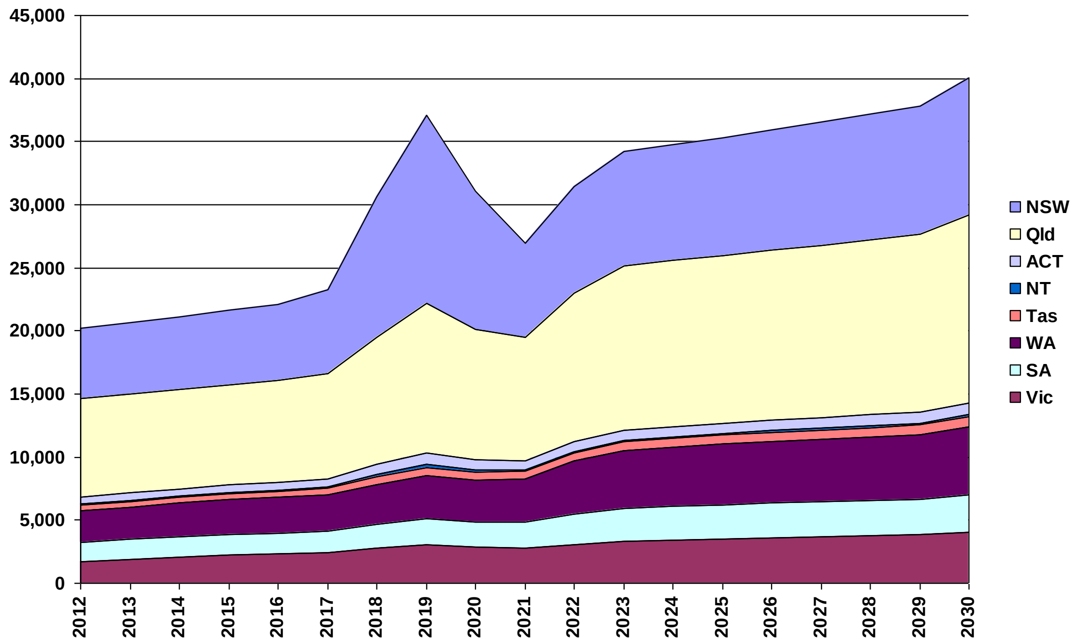
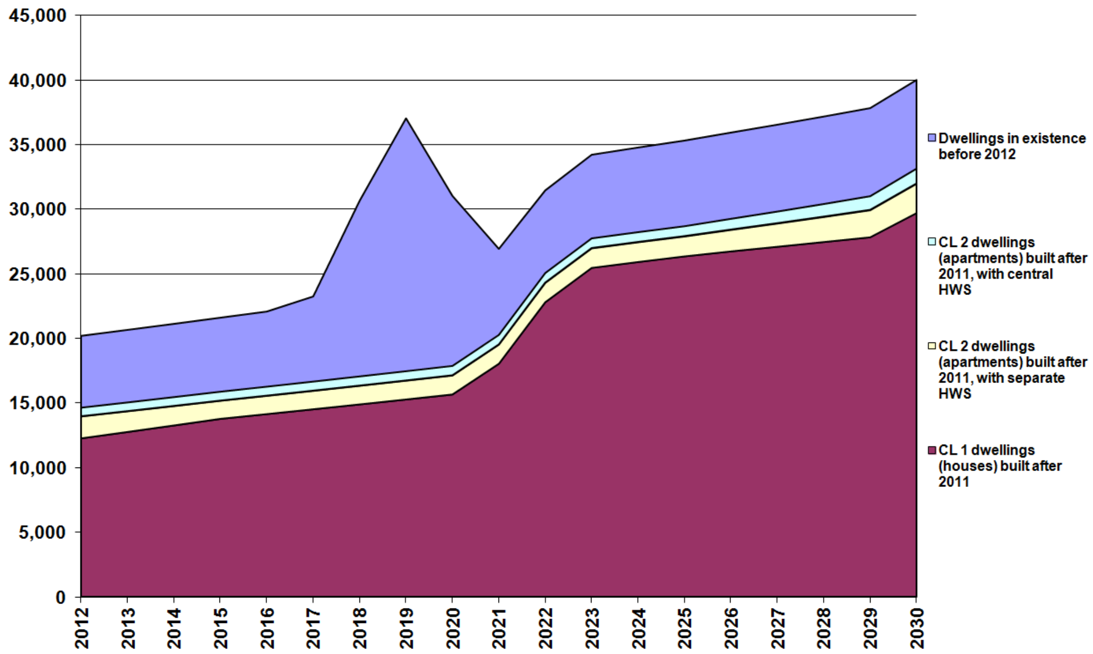


Figure 6 Projected HPWH sales by dwelling type, with current regulatory settings



New Zealand

The New Zealand Hot Water Association does not have firm sales data for HPWHs prior to 2010, but estimated sales were about 350 units in 2009 and 400 in 2010. In 2012, the market is expected to be about 500 units, given the uptake under the EECA Energywise rebate program.[15]

Most of the models offered on the New Zealand market are stand-alone products as defined in AS/NZS 5125, which can be retrofitted to an existing electric water heater. Some of these are assembled in New Zealand (Table 3). However, the majority of sales are of integral products imported from Australia.

[15] New Zealand Hot Water Heat Pump Association (Personal communication, April 2012).

3. Product Performance

Background

From a consumer perspective, it is critical that a heat pump water heater is not only energy efficient, but also meets consumer needs for satisfactory performance in other ways. Without measures to ensure 'fitness for purpose' there is a risk that increases in energy efficiency may be achieved in ways that compromise the performance of the product in other ways.

For example, greater apparent energy efficiency could be achieved with a slower heat up time; or more powerful compressors could be used to heat water faster, but this could result in a noisier product. Furthermore, some products are unsuited to operation in cold climates, rely on electric resistance boosting for cold climate performance, or can only provide adequate performance with 'continuous' rather than cheaper restricted electricity tariffs.

The risk of purchasing a HPWH which does not perform well on all the important criteria could undermine consumer confidence in the HPWH market, as occurred with the first generations of compact fluorescent lamps (CFLs) in the 1990s. Functional performance criteria to establish fitness for purpose as a part of energy efficiency performance testing are now in place for many products covered by MEPS and energy labelling. Functional performance criteria, verifiable by physical testing, are an integral part of energy tests for refrigerators, freezers, dishwashers, clothes washers and clothes dryers. However, this is not the case for heat pump water heaters.

A review of online forums and consumer reviews suggests that many consumers have found that the HPWH they purchased did not meet their needs.[16] There have also been instances of state and territory housing bodies installing HPWHs and then having to replace them with alternative water heating technology due to client dissatisfaction.

It is therefore important that any proposed measures to increase the energy efficiency of HPWHs, or to enable comparison of models should take into account the full range of functional performance criteria to avoid unintended consequences.

Measuring energy performance

Heat pump water heaters are relatively complex systems, so predicting their performance is not straightforward. For any given model, factors including electricity consumed, energy in the hot water supplied, amount of hot water supplied at a useful temperature and overall energy efficiency can all vary, depending on the following:

- the location and climate where it is installed;
- the heating efficiency or COP of the system;
- the heat loss of the storage tank;
- the quantity of hot water drawn off each day;
- the quantity, duration and time of day of each draw;
- the time interval between draws;
- the thermostat and control strategy settings; and
- the energisation profile, e.g. whether the heat pump can run at any time or whether it is restricted from running at certain times due to a restricted (off-peak) tariff.

Location, climate and tariff effects

All types of water heater vary in performance according to the climatic conditions, their degree of exposure (e.g. whether they are located indoors or outdoors) and whether their energy supply is continuous or restricted. HPWHs are particularly sensitive to these factors, because their performance depends on concentrating the heat from the ambient air and storing it in water.

[16] http://Whirlpool.net.au/forum-replies.cfm?t=1848449 , http://forums.whirlpool.net.au/forum-replies.cfm?t=1645714 and http://www.productreview.com.au/c/solar-water-heaters.html

While most heat pumps perform well under warmer conditions, performance in colder conditions (and in frost) will depend strongly on the particular system design. Better performing HPWH systems can be more energy efficient and lead to greater reductions in winter electricity peak loads, as well as maintain performance during periods of increased hot water use.

Having the storage tank located indoors can be an advantage in reducing heat loss. This, as well as the cheaper price, is one of the reasons why indoor locations for electric resistance water heaters are far more popular in New Zealand than in Australia. This in turn has led to a market for stand-alone heat pumps in New Zealand, because the indoor location of the storage tank can be retained. The installation of stand-alone units also allows the retention of low-pressure hot water services, which are common in New Zealand. All integrated and split units on the market are designed for mains pressure operation.

The rate that a HPWH can heat water after a hot water draw off is considerably slower than an electric resistance or gas water heater. Towards the end of the heat up cycle, when efficiency is at its lowest, a HPWH can typically provide 0.5 to 2.0 kW of heating compared with 2.4 to 4.8 kW for an electric storage water heater The lower the efficiency of the HPWH, the longer it takes to heat water and the larger the tank volume needed to ensure enough hot water availability in periods of high use. The slow recharge rate of HPWHs can be addressed by including a resistance boosting element, but systems that rely on larger tanks or resistance boosting elements are likely to provide a lower level of overall energy efficiency.

Recovery time is further constrained if the HPWH is connected to a restricted electricity tariff, increasing the risk that hot water will run out. HPWHs are more sensitive to restricted tariffs than electric resistance or solar-electric water heaters due to their lower energy input rates and their inability to collect ambient energy when de-energised (unlike solar water heaters).

As the householder is not likely to have sufficient knowledge about the financial impact of shifting from a cheap restricted tariff to a more expensive continuous tariff or whether such a tariff change is necessary, the decision is likely to be driven by installer advice. Installer advice is likely to be influenced by pre-conceptions, advice from the manufacturer or by experience with previous HPWH installations.

Of the householders in NSW who claimed a rebate for replacing their electric resistance water heater with a heat pump or solar-electric, at least 30% of those who installed HPWHs reported moving the new water heater to a less restrictive but more expensive electricity tariff than the unit replaced. For solar-electric water heaters, the comparable rate was about 5%.

While the energy use of an individual HPWH could be somewhat higher on a restricted tariff than a continuous tariff, increasing the suitability of HPWHs for use on restricted tariff is likely to reduce energy use overall in Australia and New Zealand, by increasing consumer uptake of the technology over electric storage water heaters. An increase in the energy efficiency of HPWHs will further reduce energy use and greenhouse-gas emissions, irrespective of the tariff.

Physical testing

The existing Australian and New Zealand standards relating to various aspects of the design, construction and performance of heat pump water heaters are listed in Appendix 1. The standards most relevant to performance are *AS/NZS 5125:2010 Heat pump water heaters – product performance assessment* and AS/NZS 4692.1:2005 *Electric water heaters - energy consumption, performance and general requirements*. The tank standing heat loss tests and MEPS requirements outlined AS/NZS 4692 will not be considered in this product profile, as their application to HPWHs and solar water heaters is being considered in a separate product profile for electric resistance storage water heaters.

AS/NZS 5125 specifies physical testing in a climate controlled test room, to be carried out at a range of five temperature and humidity conditions: Temperature Condition 1 (TC1) to Temperature Condition 4 (TC4) and a ‘Low Temperature’ (LT) test. LT involves testing at about 2°C and TC1 near 10°C. Further details of each test condition are in Table 7 of Appendix 1.

Under each test condition, the energy consumed and the water temperatures in the tank are recorded as the HPWH heats a tank of water from cold to maximum temperature of the heating cycle. The data are used to determine a COP at each test condition. The LT test is to be applied only to products claiming to be suited to low temperature operation without the use of electric resistance boosting. The purpose of the LT test is to determine the energy efficiency during frost conditions.

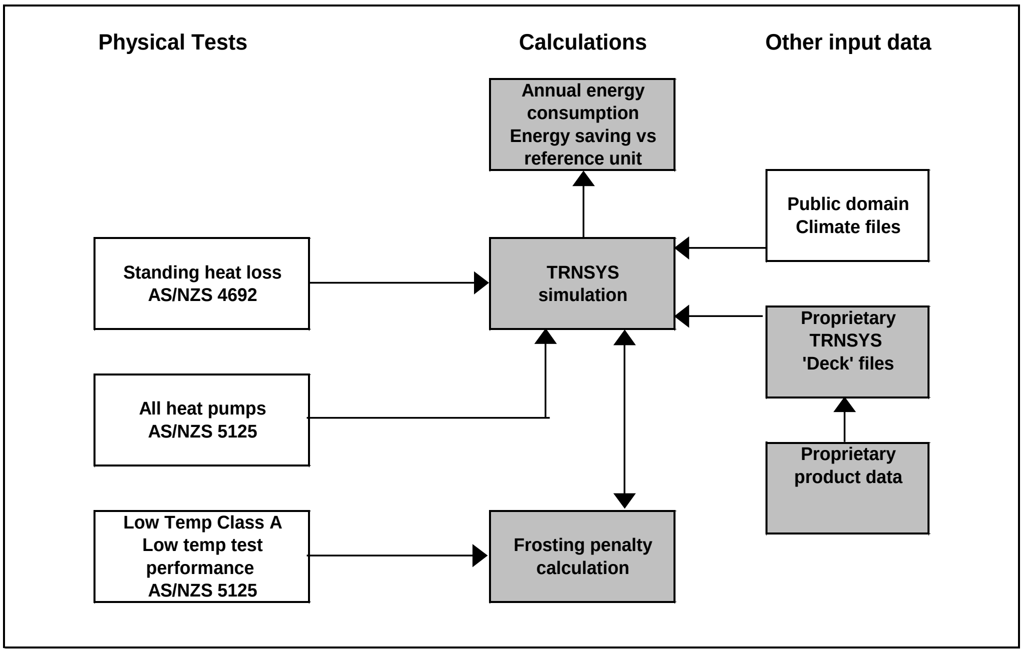
The AS/NZS 5125 testing process does not clearly define the maximum tank temperature to be reached, and during testing, some models appeared to stop heating before reaching the expected maximum temperatures. More clarity in the definition of maximum operating temperatures would ensure that the energy efficiency of products is directly comparable.

Performance modelling

AS/NZS 4234:2008 Heated water systems – Calculation of energy consumption describes the method of calculating the annual delivered energy that would be used by any given water heater when performing a specified water heating task, when installed in a specified climate zone. The standard uses modelling to compare and predict HPWH performance in five standard climate zones in Australia and two in New Zealand, and various daily deliveries and draw off patterns (Table 8, Table 9).

The estimation of energy use requires the use of a computer simulation program which meets the criteria in AS/NZS 4234. The best known of these is TRNSYS, although others may be used.[17] The modelling requires the data inputs indicated in Figure 7.

Figure 7 Data flows and relationship between test standards



The TRNSYS modelling requires the standing heat loss of the tank (as measured in accordance with AS/NZS 4692) and the COPs calculated from the AS/NZS 5125 tests to determine the annual energy savings of HPWHs. It also makes use of other input data indicated in the shaded cells in Figure 15. This is generally commercially sensitive information that is known only to the manufacturer. It includes the specification of physical components of the system and the control strategies that drive the compressor, resistance elements and other components.

These data are assembled in a particular format for TRNSYS modelling, commonly known as 'deck' files (because they have a *.DCK suffix). There are no standards that would enable independent testing to determine the accuracy of all the deck files. This is an important consideration as relatively small variations and inaccuracies in the deck file data in some cases appears to significantly influence the modelled energy efficiency estimates.

[17] TRaNsient SYstem Simulation (TRNSYS) is a public domain model originally developed by the University of Wisconsin. It is an algebraic and differential equation solver typically used to simulate performance of energy systems including water heaters, heating ventilation and cooling systems and renewable energy systems. Although other programs can be used, 'TRNSYS' will be used here to indicate all programs with the required capabilities.

During laboratory testing a range of apparent inconsistencies were identified between the deck file information provided by manufacturers and the way the product operated in the laboratory. Some of the key inconsistencies included:

- The air and tank temperatures that the heat pump compressors operated were beyond the bounds in the deck files.
- Resistance elements were operating more often than indicated by the deck files.

Considering the large number of manufacturer defined variables in the deck files, it is likely to be prohibitively expensive to independently check all these inputs. Modelling to AS/NZS 4234 also requires proprietary information from manufacturers which does not enable an 'off the shelf' test. As a result, it does not appear possible to be able to independently verify results of AS/NZS4234 modelling with high levels of certainty.

Field testing

Australia

There are currently no publicly available results of field trials of HPWH performance in Australia. However, in NSW, HPWHs ceased to be installed in public housing due to concerns of excessive noise, ongoing maintenance and uncertainty about the performance of heat pumps in cold climate areas. In the ACT, HPWHs are rarely installed in public housing due to cold temperature performance issues, and ACT Housing has replaced some units with alternative water heating technology due to client dissatisfaction. Issues of poor performance of heat pump water heaters in cold climates were also raised in submissions received as part of the consultation on the Regulation Impact Statement to Phasing Out Greenhouse-intensive Water Heaters in Australian Homes.

New Zealand

EECA undertook a large scale field trial of HPWH performance from 2009 as part of its pilot study for the Energywise rebate program. There were 470 HPWH sales eligible for an initial payment of $500, conditional on return of a consumer survey, plus a further payment of $500 on participation in a metering program returning at least 80 days of data. The product suppliers were also required to undertake TRNSYS modelling for their products (including calculation of energy saving compared with reference system) and submit the results to EECA.

By July 2010 some 339 customer surveys had been returned, and EECA had received metering data for 158 HPWHs. However, 31 were separated from the main analysis because their suppliers had either not met the modelling requirement (2 models, 25 units) or installation problems were identified after energy use was higher than expected (5 models, 6 units). Of the 31 systems removed from the final analysis 29 were re-circulating stand-alone systems.

Some of the findings of the pilot scheme were that:

- The installation of integral systems appears to be straightforward and can be successfully and consistently completed by plumbers.
- Retrofitting split systems to existing hot water cylinders can be difficult and only one supplier (of single pass stand-alone systems) managed to obtain consistently satisfactory results. This supplier employed trained installers.
- Re-circulating stand-alone systems are capable of effective operation, but there is a high incidence of poor performance, apparently caused by poor installation.
- Modelling can predict poor performance, although can underestimate the level. The two models with modelled performances of less than 40% returned average energy savings of 9% in the field (with a standard deviation of 76%).
- Modelling is less successful at ranking better performing systems (ranging from 53% to 69% energy savings) against each other. The modelling results for different systems are similar in many cases while the installed energy savings diverged.

Table 4 summarises the results. The 'energy savings' are those compared with a reference electric resistance water heater, using the method in AS/NZS 4234, not an actual comparison of electricity use for water heating before and after the change to the HPWH. The metering results, however, validated the estimate of electricity use obtained using TRNSYS (with the caveat the modelling was carried out under the supervision of the suppliers, and not independently verified. The units participating in the trial were also selected and installed under the supervision of the suppliers, rather than at random).

Table 4 EECA HPWH pilot scheme results

System type	Number of units	Average metered energy savings kWh/yr	Savings standard deviation
Integral	77	54	11
Stand-alone/ split-single pass	33	60	9
Stand-alone / split-recirculating	17	53	13
Total this group	**127**	**56**	**11**
'Problem' group [(a)]	31	NA	NA
All metered units	**158**	**45**	**42**

Source: EECA (2011) (a) In addition to the problem group, 20 other units were excluded from the analysis for a range of reasons.

Laboratory testing

During 2010 and 2011 EECA and DCCEE commissioned three independent laboratories to test a total of 13 HPWH models, from 9 manufacturers. The models tested were all commonly sold in Australia and New Zealand and represented approximately 80% of HPWH sales in Australia in 2010. Four of the models were 'stand-alone' units within the definition of AS/NZS 5125 and 9 were 'integral.' The tank sizes ranged from about 150 to 300 litres. Some models had electric resistance elements to assist performance at low temperatures. Between them, the 9 integral models account for about 80% of the Australian HPWH market.

Physical performance tests were carried out for all 13 models at the test conditions defined in AS/NZS 5125 (Appendix 1, Table 7). For the integral systems the standing heat loss of the storage tank was tested in accordance with *AS/NZS 4692.1:2005 Electric Water Heaters – Part 1: Energy consumption, performance and general requirements*.[18] The laboratories also carried out TRNSYS modelling of the integral models, using both the physical characteristics determined in the laboratory testing and the TRNSYS deck file supplied by the manufacturers.

For three of the models, the laboratories assessed whether the standing heat loss complied with the rules applied to electric resistance storage water heaters, given that HPWHs and solar water heaters are exempt if resistance heating provides less than 50% of the annual energy supplied, as calculated using AS/NZS 4234. All three water heaters had a higher standing heat loss than would have been permitted for an electric resistance water heater of the same configuration, but two met the minimum energy saving criterion and so were legitimately exempt. The third was found not to meet the energy saving criterion, even though the manufacturer's claims indicated that it should have. This apparent compliance failure could only be determined after independent testing and TRNSYS modelling, illustrating the difficulty of enforcing this particular regulatory requirement.

DCCEE commissioned a number of TRNSYS simulations using the standard inputs specified for Australian climate zones. In order to test the sensitivity of the outcomes to a range of assumptions, modelling was also undertaken with non-standard combinations of Australian and New Zealand inputs. Table 10 in Appendix 1 indicates the different combinations modelled.

Energy savings

Figure 8 illustrates the annual percent energy savings calculated by TRNSYS modelling for each model of HPWH operating in Zone 3 (Sydney, Perth, Adelaide) and Zone 5 (Auckland, Canberra).[19] The reference electric resistance water heater at each point was selected on the basis of the modelled performance of the heat pump. For example, if the simulation indicated that the HPWH could only meet a 'medium' hot water delivery task under one combination of input assumptions but a 'large' delivery under another, the energy savings are expressed with reference to medium and large delivery electric resistance water heaters respectively.

Model 8 indicated a negative savings, because the electricity use was actually higher than that of the reference water heater. This is a clear outlier and is believed to result from a faulty product – nevertheless, one that was purchased on the open market. Apart from this obvious outlier, there are also several models with energy savings of well below 50% at one or more test combinations.

[18] This is required as an input for TRNSYS modelling of HP performance. It is expressed as kWh/24 hrs, measured while the contents of the tank are maintained at 75°C in an ambient of 20°C (i.e. a ΔT of 55°C).
[19] Note that not all models were tested under all conditions, so some models are omitted from some diagrams.

Figure 8 HPWH energy savings compared with electric resistance water heater reference model

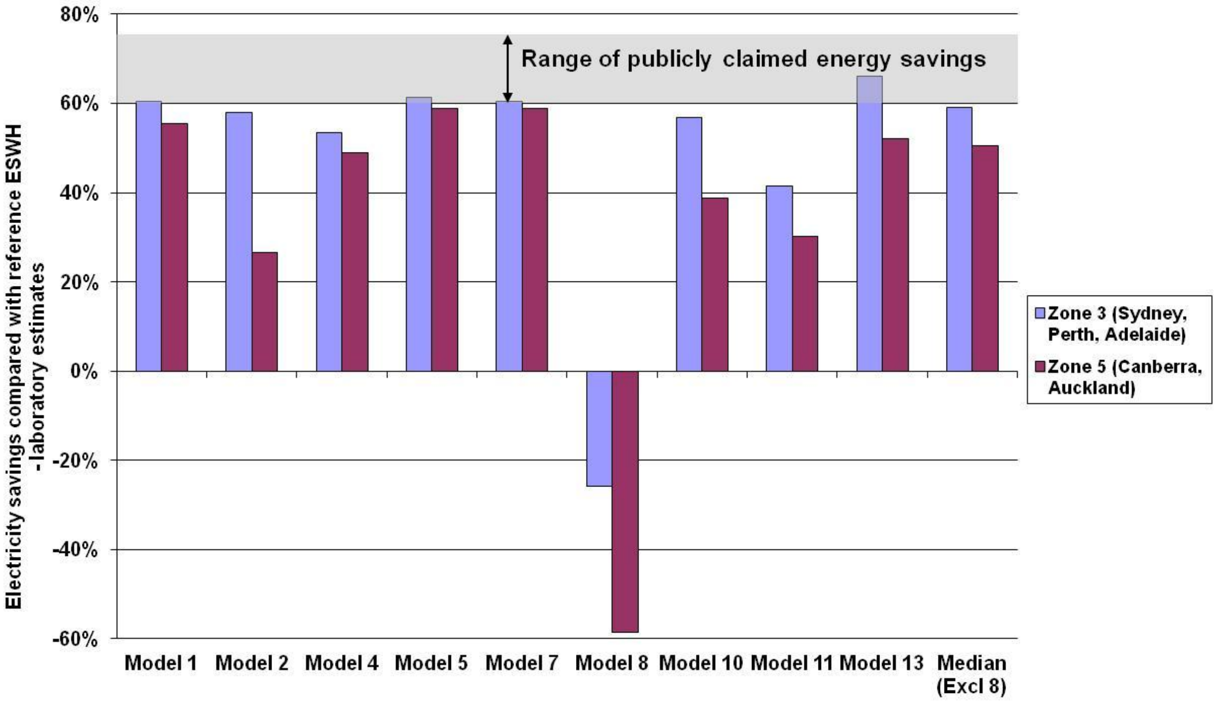
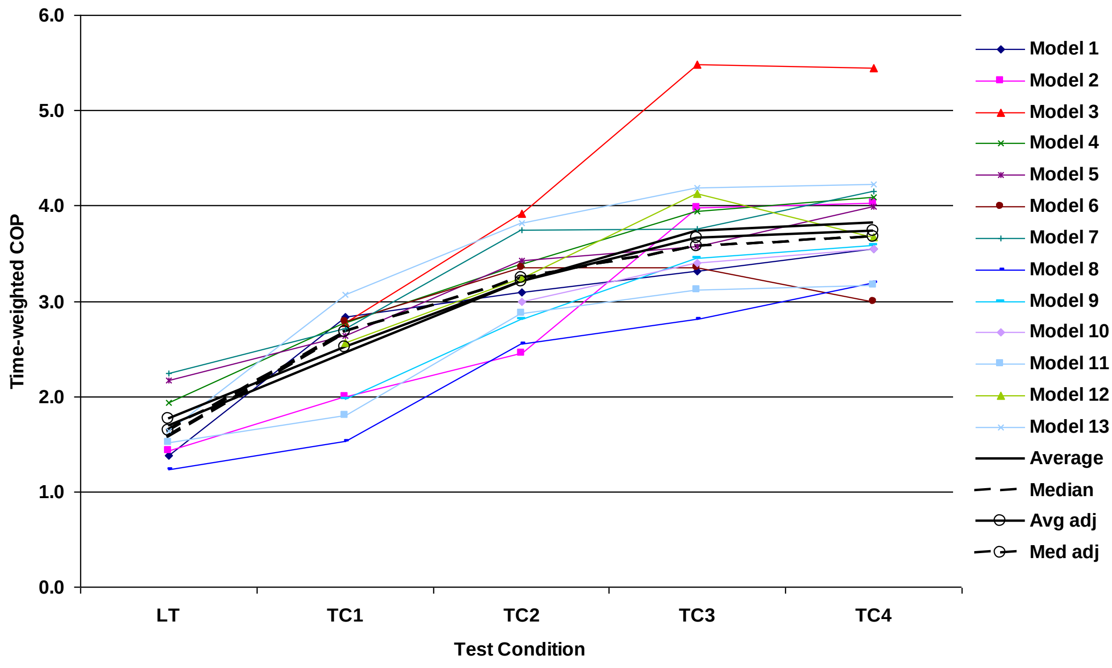


Figure 9 COPs at AS/NZS 5125 Test Conditions



On this basis the average estimated energy savings Zone 3 (Sydney, Perth, Adelaide) were 57.3% (median is 59.2%), and the average energy savings in Zone 5 (Auckland, Canberra) were 46.2% (median is 50.5%). These values are somewhat lower than the 60-75% range claimed for the same models in product brochures.

The outcome of TRNSYS modelling can also be expressed as a 'Task COP,' defined as:

$$\frac{\text{annual energy imparted to the hot water load}}{\text{annual electricity supplied to the water heater}}$$

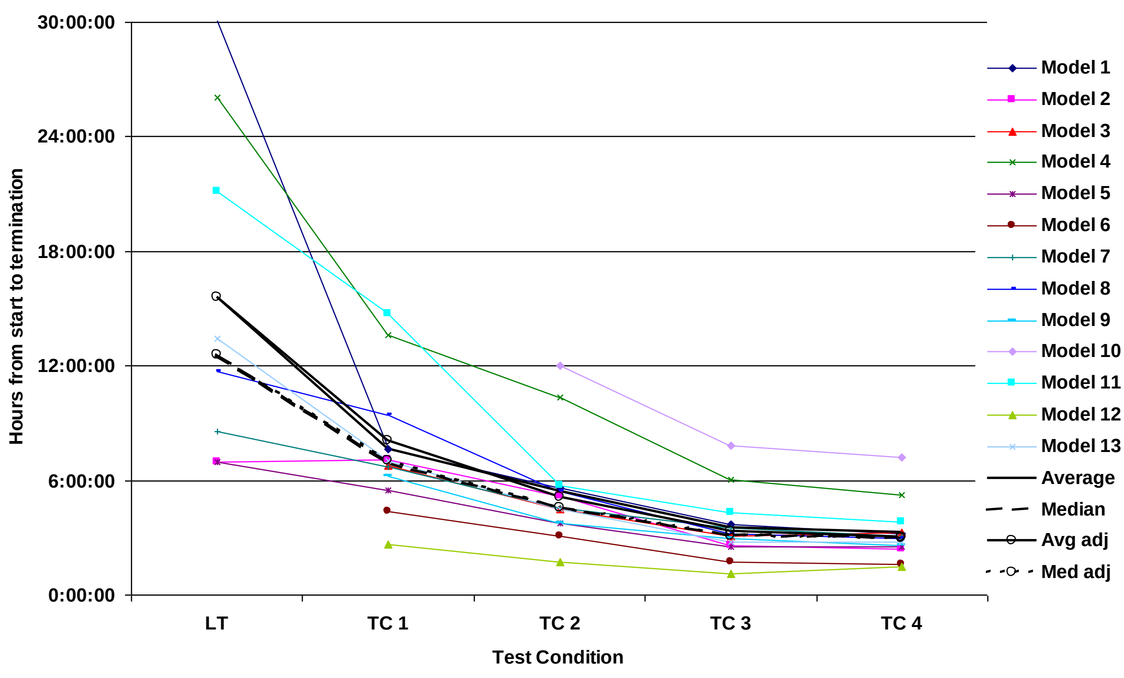
For example, if the energy imparted to the load is 18,766 MJ and the electricity consumed by the HPWH is 8,331 MJ, the Task COP would be 2.25. If the reference electric resistance water heater required 21,100 MJ to supply the same load, the energy saving would be (21,100-8,331)/21,100 = 60.5%.

The Task COPs of HPWH models calculated using AS/NZS 4234 modelling results are significantly lower than the physical COPs measured at the AS/NZS 5125 Test Conditions illustrated in Figure 9. There are two outliers – Model 8, previously identified as having exceptionally low performance, and Model 3, which has exceptionally high performance at TC3 and TC4. Average and median COP values are shown with outliers included, and 'adjusted', i.e. with outliers excluded.

Heat up time

Laboratory testing has found that some HPWHs take an unreasonable amount of time to heat up, especially in low temperature ambient conditions. The time taken for each HPWH model to reach the end of its heat up cycle under each test condition is indicated in Figure 10. More than half of the models tested took over 12 hours to heat a single tank of water from cold, while the poorest performing model took over 30 hours to reach the maximum temperature.

Figure 10 Time to heat up under each Test Condition in AS/NZS 5125



It is unusual for a HPWH to have to heat an entire tank of water from cold. The more common operating mode is recovery, which starts immediately after a volume of hot water is drawn off. For the purposes of calculating the ability of a water heater to serve its intended purpose, AS/NZS 4234 defines 'hot' water from 45°C. Figure 11 indicates the time taken to heat from cold to 45°C and from 45°C to the temperature at which the heat pump switches off. The median times are obviously much shorter under TC1, but there is still a range of nearly three hours from longest to shortest (Table 5). An alternative indication of reheating capability is the number of litres that can be raised over a designated temperature rise per hour (Figure 12 – Model 2 is not shown).

The COP during heating from the 45◦C temperature point to maximum temperature provides an indication of the energy efficiency under operating conditions that are more representative of household hot water use than COP over the entire heat up cycle. Figure 13 indicates the COP during the first part of the heat up cycle, when COP tends to be highest, and over the latter part of the cycle (between 45◦C and the maximum temperature) when it tends to be lowest. The intermediate point is the COP over the entire heat up cycle.

AS/NZS 4234 simulates performance over an entire year, and captures the proportion of time the HPWH spends in each part of the operating cycle in response to simulated draw off patterns and daily and seasonal variations in climate. However, the raw heat up time and COP data from AS/NZS 5125 gives an indication of the main factors that will bear on energy efficiency and useability, without the need for AS/NZS 4234 simulation.

Figure 11 Heat up time from cold to 45◦C and to maximum temperature (hr) by Test Condition

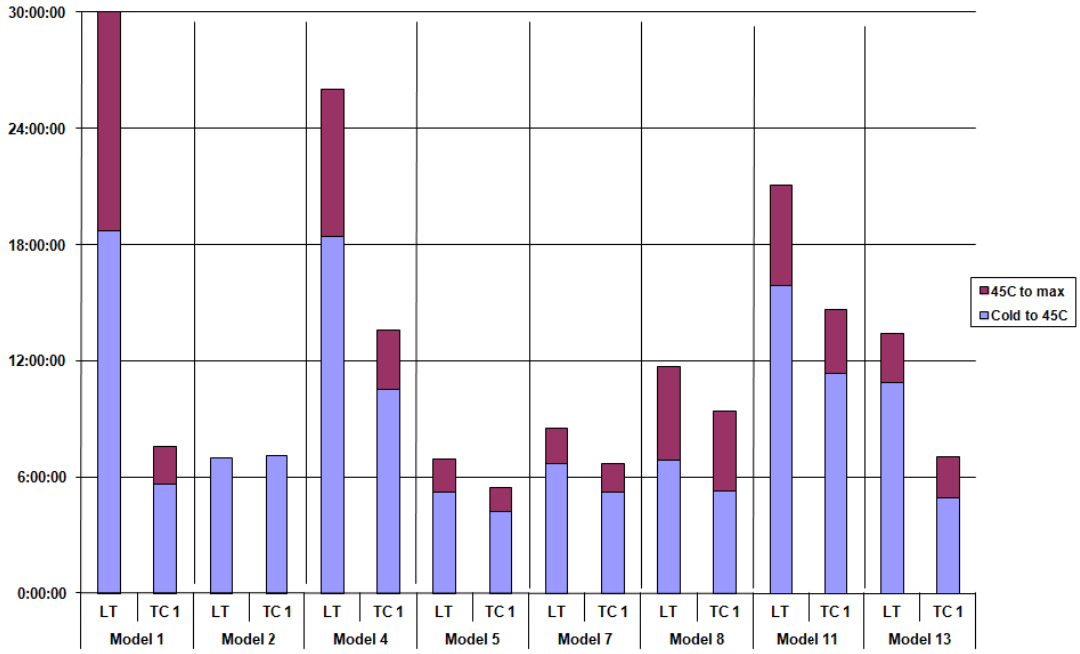
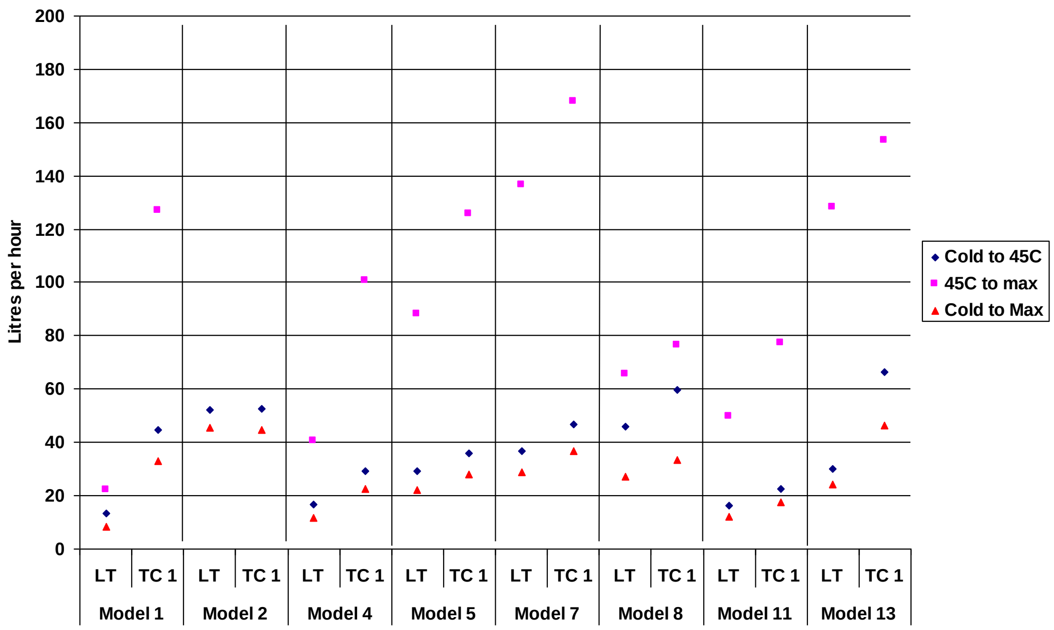


Figure 12 Reheat capacity from 45°C to maximum temp (litres/hr)



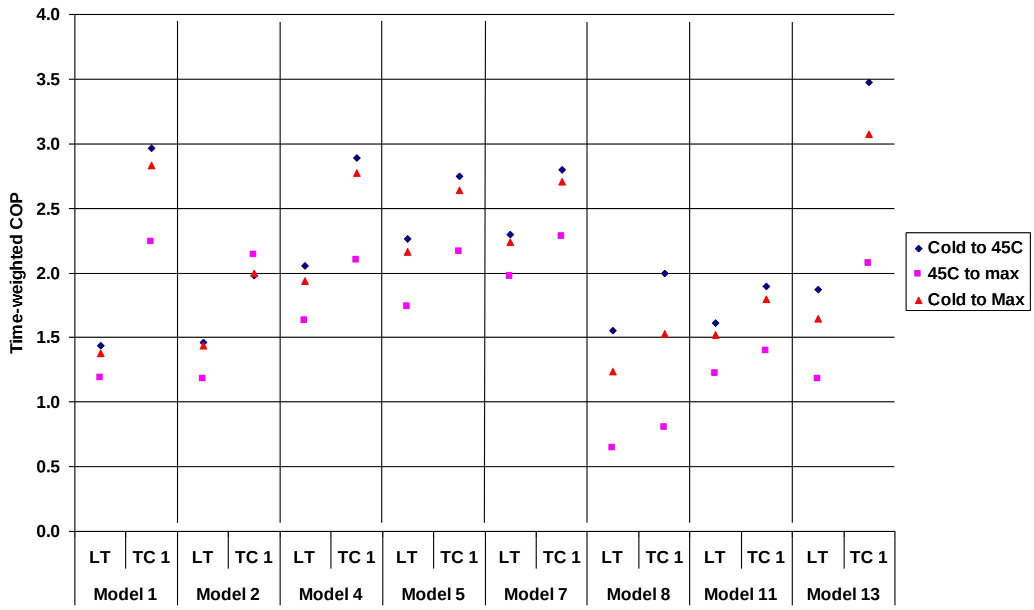
Note: Model 2 raised over 300 litres/hr between 45◦C and maximum, because it used its electric resistance element under both LT and TC1 conditions

Table 5 Heat up performance from 45°C to maximum temperature

	Time (hr:min)		Litres per hr	
	LT test (2°C)	TC 1 (9°C)	LT test (2°C)	TC 1 (9°C)
Maximum	11:19	4:08	137	168
Minimum	1:44	1:13	22	77
Average	5:00	2:28	101	141
Median	4:50	2:08	65	126

Excludes Model 2, which functioned as an electric resistance water heater at these TCs

Figure 13 COP at different phases of the heat up cycle



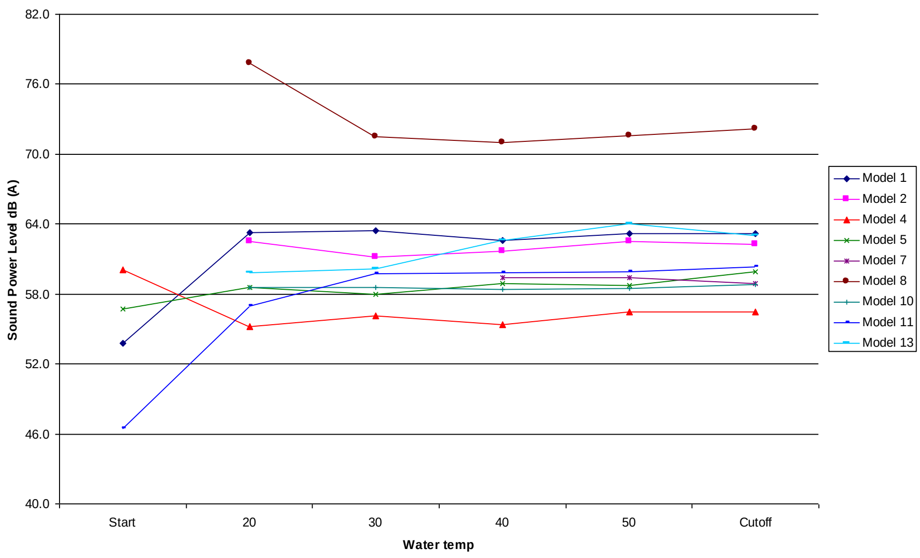
Noise

DCCEE commissioned acoustic testing of 9 models. There is no AS/NZS noise test standard for HPWHs, so the test procedure used was based on ISO 3741 *Acoustics - Determination of sound power levels and sound energy levels of noise sources using sound pressure - Precision methods for reverberation test rooms*. The HPWHs were filled with cold water at less than 20°C at the start of the test, and the test room was maintained at 20°C ± 3°C, i.e. between TC2 and TC3 in AS/NZS 5125 (Table 7).

Measured sound power readings at various points in the heat up cycle are illustrated in Figure 14. The vertical scale is marked in increments of 6dBA. Sound power is measured on a logarithmic scale, and a 6dBA increment indicates a doubling of sound power. Most models operate in the range of 58-64 dBA (i.e. a noise range of 2:1). However, Model 4 was quieter than the others across the heat up cycle (once it started up), and Model 8 – which may have had a manufacturing fault – was twice as noisy as the next loudest.

The testing laboratory found the application of ISO 3741 to HPWHs was suited to the task. The sound levels estimated during the laboratory testing were consistently higher than the noise levels reported by manufacturers, who are likely to have used different test methodology.

Figure 14 Sound power over the heat up cycle



Conclusions

The independent laboratory testing of HPWHs using AS/NZS 5125 gave consistent results with the tests undertaken by manufacturers in most instances. Testing has raised concerns with HPWHs that had very slow heat up times, particularly in colder temperatures. Key concerns raised as a result of testing include:

- low energy efficiency in cold ambient temperatures in some models;
- slow reheat times, especially in cold ambient temperatures in some models; and
- many models had higher noise levels than expected.

While physical test results were largely consistent, the modelled performance estimates using AS/NZS4234 were often inconsistent with manufacturer-modelled results. This divergence appears to be a result of:

- a lack of clarity in some definitions in the standards;
- inconsistencies between deck files and how the model operated; and
- the small, medium and large load categories in AS/NZS4234, which can result in step changes in calculated displaced energy if a product is only marginally below the requirements of a particular load category.

4. Main Issues Facing the Market

Market failures regarding energy efficiency

Information impediments and split incentives in the water heater market

The water heater market is subject to a range of market failures, including lack of information and split incentives, in which there is conflict between the interests of householders and intermediaries such as builders and plumbers who are influential in water heater choice. In these circumstances government intervention in the market has the potential to improve the overall welfare of the community if the intervention is aimed at correcting or reducing the impact of market failure.

Market failures tend to result in sub-optimal purchasing decisions, with too little consideration given to operating costs, resulting in energy consumption, and greenhouse gas emissions, in excess of the efficient level.

To make an informed decision, a purchaser of a water heater needs to consider two costs: the initial up-front or capital cost and the running cost or cost of operating the water heater. The initial up-front cost is the sale price or purchase price, which can be easily understood by a purchaser. However, the operating cost, which largely relates to energy use, is much less clear, although it can form a major component of the overall cost. A decision made without appropriate knowledge or consideration of the operating costs is unlikely to factor in energy efficiency.

Consumers may not be able to determine the ongoing energy used by an appliance without research or outside assistance. This may also allow opportunism, as a supplier could mislead a buyer on the efficiency and efficacy of a product, which the buyer is unable to verify. Such risk can result in consumers focussing too heavily on purchasing costs. Even where consumers have access to information, the complexity may result in decisions which are suboptimal. Operating costs reflect future use and energy costs, which are uncertain and difficult to forecast. The lack of information in the Australian water heating market is discussed in more detail below.

There are also split incentives in the water heater market where the economic benefits from superior energy efficiency purchases do not accrue to the person making the purchasing decision. A particular case is water heaters installed as part of a housing development. The developers have an incentive to minimise capital cost to maximise their profit. As a water heater is only one relatively minor part of a property, the ability of a purchaser to compare and reflect such costs in a purchasing decision is limited. Another example of a split incentive is in the rental markets where the landlord is responsible for the purchase of a water heater, but the operating costs are the responsibility of the tenant, so a landlord has little incentive to purchase more energy efficient products.

Water heaters tend to be purchased in ways which intensify such problems. The purchase of a water heater is often made under time pressure after an existing water heater has broken down, which is not conducive to orderly research and comparison of products. The decisions are often made by or with the advice of intermediaries such as plumbers, who are less concerned with operating cost.

There is some evidence which supports the case that such market failures have led to less than optimal purchasing decisions in the water heating market. Laboratory tests undertaken to inform the product profile indicate that there is a wide range of efficiencies in HPWHs in the Australian and New Zealand markets. Many HPWH models rate poorly on at least one of key performance criteria.

The tests also indicate that some models have poor energy efficiency, especially at low temperature conditions, due to either a low COP or excessive use of a resistance element. Other models have very long heat up times from cold, or low reheat rates after hot water is drawn off. Some are noisy and some models have more than one serious performance shortcoming. Few have none.

A preliminary analysis of purchase prices of the nine models tested in Australia found no clear relationship between purchase price and COP, hot water delivery rates, cold temperature performance or noise. While this analysis is preliminary, it does suggest that many of the key performance characteristics of HPWHs, including energy efficiency, are not directly influencing price, suggesting the possibility of market failure.

Lack of consistent and reliable information

There is a lack of consistent public information about key aspects of HPWH performance: energy efficiency, noise and the ability to perform under different climate conditions and electricity tariffs. What data is available is difficult to verify, as it requires extensive testing and modelling with the use of proprietary information. Where this has been done, physical testing results were relatively consistent, however, the correspondence between published and independently modelled values is poor.

In Australia, the only public information reported in a consistent format is the number of STCs that each HPWH and solar water heater model is eligible to create under the Commonwealth Small-scale Renewable Energy Scheme. Most HPWH suppliers publish these values on their websites and in product brochures. As STCs only provide an indication of renewable energy contribution, not energy efficiency, they are not suitable for comparing the energy efficiency of HPWHs.

Some suppliers also publish explicit COP values, which are invariably higher than the task COPs calculated independently from AS/NZS 4234 for the same models. The COP values given are usually in the range 3.5 to 4.5, values which can only be achieved at the temperature and humidity conditions which are the most favourable for HPWH performance. This is rarely explained.

Other ways in which performance claims are made are:

- in diagrams which show, for example, 1kW of electricity supplied to the HPWH and 3kW of hot water out (an implied COP of 3.0);
- as percentage efficiencies above 100% (e.g. '300% efficiency'); and
- as 'percent saving on water heating costs' usually in relation to the reference electric resistance storage water heater as determined in AS/NZS 4234. It is not explained that this may or may not correspond to a user's actual existing water heater, and makes no allowance for the possibility that the cost savings could be less than the energy saved if a tariff change occurs.

Published statements about noise levels were found for four of the nine models tested for noise. The ranking of sound power levels (from highest to lowest) matched the order in the test results, but reported values were about 10 to 12 dBA lower than the test results. (A difference of 12 dBA indicates a four-fold difference in sound power). There was no explanation of the method or standard used for noise testing any of the models.

Public claims for heat up time from cold were only made for one of the models tested.

In New Zealand, modelled performance based on AS/NZS 4234 has been available on the EECA website, along with some advice on performance in frost conditions. However, as many HPWHs tested for this study are available in New Zealand, the same issues apply with the reliability of information.

As a consequence of the lack of complete, consistent and reliable information on HPWH performance, and the wide ranges in product performance:

- Prospective purchasers cannot be assured of getting a product that performs adequately;
- Those purchasers who are motivated to do so are unable to reliably identify good performers (and avoid poor performers); and
- There is limited market pressure on suppliers to improve product performance.

Without consistent and representative information consumers in Australia and New Zealand are not able to compare key performance characteristics of HPWHs, including heat up times, noise and energy efficiency.

Policy options to improve energy efficiency

There are a range of policy options to reduce market failures and improve the energy efficiency and product performance of HPWHs in Australia and New Zealand. These could range from a registration of publicly available performance results for energy efficiency, heat up times and noise, through to MEPS and labelling. These options are explored below.

Public information

The results presented in this study represent the first systematic comparison of a significant number of the HPWH models on the Australian and New Zealand markets, using independent laboratories and the latest test procedures.

Government agencies could continue to commission tests that do not require commercially sensitive information, and choose to make the information freely available to the public. Indeed, giving manufacturers advance notice of the intention to do so may be sufficient to motivate them to make improvements, in order to forestall the identities of poor performing models from being revealed.

However, it would be very expensive to cover the entire market (there are nearly 100 models of HPWHs sold in Australia and New Zealand) and it would be difficult to keep up as designs are modified and new models are introduced. Furthermore, the government – rather than the suppliers – would have to assume responsibility for the accuracy and administration of the testing.

Ultimately, the ability of information to influence a market towards higher energy efficiencies relies on consumers or installers seeking out the information and acting on it at the time they make a purchase or recommend a product. While this is now common with other appliances - after years of mandatory energy labelling – there is evidence that the water heater market operates under conditions of rushed decisions and split incentives, which mean that information of this kind is less likely to be used (GWA 2010).

Testing and registration of key product characteristics

The common basis for measures to improve the energy efficiency of household appliances is a system of reproducible and repeatable testing of products, with public notification or declaration of the test results. This can be achieved by a mandatory requirement for HPWH manufacturers and suppliers to test products to specified standards and to disclose the results before the products can be lawfully sold. This is the same as the requirements for other products regulated for energy efficiency by the E3 Program.

The disclosure could cover a range of factors bearing on the performance of the product, including the following:

- the energy efficiency at selected operating conditions;
- heat up times, hot water load or size of household it can serve (depending on the climate zone and the tariff);
- the climate zones for which the product is suitable (assuming that there is no obligation for all models to perform in all climate zones);
- the noise levels at selected operating conditions;
- for models designated as suitable for cold climates, performance under low temperature and frost conditions: e.g. the temperature at which the evaporator starts to frost, and (for models with elements) the temperature at which the unit ceases to function as a heat pump and relies on the element;
- ability to operate with restricted (off-peak) tariffs; and
- other product characteristics that may be important to prospective purchasers, e.g. whether a model meets criteria for drinking water safety (e.g. by having a double wall heat exchanger).

Most of these factors could be expressed in many different ways. If the form of disclosure were left to suppliers, they would most likely present it selectively (as is the case now) and it would be tempting for suppliers of poor performing products to ensure that the information was difficult for the public to find, or ambiguous. Placing the test results on a public register, in a standard format, would achieve the following:

- common registration requirements will ensure consistency in the type and form of data submitted;
- the act of registration constitutes a form of legal declaration that the tests have been conducted properly;
- if it is later determined that the data registered for a particular model are at odds with check tests conducted by a competent independent authority, and the differences cannot be resolved through dispute resolution, then removal of the model from the register constitutes the ultimate sanction, making sale of the product unlawful; and
- making the register public ensures that prospective purchasers or consumer advocates can compare the characteristics of all models.

An independent authority should be able to verify the registered characteristics by purchasing a sample of the model on the open market and testing it using published standards. It should not be necessary to obtain any proprietary information necessary to test the sample from the supplier or the manufacturer.

This would disqualify any testing regime based on the present version of AS/NZS 4234, because the simulations require access to proprietary TRNSYS deck files (see Figure 7). The energy performance test regime would need to be based on AS/NZS 5125 and AS/NZS 4692. The noise test would need to be specified, either as a new standard or by the use of an existing ISO standard (e.g. ISO3741 with defined ambient and water temperatures).

MEPS and functional performance requirements

While some water heater buyers would respond to better information, this alone would not resolve the split incentives issue (e.g. landlord-tenant effects). There is a case for the introduction of MEPS, to remove the worst performing products from the market, some of which are significantly less efficient than the median and much less efficient than the commonly claimed benchmark, i.e. a nominal 60% energy saving compared with a reference electric resistance water heater.

If MEPS are considered it is suggested that AS/NZS 5125 would provide readily verifiable physical measures of performance. The following performance measures have been identified as providing comparative measures of key performance features and could provide suitable metrics for MEPS.

- Energy efficiency under normal and cold operating conditions
  - Time weighted COP from 45°C to maximum (or 55°C), at Test Condition 1;
  - Time weighted COP from 45°C to maximum (or 55°C), at Low Temperature Test Condition;
- Rate of reheating under normal and cold operating conditions
  - Litres per hour from 45°C to maximum (or 55°C), at Test Condition 1; and
  - Litres per hour from 45°C to maximum (or 55°C), at Low Temperature Test Condition.

Another option to consider is whether to permit suppliers to nominate models as suitable for different climate conditions (e.g. for cold climates, frost-prone areas or warm climates) and set different values under the above metrics for the different climatic categories. The alternative would be to require all models to meet minimum performance criteria at each test condition in AS/NZS 5125. The latter approach would make it unnecessary for consumers to consider the suitability of a purchase for their particular location, but would increase the cost of compliance through the need to conduct additional testing for some models. It may also lead to sub-optimal outcomes if suppliers have to compromise performance in the climate zones with the highest use of HPWHs in order to accommodate relatively few sales in other climate zones.

A further issue is how to indicate whether HPWH models are suitable for operation – or how their performance may be affected – under restricted and off-peak tariffs.

It may also be in the public interest to set mandatory maximum noise levels, so that even purchasers who may not be concerned with high noise levels themselves (e.g. because their own windows are far from the HPWH location) do not impose it on their neighbours.

Energy and performance labelling – mandatory and voluntary

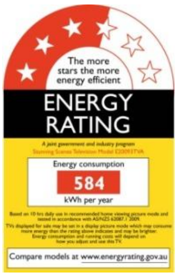
Mandatory product registration and minimum performance standards may be the most effective way to ensure acceptable levels of performance for HPWHs for all purchasers. However, some suppliers may have products which are more energy efficient or perhaps quieter than any minimum standards and may wish to target segments of the market accordingly.

A public product register could function in similar ways to energy labelling, since it would enable consumers to sort products in order of criteria such as COP or noise. However, some suppliers may wish to gain further commercial advantage by attaching physical labels to their better performing models. Alternatively, there could be a requirement to physically label every model, as is the case with gas water heaters.

A mandatory regime would need to anticipate the possibility of such labelling, and either prohibit it entirely (on the grounds that it could become another area of selective and confusing disclosure), require it on every unit or specify the format to be used but leave it up to suppliers to physically label if they wish. As only a small proportion of buyers will bother to physically inspect water heater before they make a selection (or have someone else make the selection on their behalf) the most effective way to disseminate HPWH performance information may be to require its disclosure in brochures, on supplier websites, and for procurement/bulk purchasing purposes. There may be scope for a more limited form of labelling (and/or physical marking on the product) which identifies a model's suitability for operation in specific climate zones.

In New Zealand, the international ENERGY STAR mark is used as voluntary endorsement on a range of energy using products to identify those high efficiency models, usually in the top 25% of models available in the market. Registration of all HPWH models would enable EECA to monitor the efficiency distribution on the market and set the criteria for use of ENERGY STAR.

In Australia, ENERGY STAR is currently reserved for information technology, entertainment and office products which meet the ENERGY STAR criteria established by the US Environment Protection Agency.



The Energy Rating label is used in Australia and New Zealand to indicate comparative product energy efficiency on a scale of 1 to 6 (and more recently, 1 to 10) stars. The grading rules are specified in the relevant standards.

To date, the only types of water heater for which a form of star rating label have been used are gas water heaters. These were introduced in the 1980s by the then Australian Gas Association. The industry led gas labelling program now exists alongside the electric appliance labelling program but is not part of it.

Conclusions

The use of HPWHs instead of electric resistance water heaters could result in significant electricity savings and as a consequence save households money. However, while most HPWHs perform well under warmer conditions, performance in colder conditions (and in frost) depends strongly on the particular model. High performing HPWH systems can be more effective at reducing winter electricity loads than lower performing models, as well as offering constant performance over a wide range of loads.

The technology of HPWHs is still evolving, and there is a wide range in product performance, as shown by independent laboratory testing in Australia and New Zealand and by field testing in New Zealand. In both laboratory and field testing the performance was sometimes far below expectations.

Considering the range of performance issues and consumer information concerns, water heater purchasers are likely to benefit from new strategies to improve the performance, quality and information available on HPWHs.

As such, the following strategies are proposed for consideration by stakeholders:

1. Establish a system of mandatory product testing and registration, based on AS/NZS 5125, as well as noise testing to ISO 3741. As HPWH suppliers already conduct physical tests to AS/NZS 5125 and governments already maintain registers of other appliances, the additional costs should be relatively minor in comparison with the potential public benefits.

2. Introduce MEPS and functional performance requirements, including addressing cold temperature performance and noise issues, with proposed notification of the requirements no later than mid 2013 and requirements to take effect by mid 2014. There are likely to be significant benefits from ensuring that all models are fit-for-purpose and achieve MEPS.
3. Enable public access to the registered data, with models identified. This will provide potential purchasers, competing suppliers and regulators with an overview of the range of products and performance levels on the market.
4. Develop energy labelling standards, either as a mandatory requirement or initially for voluntary use by suppliers.
5. Develop a roadmap of potential future increases in minimum performance criteria and associated measures such as labelling.

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Appendix 1: Heat Pump Technology and Standards

Factors impacting energy efficiency

The theoretical maximum COP of a heat pump depends on the properties of the refrigerant fluid. In practice, the COP will always be lower, because of tank heat loss, de-frosting cycles, and energy losses at the valve which controls the expansion of the refrigerant fluid, at the points of heat transfer in the evaporator and the compressor, and in the compressor motor and pump. For example, even a relatively efficient heat pump is typically only about half as efficient as the theoretical limit[20]. Even so, it can still be two to three times as energy efficient as an electric resistance water heater.

The actual COP of the heat transfer process in any given HPWH will vary under different ambient temperature and humidity conditions. Even if those conditions are held constant in a test room, the COP will gradually fall as the unit heats up a tank of water from cold to the maximum operating temperature. The reducing COP is due to the lower temperature difference between the air source and the tank water temperature.

Heat pumps can be designed to operate at very low ambient temperatures – some refrigerant fluids can extract heat from the ambient environment at temperatures well below 0°C. However, if cold temperatures are accompanied by high humidity, the evaporator surfaces will 'frost' or ice up, and this will form an insulation barrier that inhibits heat transfer. To address this problem, some designs reverse the refrigerant flow from the stored hot water to the evaporator until the ice melts off; others incorporate de-icing resistance elements in the evaporator or in the water storage tank itself, so that the unit operates as an electric resistance water heater rather than as a heat pump while the frost conditions persist.

Some HPWHs lack de-frosting capabilities, and so are unsuitable for use in frost-prone areas. Where de-frosting capabilities are present they incur an energy penalty, which can be quantified if the unit is physically tested under frosting conditions or its performance is modelled by computer simulation.

In common with all other storage water heaters, heat pump water heaters incur a standing heat loss. Even if no hot water is drawn off, heat will be lost from the stored water, by conduction through the walls of the storage tank and through the pipes that connect the tank to the refrigerant circuit and to the cold water inlet and hot water outlets. The better the insulation of the tank and the connecting pipes, the less the amount of energy needed to make up the heat loss.

The overall 'task efficiency' or 'task COP' of a water heater needs to take into account all categories of its electricity consumption and loss:

- The electricity used by the refrigerant compressor motor and other auxiliaries (e.g. fans to increase air movement over condenser surfaces) in the process of heating the water;
- The electricity used by the refrigerant compressor motor and other auxiliaries (e.g. a resistance element) to impart additional energy to the water to compensate for standing heat losses and water use; and
- The additional energy used during de-frosting and any other special operating cycles (e.g. regularly heating the water up to a level that kills *Legionella* bacteria).

Some COP values publicly quoted for HPWHs only take into account the first of these categories measured in optimum environmental conditions, and so overstate the COP achievable in actual use. Others take into account a standard pattern of use, standing heat losses and frequency of operation under frost conditions, and so calculate a more realistic task COP.

It is also common to express heat pump energy use in terms of the estimated reduction in electricity use compared with a 'reference' electric resistance water heater that could provide a similar level of service.

[20] Williamson et al. p10.

Product types

The main parts of a heat pump water heater are the evaporator unit (usually housing the evaporator, fan and compressor), the condenser that transfers heat to the water and the water storage tank itself. These can be physically configured in a number of ways, generally called integral, split and stand-alone.

Integral heat pump water heaters have all their parts housed in a single cabinet, with the evaporator unit commonly above the storage tank (Figure 15). The condenser may be in the wall of the tank (as in this example) or centrally located in the tank Figure 16. Integral systems are usually installed outside.

Figure 15 Integrated Heat Pump Water Heater (with wrap-around condenser)

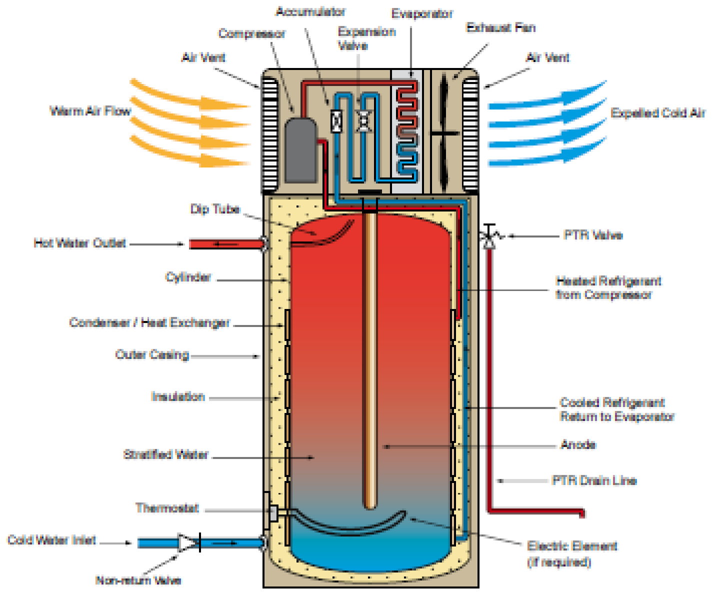
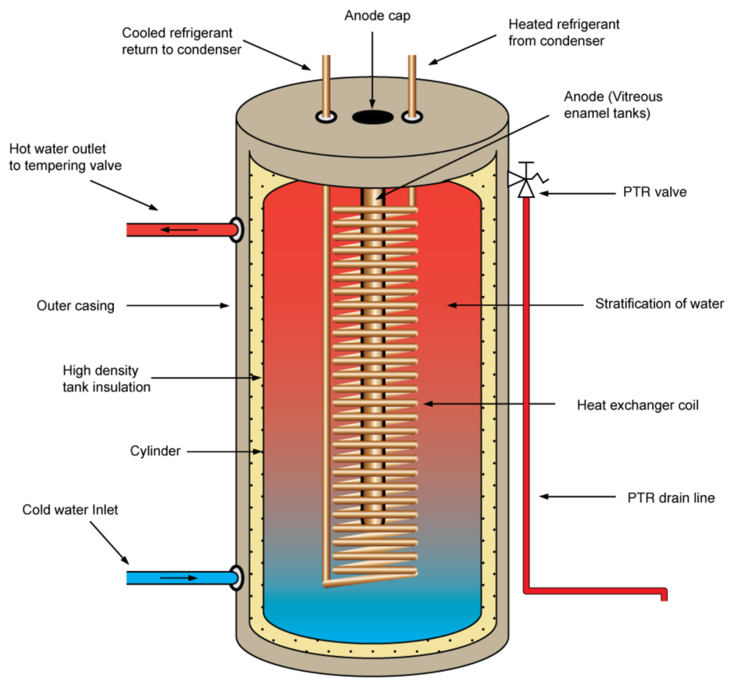


Figure 16 Storage Tank for Split Heat Pump (with internal condenser)



The heat pump may be ‘split’ by separating the evaporator unit from the storage tank, and connecting them either by refrigerant flow and return lines or by hot water and cold return lines. In either case, the evaporator unit and the storage tank are designed to work together and are supplied and installed together. The advantage of split units is that the tank can be located inside and the evaporator outside or the evaporator can be placed in a location where any noise will be less of an issue.

A ‘stand-alone’ heat pump water heater has the evaporator and the condenser in a self-contained unit that can be connected, by water lines, to any storage tank. Stand-alone heat pumps can be purchased separately and are commonly retrofitted to some types of existing electric resistance storage water heaters in New Zealand (although they are often marketed with a nominated tank as a package deal). Where a stand-alone heat pump is retrofitted to an existing electric resistance water heater, the overall efficiency of the combined system will only be increased if enough of the heating task is transferred from the resistance element to the heat pump (e.g. by raising the element thermostat cut-in point or installing an ‘intelligent’ controller) or if the element is disconnected altogether.

One key difference between stand-alone and split heat pumps is that the performance of the stand-alone system can vary considerably depending on the heat loss characteristics of the tank to which it happens to be connected (heat loss, stratification, resistance element), and how well the hot water in the tank is stratified. A well stratified tank will have a higher proportion of the stored heat concentrated at the top, so more of it can be drawn off before the water flow becomes too cool to be useful.

Noise

The noise regulations developed and administered by local councils and state environment protection agencies vary considerably in their scope and application. For example:

- In SA, the noise policy requires that a HPWH must not exceed 45 dBA between 10 pm and 7 am, or 52 dBA between 7 am and 10 pm when measured at the receiver’s premises.
- The NSW State Guideline states that noise from domestic equipment should be less than 35 dBA at the neighbour’s boundary or less than 30 dBA if sensitive areas (bedrooms) are located within 2m of the boundary.
- In VIC, noise from fixed domestic plant is subject to Section 48A of the Environment Protection Act 1970 and the Environment Protection (Residential Noise) Regulations 2008. These requirements state that noise from any fixed domestic plant must not be audible within a habitable room of any other residence (regardless of whether any door or window giving access to the room is open) during prohibited hours. For HPWHs the prohibited hours are 10 pm - 7 am Monday to Friday and 10 pm - 9 am weekends & public holidays. During other times, the intrusive noise must not exceed background noise level by more than 5 dBA at the measurement position.
- In QLD, local councils specify the noise restrictions. For example, the Brisbane City Council guidelines for air conditioners are that noise levels should not exceed 5 dBA above background noise from 7 am to 10 pm and 3 dBA above background noise from 10 pm to 7 am.

There are recognised international standards for noise measurement from HPWHs (e.g. DIN 12102) and moves to mandate maximum noise levels in some jurisdictions. The draft European Ecodesign Directive for boilers and heat pumps includes maximum outdoor sound power level of 65 dBA for HPWHs with a rated capacity of <6kW (EC 2011).

While the New Zealand Building Code specifies noise levels inside residential buildings, respective external noise levels are ambiguous, in that local bylaws have precedence and thus distance from the boundary becomes important.

Permitted external noise levels (at the property boundary) are specified by many New Zealand city councils. Table 6 shows an example of noise regulations from the Dunedin City Council. The night time noise level tolerance in suburbs is 35 dBA.

Most manufacturers and suppliers specify the noise levels of their heat pump water heaters (see Table 4: Systems supported by EECA 2009).

HPWH noise levels are measured in the range 47 to 62 dBA at a distance of 1 to 1.5 m.

Therefore, depending on how they are installed, HPWHs (especially in large numbers) could exceed the night-time tolerance in many suburbs.

On a more general note, the perception of noise from a given source depends strongly on background noise levels. In this respect it is always difficult to specify a particular level for any one source. For reference, 47 dBA is in the range of normal conversation, 50-53 dBA is the level of a dishwasher and 63 dBA is the level of a hand-held kitchen blender.

As evident from internet fora (such as www.consumerforums.org.nz), there are already problems with noise from space heating heat pumps (i.e. air conditioners) in New Zealand, which are generally larger than water heating systems. However, there is anecdotal evidence that HPWHs are perceived as noisy.

In New Zealand there appear to be no regulations specifically for heat pumps. Europe has standards for determining sound levels of domestic appliances (e.g. ISO 3741: 2010).

Table 6 Example of city noise level regulations - Dunedin City

	Day-time 7:00 - 21:00	Night-time 21:00 – 7:00 (week) 24 hours (weekends & stat. holidays)	Shoulder period 7:00 – 20:00 (Mon - Fri) 18:00 – 21:00 (Mon - Sat)
Inner suburbs	50 – 55 dBA	40 dBA	45 dBA
Outer suburbs	50 dBA	35 dBA	45 dBA
City centre	60 dBA	60 dBA	n/a
Rural	55 dBA	40 dBA	n/a

Standards applicable to heat pump water heaters

Australian/New Zealand Standards

AS/NZS 2712: 2007 Solar and heat pump water heaters - design and construction plus appendices

Section 8 covers design and construction of solar water heater and HPHW with appendices; note the new addition of appendix H. This arose as an ad-hoc addition to the original solar water heater standard. The standard covers the evaluation of the overall system for integral systems and the heat pump itself for split/stand alone systems.

AS/NZS 5125.1: 2010 Heat pump water heaters – performance assessment

This standard covers the test conditions and test procedures for determining the energy performance characteristics of single circuit air-source heat pump water heaters. It does not apply to solar boosted heat pump water heaters.

AS/NZS 4234: 2008 Heated water systems - calculation of energy consumption

This standard covers the computation from physical test results, proprietary information, known component properties and weather data of the expected annual performance of a range of water heaters including conventional solar and heat pump water heaters. The computation is based on a particular modelling software package, known as TRNSYS. This standard was originally formulated for solar water heaters and has to be modified to deal with HPWHs.

AS/NZS 4692.1:2005 Electric water heaters - energy consumption, performance and general requirements

Will supersede NZS 4602 at a date yet to be determined (see Preface to AS/NZS 4692).

AS/NZS 4692.2: 2005 Electric water heaters - energy consumption, performance and general requirements: Amendments

Will supersede NZS 4602 at a date yet to be determined (see Preface to AS/NZS 4692).

AS/NZS 4020:2005 Testing of products for use in contact with drinking water

Relates to materials in contact with drinking water (formerly referred to as potable water).

AS/NZS 1677 Refrigeration systems

This refers to labelling of refrigerant types and safety measures relating to refrigeration system installations. This includes the heat pumps of HPWH systems.

AS/NZS 1056.4: 1997 Storage water heaters - daily energy consumption calculations for electric types

This standard sets out a method for calculating the energy consumption of electric storage water heaters fitted with electric resistance elements. Exemptions within this standard result in the standard not applying to gas water heaters, solar water heaters, heat exchangers or heat pumps.

AS/NZS 3000:2000 the Australian/New Zealand electrical wiring rules

AS/NZS 3350.2.40: 2001 Safety of household and similar electrical appliances – particular requirements – electrical heat pumps, air-conditioners and dehumidifiers

This refers to electrical safety of heat pumps it appears to correspond to IEC 60335.2.40 and will be replaced by AS/NZS 60335.2.40 in June 2013.

AS/NZS 60335.2.40:2006 Household and similar electrical appliances - safety - particular requirements for electrical heat pumps, air-conditioners and dehumidifiers

Australia specific Standards

AS 2984: 1987 Solar water heaters - methods of test for thermal performance - outdoor test method

This standard describes the outdoor testing of solar and heat pump water heaters.

AS 3498: 2009 Authorization requirements for plumbing products – Water heaters and hot-water storage tanks

This standard provides uniform requirements in Australia for basic safety and public health issues relating to the use of water heaters and hot-water storage tanks.

New Zealand specific Standards

These four standards cover the main features of heat pump water heaters. However installations may also be subject to a number of other regulatory requirements. For example hot water cylinders, including those used in heat pump water heaters, incorporated into new installations, must conform to the relevant national standards and regulations, domestic plumbing related to the systems must conform to the relevant national plumbing regulation and building codes, and electrical installation must conform to the relevant electrical regulations.

In New Zealand this includes the standards for hot water cylinder manufacture and installation:

NZS 4602: 1988 Low pressure copper thermal storage electric water heaters

This covers design, materials and thermal performance of thermostatically controlled heaters of 6.5 L to 450 L designed for pressures up to 120 kPa installed vertically and either open vented to NZS 4603 or valve vented to NZS 4207.

NZS 4603: 1985 Installation of low pressure thermal storage electric water heaters with copper cylinders (open vented systems) complying with NZS 4602

This applies to dual systems which supply hot water supplementing heat derived from the electric element. Solar assisted systems are not covered.

NZS 4606: 1989 Storage water heaters

Part 1 General requirements: This covers general construction and performance requirements for storage water heaters 6.5 l to 630 l other than those covered by NZS 4602. It also specifies allowable heat loss. This is based in part on AS 1056 part 1.

NZS 4607: 1989 Installation of thermal storage electric water heaters: valve vented systems

Applies to the installation of thermal storage water heaters complying with NZS 4602 and NZS 4606 fitted with a pressure relief valve instead of an open vent (referenced in BIA approved document G12).

NZS 4608: 1992 Control valves for hot water systems

Sets out the design, construction performance and testing of valves for pressure control, expansion control pressure relief, vacuum relief, temperature relief and non-return functions. Referenced in BIA document G12

NZS 4305:1996 Energy efficiency – domestic type hot water systems

This standard sets out minimum energy efficiency requirements in terms of heat losses from domestic type hot water systems. It applies to all domestic type hot water systems irrespective of energy source and covers systems that may be found in residential, industrial and commercial buildings. Of particular note are section 2.1.1 and 2.1.2 which define values for heat loss from domestic sized cylinders.

Other Standards

IEC 60335-2-40: 2005 Household and similar electrical appliances – safety – particular requirements for electrical heat pumps, air conditioners and dehumidifiers

This refers to electrical safety of heat pumps and references IEC60335-2-21.

EN 14511: 2004 Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling

These are for air-water heat pumps but appear to be mainly designed for systems for space heating. Nonetheless they are quoted by some manufacturers. Results for 34 systems from WPZ indicate that tests are specified for water temperatures up to 55°C.

Although EN14511-2004 relates to air-source heat pumps for space heating and water chilling and heating, it is quoted by some Chinese manufacturers of air-source heat pump domestic water heaters (e.g. Sirac).

EN 255: 1997 Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors – heating mode – requirements for space heating and sanitary hot water units

This standard is for heat pumps for heating sanitary (domestic) hot water. Test results for 59 systems from WPZ indicate that tests are carried out with water temperatures up to 50°C.

CAN/CSA C652-00:2000 Installation of electric storage tank and heat pump water heaters for residential use

This specifies requirements for the installation of electric storage tank and heat pump water heaters intended for use in residential premises.

Canada C745-00: 2000 Energy efficiency of electric storage tank water heaters and heat pump water heaters

This standard specifies the methods for determining the energy factor for electric storage tank water heaters and heat pump water heaters

Test conditions used for this product profile

Table 7 AS/NZS 5125 Test Conditions (TCs)

Test Condition	Temperature range in test room	Relative Humidity in test room	Water temperature at start of test
Low Temperature (LT)	0 – 2 C	>= 90%	< 10 C
TC 1	<10 C	80 – 90 %	< 10 C
TC 2	18 – 20 C	60 – 70 %	< 15 C
TC 3	20 – 35 C	30 – 40 %	< 25 C
TC 4	20 – 35 C	55 – 65 %	< 25 C

Table 8 Peak daily load and annual purchased energy reference water heater

Climate zone	Climate data source	Small load		Medium load		Large load	
		Peak MJ/day winter	Purchased energy MJ/yr (a)	Peak MJ/day winter	Purchased energy MJ/yr (a)	Peak MJ/day winter	Purchased energy MJ/yr (a)
HP1-Au	Rockhampton	18	7,620	30	12,560	45	17,180
HP2-Au	Alice Springs	18	7,690	30	12,640	45	17,260
HP3-Au	Sydney	22.5	9,270	38	15,260	57	21,100
HP4-Au	Melbourne	25.2	10,280	42	16,670	63	23,140
HP5-Au	Canberra	25.2	10,400	42	16,850	63	23,320
HP1-NZ	Auckland	25.6	9,280	39	13,050	52	16,900
HP2-NZ	Dunedin	25.6	17,240	39	21,870	52	26,350

Source: AS/NZS 4234:2008 Amdt 1:2011 (a) Electricity used by a reference electric storage water heater serving this load

Table 9 Load profile data in AS/NZS 4234

	Australia	New Zealand
Daily load profile	Table A4 8 draws, 07:00-18:00	Table B4 10 draws. 06:00-23:00
Seasonal load profile	Table A5 0.71 to 1.0 of peak daily load	Table B5 0.51 to 1.0 of peak daily load

A4 etc refer to Table numbers in AS/NZS 4234

Table 10 Combination of assumptions for TRNSYS modelling

	HP3-Au	HP3-B3	HP3-B4	HP3-B5	HP3-B345
Climate Zone	H9.1	H9.1	H9.1	H9.1	H9.1
Cold water temp	H9.2	H9.2	H9.2	H9.2	H9.2
Peak daily thermal load	A3 (Aust)	B3 (NZ)	A3 (Aust)	A3 (Aust)	B3 (NZ)
Daily load profile	A4 (Aust)	A4 (Aust)	B4 (NZ)	A4 (Aust)	B4 (NZ)
Seasonal load profile	A5 (Aust)	A5 (Aust)	A5 (Aust)	B5 (NZ)	B5 (NZ)

Shading indicates the standard combination used to estimate energy savings in Zone 3 for Australia.

Product Profile: Heat Pump Water Heaters

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