INTERNATIONAL REVIEW OF MINIMUM ENERGY PERFORMANCE STANDARDS FOR ELECTRIC RESISTANCE STORAGE WATER HEATERS

Report for the

National Appliance and Equipment Energy Efficiency Committee

and

The Australian Greenhouse Office

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INTRODUCTION

Since the late 1970s, Australian Standards have contained voluntary Minimum Energy Performance Standards (MEPS) for electric storage water heaters (EWH), which are expressed in terms of the maximum allowable heat loss specified in AS1056. In 1999, government regulations made the latest revision of these MEPS levels mandatory for mains pressure storage models while the MEPS levels for other types of electric storage water heaters remained voluntary.

In 1999, the Ministerial Council responsible for energy efficiency matters agreed to consider:

> …"developing MEPS for Australia that match best practice levels imposed by our major trading partners for internationally traded products that contribute significantly to Australia's growth in greenhouse gas emissions" (NAEEEC, 1999, p8 [1]).

Where appropriate, reaching this established level may be achieved through a staged process that introduces progressively more stringent requirements over time.

This report expands and updates a previous submission to the National Appliance and Equipment Energy Efficiency Committee (NAEEEC) which was prepared by EES in December 1998 [2]. The aim of this document is to provide more up-to-date information on the status of overseas MEPS levels for electric storage water heaters and to provide a more rigorous modelling approach to the comparison of overseas MEPS levels with the equivalent standing heat loss level in AS1056. The report is intended for use by government when considering the MEPS levels in force overseas as models for implementation in the Australian context.

Electric resistance storage water heaters covered by AS1056 are the focus of this review, including size ranges 25 to 630 L rated hot water delivery capacity. This report does not consider heat exchange water heaters.

A draft of this report was provided in July 2000. The water heater MEPS rules in the USA were released in January 2001 and these have been incorporated in this final report, along with the revised options for consideration.

MARKET CHARACTERISTICS

The historical and forecast supply of electric hot water systems in the Australian market is shown in Table 1.

Table 1: Actual and forecasts of electric hot water systems, 1988-2001

Year	Domestic Units Supplied ('000)
1988	299.1
1989	384.5
1990	343.2
1991	333.3
1992	373.7
1993	441.1
1994	421.8
1995	457.0
1996	395.8
1997	403.3
1998e	421.8
1999e	423.4
Forecasts	
2000	455.4
2001	377.0

Source: BIS Shrapnel May 2000. 1998 and 1999 are estimated by BIS Shrapnel

The estimated market share of new mains pressure electric hot water heaters installed in 1992 is shown in Table 2 [3]. The market share would now be different from 1992, presumably with a shift from Peak to Off Peak tariffs and most likely with greater share of Twin Element.

Table 2: Estimated Market Share of New Mains Pressure Hot Water Heaters Installed 1992

Delivered Capacity	Peak	OP1	TEOP	OP2	Total
18	12.0%				12%
25	7.0%				7%
50	7.0%				7%
80	8.0%				8%
125	8.4%	1.2%		2.4%	12%
160	2.5%	1.5%		1.0%	5%
250		25.9%	1.1%		27%
315		12.8%	4.3%		17%
400		1.3%	3.8%		5%
Total	44.9%	42.6%	9.1%	3.4%	100%

Notes: OP1 – Off peak restricted, TWOP – Twin Element Off Peak, OP2 – Extended Off Peak.

According to recent surveys (ABS 4602.0 1999) and projections based on this data by EES [4], electric storage water heater penetration was about 59% in 2000 and this share is very slowly declining as gas system ownership slowly increases, although the total stock of electric storage water heaters appears to be remaining stable.

STANDARD TEST & MEPS LEVELS – AUSTRALIA

Overview of the Standard Test Method

MEPS levels for electric water heaters are measured in accordance with AS1056.1 Appendix B. AS1056.1 defines allowable heat losses for vented and unvented displacement water heaters for a range of specified hot water delivery capacities. Heat exchange water heaters are covered by AS1361 and are not considered in this report as the hot water delivery characteristics a very different to displacement types. All of the storage water heater test methods are under revisions and it is hoped that these will be republished by late 2001.

The heat loss test involves the water heater being operated at a fixed thermostat setting for about 24 hours with no water being drawn off. All plumbing connections as supplied are fitted and lagged (except for the TPR valve which is not lagged). A single thermocouple is placed at the centre of gravity (centroid) of the water heater and readings are taken at intervals not exceeding 2 hours (more frequent readings are allowable). An air thermocouple is placed 1.5m from the water heater and 1m from the ground and the sensor is placed in a mounting that has a thermal mass of 10 to 20g of water (usually a brass cylinder). Average air temperature is determined from 2 hourly readings. Thermostat temperature is generally set to be nominally 55°C above ambient (or T minus 20°C above ambient if the maximum thermostat temperature T is greater than 75°C). The element supplied with the unit is operated at rated voltage. The water heater is operated for not less than 24 hours to allow stabilisation. It is then disconnected at the inlet and outlet and readings commence at a thermostat cut-out and continue until the first thermostat cut-out after 24 hours. The energy consumption value measured is adjusted for average hot water and air temperature for the duration of the test back to a ΔT of 55°C and a period of 24 hours.

The most important point regarding the Australian Standard is that maximum allowable standing heat losses are defined in terms of hot water delivery capacity, as opposed to tank volume in most other systems and test procedures. The relationship between tank volume and hot water output can vary somewhat between models and depends on the level of stratification achieved during drawoff. For the purposes of this analysis, a constant ratio between tank capacity and hot water output has been assumed (about 1.15) where the precise relationship is not known.

MEPS Levels

Australia has had a form of MEPS for water heaters for nearly 20 years, based on a maximum allowable standing heat loss under static conditions, contained in the Australian Standard AS1056 Part 1. While not mandatory in a legislative sense, this requirement became a de facto mandatory standard for larger capacity models since a number of the major electricity utilities used to require water heaters to comply fully with the Australian Standard if they were to be connected to an off peak tariff (off peak tariffs supply more than 50% of all electric water heater installations in Australia). In addition, government contracts may specify compliance with the standard as a pre-requisite. Allowable values from 1977 to date are shown in Table 3 and Figure 1.

The MEPS levels for mains pressure units were made more stringent by the introduction of Amendment 3 of AS1056.1 (issued 5 August 1996) which came into force on 1 October 1999. This amendment has been made mandatory for mains pressure models through the introduction of government regulations for energy efficiency. The MEPS levels for other types of units (vented types) remained at the 1985 levels and these are still voluntary in nature. Until Amendment 3 was introduced, MEPS levels for vented models without an attached feed tank were the same as those for mains pressure, while those with an attached feed tank were 0.3 kWh/day higher.

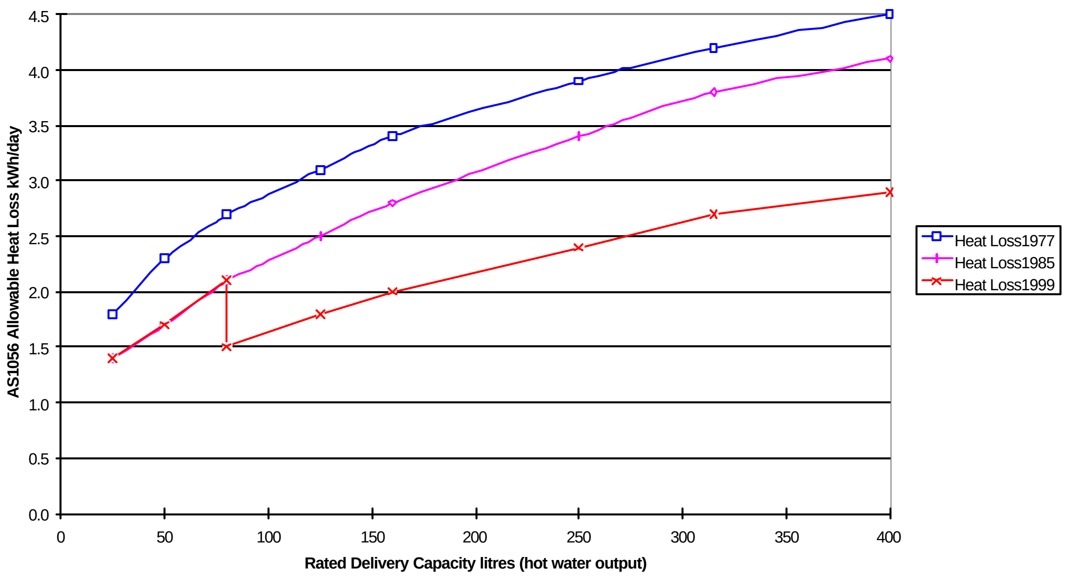
Table 3: Allowable Standing Heat Loss (kWh/day) Mains Pressure Electric Storage Water Heaters from 1977 to 1999, Australia

Rated Hot Water Delivery Litres (a)	Allowable Heat Loss 1977	Allowable Heat Loss 1985	Allowable Heat Loss 1999 MEPS
25	1.8	1.4	1.4
50	2.3	1.7	1.7
80	2.7	2.1	1.47
125	3.1	2.5	1.75
160	3.4	2.8	1.96
250	3.9	3.4	2.38
315	4.2	3.8	2.66
400	4.5	4.1	2.87

Source: AS1056-1977, AS1056.1-1985 & 1991, AS1056.1 Amendment 3 1996.

Notes: The above allowable heat losses are for unvented displacement water heaters only (mains pressure). Allowable heat losses in AS1056.1-1991 are the same as those in AS1056.1-1985. Extra 0.2 kWh allowance for each hot side penetration (minimum of 1 for T/PR valve). Rated hot water delivery capacity is the volume of water that can be delivered (this is called hot water output in IEC60379 but the test method is different to AS1056.1). Voluntary MEPS levels for vented electric storage water heaters without an attached feed tank remain at the 1985 levels shown above. Voluntary MEPS levels for vented systems with an attached feed tank remain at 1985 levels shown above + 0.3 kWh/day.

Figure 1: Development of Australian Water Heater MEPS Levels from 1977 to Date



In the first instance, government made MEPS mandatory only for mains pressure units, as these were seen as dominant in the marketplace and their regulation captured the bulk of the potential savings. However, in recent times elements of industry have suggested that MEPS for these other types should also be made mandatory and more stringent to a level comparable with MEPS for mains pressure systems. It is important to note that overseas MEPS systems for electric storage water heaters do not differentiate between vented and unvented types.

STANDARD TESTS & MEPS LEVELS – OVERSEAS

Canada

Test Procedure

The current test procedure is CAN/CSA-C191-M90 and covers the design, construction and energy efficiency of electric storage water heaters. Under CAN/CSA-C191-M90, the static volume of the tank is determined as the capacity. Hot water delivery capacity is determined under the "diffusion test" (drawoff test) for a temperature drop of 17°C. The standing heat loss is determined under static conditions for an air-hot water temperature differential of 44°C. Maximum allowable heat loss levels are specified in the standard as a function of static (storage) capacity.

Canada is currently considering the adoption of CAN/CSA-C745-95 in the near future (this is a drawoff test which is equivalent to the US test specified in the Code of Federal Regulations). Although a hot water delivery capacity test is specified (called first hour rating test), this is not essential except for heat pump systems, where the recovery efficiency has to be determined from this test. An energy delivery test is conducted consisting of 6 drawoffs totalling 243.4 litres at 1 hour intervals. Standing heat losses are then determined over the remained of the 24 hour test period. For this test the air-hot water temperature differential is 37.5°C while the hot-cold water temperature differential is 42.8°C. The energy factor is determined as the ratio of the energy delivered in the hot water to the measured energy consumption.

MEPS Levels

Canada introduced the current level of MEPS for mains pressure electric water heaters from 50 to 450 litres capacity on 3 February 1995. MEPS for gas water heaters (<21.97 kW) and oil water heaters (<30.5 kW) were also introduced on that date. Allowable heat loss is defined in terms of watts loss during a standing heat loss test. The test procedure is defined under CAN/CSA-C191.1-M90 (standing heat loss test). The ΔT between air and water during the test is 44°C. The Canadian regulations define MEPS as the allowable watts loss for electric storage water heaters:

Watts $\leq$ $61 + 0.20 \times V$ for V from 50 to 270 litres

Watts $\leq$ $0.472 \times V - 12.5$ for V from 271 to 450 litres

These requirements are converted into standing heat loss in Table 4.

Table 4: Canadian MEPS Requirements

Storage Capacity (Litres)	Nominal Delivery Capacity (Litres)	Maximum Heat Loss (Watts)	Heat Loss (kWh/day)
60	50	73	1.75
90	80	79	1.90
135	120	88	2.11
180	160	97	2.33
225	200	106	2.54
270	250	115	2.76
360	315	170	4.08
450	400	212	5.10

Notes: Nominal Delivery Capacity is estimated from similar water heaters . Heat loss values quoted above are based on Canadian test conditions.

New Zealand

Test Procedure

NZS4606.1-1989 is a standard which covers the design, construction and energy efficiency of mains pressure electric storage water heaters. The requirements for low pressure systems are set out in NZS4602.

Under NZS4606 and NZS4602 the standing heat loss is determined under static conditions and involves the water heater being operated at a fixed thermostat setting for at least four 24 hours periods with no water being drawn off. All plumbing connections are plugged and insulated with 25mm fibreglass. The outlet is plugged with a cork and insulated with 25mm fibreglass. At least two thermocouples are placed two thirds of the distance between the top of the element and the top of the water heater at the cross sectional centroid of the water heater and readings are integrated over the period (standard suggests continuous readings with a chart recorder). An air thermocouple is place 1.5m from the water heater and 1 to 1.5m from the ground and has a thermal mass of 10 to 20g of water. Frequency of air temperature measurements are not specified. Thermostat temperature is set to be nominally 55.6°C above ambient[a]. The water heater is placed on 20mm particle board at least 400mm off the floor. The water heater is operated for not less than 24 hours to allow stabilisation. Readings commence at a thermostat cut-out and continue with energy readings taken at roughly 24 hour periods at times when the thermostat cuts out. The energy consumption value measured is adjusted for average hot water and air temperature for the duration of the test back to a nominal ΔT of 55.6°C and a period of 24 hours. A correction for temperature drift is also included - this corrects for the heat content in the water if the final thermostat cut-out temperature is higher or lower than the initial thermostat cut-out temperature (although the exact procedure is not specified).

Another requirement of the New Zealand method is that the water temperature at any stage should not be more than ±2.4°C (±4°C for 100 litres or less) from the mean hot water temperature during the test. The standard also suggests using a heater element power of 300W (60W for 100 litres or less), although this is not mandatory.

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[a] 55.6°C is equivalent to 100°F and has not been rounded after conversion to a metric value.

MEPS Levels

Maximum allowable heat loss levels are specified in the standard for a range of tank capacities. However, heat losses are defined in terms of tank volume rather than hot water delivery. Allowable standing heat losses are defined as follows:

$H_L \leq 0.40 + 0.0084 \times V$ for volumes ≤ 90 litres

$H_L \leq 0.72 + 0.0048 \times V$ for volumes ≥ 90 litres

Table 5 shows the maximum allowable heat loss for various tank capacities. The NZ government proposed to make these heat loss requirements mandatory for all installations in new dwellings, but to date no legislation has been in place to give this effect so this requirement is advisory only at this stage. During May 2000 the NZ government passed their energy efficiency bill which enables them to enact regulations including MEPS for appliances. However, the scope and timing of MEPS for water heaters is yet to be announced.

Table 5: New Zealand Maximum Heat Loss

Storage Capacity (Litres)	Nominal Delivery Capacity (Litres)	Heat Loss (kWh/day)
30	25	0.65
45	40	0.78
60	50	0.90
90	80	1.16
135	125	1.37
180	160	1.58
225	200	1.80
270	250	2.02
360	315	2.45
450	400	2.88

Notes: Nominal Delivery Capacity is estimated from similar water heaters. Heat loss values quoted above are based on NZ test conditions.

Chinese Taipei

Test Procedure

CNS3263 is a standard which covers the design, construction, safety and energy consumption of electric storage water heaters. It is not related to any other water heater test procedure. The tank capacity is determined for the volume of water held. Three main energy related tests are conducted under CNS3263. First is Test of Heating Performance - the level of efficiency during a 66% discharge is measured. The second is the Test of Heat Preservation where the power is disconnected and the temperature fall over 16 hours is determined. The final test is the Test of Use Performance where the tank delivers a specified hot water profile and the temperature at the end of the last discharge is determined (this only applies to low-pressure tanks).

MEPS Levels

Performance requirements for the three tests, including those for energy efficiency, are specified in CNS11010. As the energy efficiency is defined below:

$$\text{Energy efficiency} = V_{cap} \times (T_2 - T_1) / P \times 860)$$

Where V_{cap} = capacity of water tank (l)

T_2 = water temperature after heating (°C)

T_1 = inlet water temperature (°C)

P = energy consumption (kWh)

Those requirements relevant to high pressure vessels are specified as:

Tank capacity	Heating Performance (Energy efficiency)	Heat insulation Performance (Temperature of hot water after 16 hours)
Up to and including 100 L	80% min	$(T_2 - 18\,^oC)$ min
100 – 350 L	85% min	$(T_2 - 18\,^oC)$ min
Over 350 L	90% min	$(T_2 - 18\,^oC)$ min

USA

Test Procedure

The test procedure is set out in CFR430 Subpart B Appendix E for consumer products (mainly residential sector) and ASHRAE 90.1 for non-residential products (commercial and industrial).

The requirements in CFR430 Appendix E are the same as those set out in CAN/CSA-C745-95, but US CFR430 also covers instantaneous electric water heaters as well as gas and oil systems. Although a hot water delivery capacity test is specified (called first hour rating test), this is not essential except for heat pump systems, where the recovery efficiency has to be determined from this test. An energy delivery test is conducted consisting of 6 draw-offs totalling 243.4 litres at 1 hour intervals. Standing heat losses are then determined over the remainder of the 24 hour test period. For this test, the air-hot water temperature differential is 37.5°C while the hot-cold water temperature differential is 42.8°C. The energy factor (the method of specifying the MEPS level) is determined as the ratio of the energy delivered in the hot water to the measured energy consumption over the period (nominal overall efficiency).

Non-residential products are covered under the Energy Policy Act 1992 and the test procedures are specified in ASHRAE 90.1. This cites ANSI Z21.10.3 for gas water heaters as the method to be used for the determination of standby loss for electric systems. Details on the requirements of this standard are yet to be determined.

MEPS Levels

The US DOE regulations define the allowable minimum energy factor[5] Ef for an electric water heater from 15 April 1991[b] as being:

$$Ef \geq 0.93 + 0.00132 \times V$$

where V is in US gallons

In April 2000 the US DOE released a revised MEPS level[6] for electric water heaters and the proposed rule for MEPS is shown below:

$$Ef \geq 0.97 + 0.00132 \times V$$

where V is in US gallons

The proposed rule is a major increase in energy efficiency compared to the 1991 MEPS levels and represents an "*electric water heater with a heat trap, 1.5 inches of insulation and an insulated bottom*". The DOE requested comments on the proposed rule by the 12 July 2000 and received numerous submissions throughout 2000. The final rule was issued on 17 January 2001 [7]. In both cases, MEPS applies to electric storage water heaters:

- with an input of 12 kilowatts or less;
- that store water at a thermostatically controlled temperature of less than 180°F (82°C),
- with a rated storage capacity of not less than 20 gallons (76 litres) nor more than 120 gallons (450 litres).

In the final rule, the DOE proclaimed the new MEPS levels was the same as shown in the Proposed Rule for electric storage water heaters. The new MEPS level comes into force on 20 January 2004. However the final rule introduced a new category of water heaters called "tabletop water heaters" that remained at the previous (1991) level of MEPS. This tabletop water heater is defined as "*water heater in a rectangular box enclosure designed to slide into a kitchen countertop space with typical dimensions of 36 inches high, 25 inches deep and 24 inches wide*". The basic premise behind this new definition is that these water heaters are designed to fit into a small kitchen space and they are not able

[b] The MEPS level quoted came into force on 15 April 1991, but the original MEPS level was introduced on 1 January 1990. The level original introduced in 1990 appears more stringent at face value ($0.95 - 0.00132 \times V$) but the change between 1990 and 1991 was due to a change in the test procedure and these MEPS levels are regarded as equivalent.

to economically justify the increased efficiency of the new MEPS level. The insulation requirements of the new MEPS would require significant increases in dimensions and hence the replacement of older water heaters would be not be possible within the same space. It appears that the vast majority of "tabletop water heaters" are approximately 40 gallons (150 litres). There is no product that is directly equivalent on the Australian market.

Europe

Test Procedure

IEC60379-87 is essentially a method for measuring the performance of electric storage water heaters. It is not applicable to heat pump or solar units or those with more than one heated volume. The main performance measures determined under the test procedure are:

- Static capacity based on volume of water;
- Standing heat loss per 24 hours (no drawoff) at an air hot water temperature differential of 45°C (nominal ambient air of 20°C and hot water at 65°C);
- Hot water output, defined as a capacity of X litres at Y °C, is determined from a measurement of water temperatures for a drawoff equal to the claimed rated capacity;
- Reheating time is determined from cold to first thermostat cutout and corrected back to a temperature rise of 50°C (cold water at 15°C and hot water at 65°C);
- Mixing factor is determined by comparing the hot water temperature without cold replenishment to the hot water temperature with cold replenishment.

Most European water heater standards are now aligned with the IEC60379 test procedure, which determine standing heat losses with a ΔT between air and water during the test of 45°C. This includes the German, Swiss, French and British Standards.

MEPS Levels

Heat loss requirements for Germany are defined in DIN44532. Switzerland also has harmonised heat loss requirements with Germany.

French heat loss requirements for tanks sizes from 10 litres to 1500 litres are defined in NFC73-221. These are defined as Wh loss per litre per °C per 24 hours for various tank sizes. For tanks over 150 litres, there is a differing allowance for vertical and horizontal tank configurations, with less stringent allowances being provided for horizontal tanks above 150 litres. The UK has two standards for water heater heat losses. The first is a general standard under BS699 while the second is a heat loss level defined by electricity utilities for connection to the Economy 7 tariff, which is equivalent to off peak in Australia.

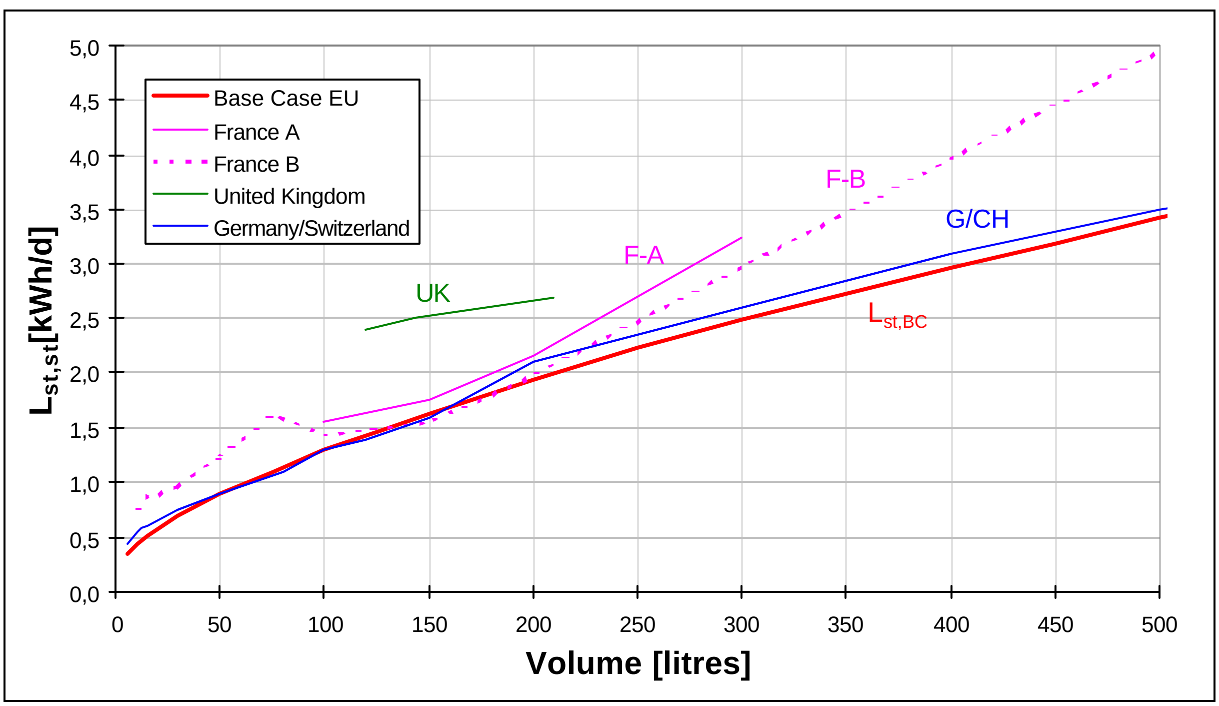
The EU is currently studying MEPS levels for implementation commission wide. A recently SAVE funded study has proposed MEPS level which are very close to the current German/Swiss levels[8]. The proposed MEPS level for the EU are shown in Table 6.

Table 6: EU Proposed MEPS

Type of DESWH	*Capacity (litres)*	*Minimum energy efficiency requirements (V in litres)*
Vertical	> 50–1000	$0.2 + 0.051 * V^{2/3}$
Horizontal	> 50–300	$0.75 + 0.008 * V$
Small	5–50	$0.13 + 0.0553 * V^{2/3}$

The proposed level compared with the other EU countries (measured in accordance with IEC 60379-87) are shown in Figure 2.

Figure 2: EU Proposed Base Case MEPS and Other EU Countries



Comparison with Overseas MEPS Levels

Approach

The MEPS levels of all the countries considered in this analysis were converted using the relevant conditions in their test procedure to the equivalent standing heat bss levels if tested under AS1056.1. Two methods were used to determine the equivalent AS1056.1 standing heat loss:

- Test conditions were modelled in TRNSYS, to determine the equivalent standing heat loss if the test method utilised a draw-off test to determine energy performance (USA test method).

- Calculations were performed in a spreadsheet to convert overseas MEPS levels to the equivalent in Australia where the test method was largely similar to AS1056.1 except for the temperature conditions (i.e. standing heat loss test eg IEC, Canada, NZ).

TRNSYS Model

TRNSYS is a transient system simulation program developed at the University of Wisconsin Solar Energy Laboratory. TRNSYS has gained worldwide acceptance as a result of its modular construction and due to the availability of the code in the public domain. To develop a simulation package suitable for Australian solar water heating products the Solar Thermal Energy Laboratory at the University of New South Wales has extended the TRNSYS code to include many of the unique features that have been developed by Australian water heater manufacturers. The modified code is referred to as TRNAUS[9]. This model has been used in the modelling of electric water heater performance and conversion of overseas test conditions to Australian Standard test conditions

As TRNAUS is a complex program to operate so a front end user interface called "RATING"[10] has been developed. The front-end interface has been structured so that data input by the user is as similar as possible to the component performance data available from tests defined in Australian Test Standards (AS1056, AS2984). The RATING program is provided as part of AS4234, to calculate the energy consumption of solar water heaters.

The program can be used to simulate the energy performance of the following types of water heaters:

- Conventional water heaters
    - electric storage (any tariff and multiple element systems)

- gas storage
- instantaneous gas

- Solar water heaters
  - Thermosyphon circulation
  - Direct connection between collector and tank
  - Heat exchanger between collector and tank
  - Pumped circulation
  - Auxiliary boosting of solar water heaters can be electric, gas storage (in solar tank or in a series gas tank) and series instantaneous gas boosting.

- Heat pump water heater with solar boosting

As this modelling exercise was using a limited amount of the inputs to the TRNAUS model, and numerous runs of the model were required, the RATING front-end was not used and a spreadsheet interface was developed to more easily control the inputs to the simulation model and to review the outputs. The limited inputs that were used in the spreadsheet for input to the TRNAUS model are shown in Table 7.

Table 7: TRNAUS Inputs – Conventional Electric Water Heaters

Description	Code	Units
Ambient/Tank Temperature Diff	D_{temp}	*K*
Standing Heat Loss (AS1056)	*H*	*MJ/day*
Heat Transfer Rate	UAref = H/D_{temp} x 1000/24	Calculated kJ/K
Element power	AUXEref	kW
Off peak Start, stop times	UNIT 1 TYPE 14, PARAMETERS 4	Hours
Volume of Tank	VOLref	L
Height of Tank	Href	m
Tank wall thickness x conductivity	KWALL	W/K
Rated Delivery (AS1056)	V_{cap}	*L*
Total capacity	V_{total}	*L*
Equivalent cold delivery connection	HCOLD3 = 1.974 x (1 - V_{cap} / V_{total})	Calculated
Thermostat Setting	Temp	C
Thermostat Dead Band	TDBref	K
Peak Load (daily)	PKLoad	MJ
Ambient temperature	TempA	C
Seasonal Load Pattern (monthly)	Set to unity	Proportion
Daily Load Pattern (Hourly)	DL1 to DL24	Proportion
Monthly cold water temperature	TempC	C

The useful outputs of the TRYAUS model are shown in Table 8.

Table 8: TRNAUS Outputs

Output Description
Output 1 is inclined irradiation, GI
Output 2 is daily average ambient temperature, TA
Output 3 is load volume, VOL
Output 4 is load energy, ENERGY
Output 5 is auxiliary energy use, AUX (Electricity or Gas)
Output 6 is useful energy delivered into the tank, QUT
Output 7 is change in tank energy since start of simulation, DE
Output 8 is tank heat loss, TLOSS
Output 9 is heat loss from pipes between collector & tank, PLOSS

As the AS1056 *Standing Heat Loss (H)* variable is specified as an *input* to the TRNAUS model, while the total energy input and tank heat loss (and therefore MEPS levels) are outputs, the analysis approach required several iterative runs to solve for the value of *(H)* for any given draw-off characteristics, tank capacity and temperature levels when determining a MEPS level.

Use of the TRNAUS Model to Convert US MEPS Levels

The TRNAUS model was used to model the USA MEPS levels as the testing method utilises an energy delivery test consisting of 6 draw-offs (totaling 243.4 litres) at 1-hour intervals. For this test the air-hot water temperature differential is 37.5^{o}C while the hot-cold water temperature differential is 42.8^{o}C. The energy factor (EF) is specified for MEPS levels and is determined from the energy delivery test energy consumption[11]. The formulae for EF is shown below:

> *Energy Factor = Energy drawn off in water divided by total 24 hour energy consumption (heat losses + draw-off energy)*

The US DOE test was replicated in the TRNAUS model and calibrated to ensure that tank heat loss output (TLOSS) was equal to the standing heat loss (H) under static conditions. As the delivered energy is known, for any given water heater size the total allowable losses during the test can be calculated from the minimum energy factor.

For each tank capacity the minimum H was calculated for the new MEPS of:

$$Ef \geq 0.97 + 0.00132 \times V$$

Table 9 below shows the US new MEPS levels converted to the equivalent AS1056 Standing Heat Loss.

Table 9: New & Current USA MEPS Levels converted to AS1056 Standing Heat Loss

	Current 1991 USA MEPS levels		New USA MEPS levels	
L Tank Volume (Litres)	**Ef - Energy Factor**	**H - Standing Heat Loss (kWh/day)**	**Ef - Energy Factor**	**H - Standing Heat Loss (kWh/day)**
100	0.895	2.189	0.935	1.233
150	0.878	2.548	0.918	1.593
200	0.860	2.927	0.900	1.968
250	0.843	3.350	0.883	2.358
300	0.825	3.793	0.865	2.763
350	0.808	4.256	0.848	3.186
400	0.791	4.731	0.831	3.626

The major advantage for using the TRNAUS model was to determine the effect of the DOE test method (which utilises 6 separate draw-offs) and then to convert the USA MEPS values into the heat loss equivalent of testing under AS1056 conditions. From the modelling using TRNAUS, and where the draw-off volume of less then 40% of total tank volume, we found that the DOE test method was almost equivalent to a standing heat loss test once the delivered energy had been separately calculated and removed from the comparison. This means that for tank volumes of greater than 100 L, the draw-off has an almost immeasurable effect on the total energy consumption (assuming that the tank has continuous electricity supply, which is typical in the USA). Theoretically, any draw-off would decrease the tank heat losses as the average tank temperature is lowered during the recovery period, however this effect is small in the US DOE test due to the large size of the electric element (which reduces recovery time and hence increases average temperature) and the small level of draw-off (typically less than 40% of tank volume in most cases).

Calculations for Other Overseas MEPS Levels

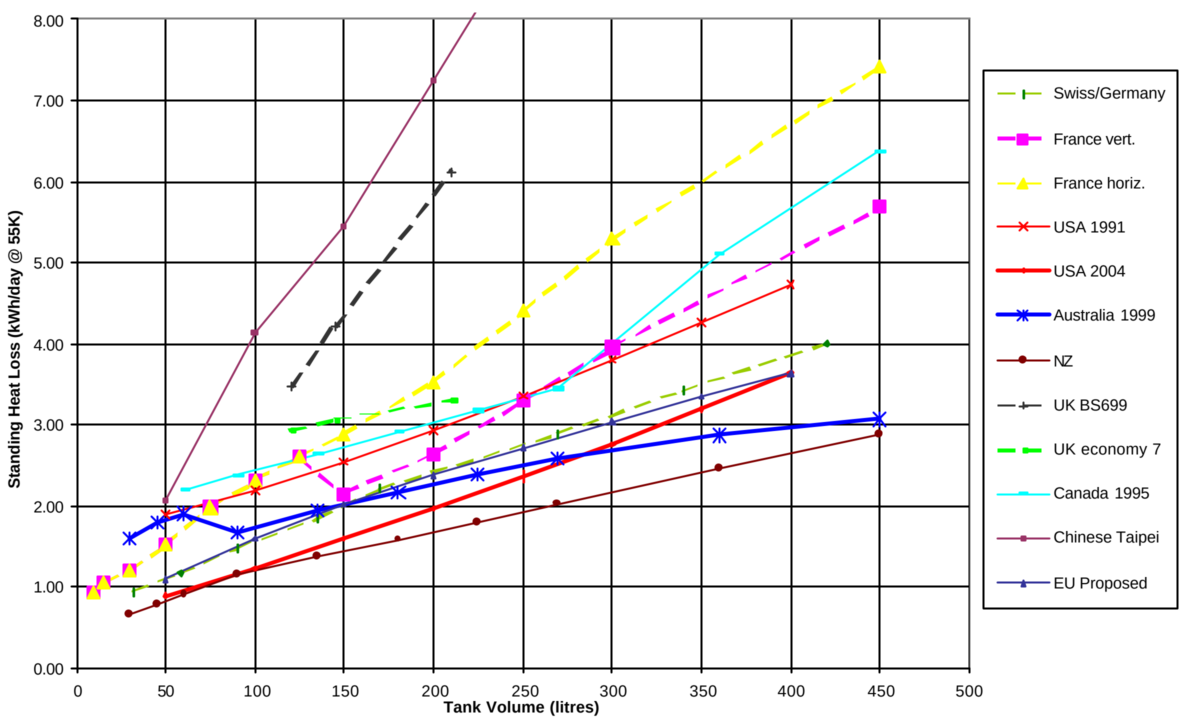
The majority of the overseas standards did not involve a draw-off test to determine the energy efficiency level or MEPS requirements. The tests were typically modelled in a spreadsheet and test conditions were normalised to AS1056 temperature conditions. The only exception was the Chinese Taipei standard, which involved a draw-off test of 2/3 of the total tank capacity, however the spreadsheet calculations showed the allowable heat loss of over 40% which is far in excess of the current Australian Standard. Therefore, refinement of the MEPS level with the TRNAUS model was not considered necessary.

International Comparison

Summary

To compare all different country specific MEPS level within a common framework, all MEPS level were converted to the equivalent AS1056 Standing Heat Loss and graphed according to total tank capacity. Figure 3 show the levels for each country compared to the current Australian MEPS levels.

Figure 3: Comparison of International MEPS Levels



Notes: Australian voluntary MEPS for non mains pressure models are not shown.
New US 2004 MEPS levels for Tabletop units are equivalent to 1991 levels.

USA

The final rule published by the US DOE (shown as a thick red line) would make the new USA MEPS levels for 2004 more stringent than Australia 1999 for tank volumes of up to 250 Litres and slightly less stringent for larger tank volumes.

Table 10 illustrates the differences between the USA 2004 MEPS levels and the Australian MEPS levels when converted to minimum AS1056 heat loss requirements. For example, the Australian MEPS would need to be 31% more stringent for a tank with a delivery capacity of 80 litres compared to the present levels.

Table 10: USA New MEPS compared with Present Australian MEPS

Volume (Litres)	Delivered (Litres)	Aus 1999 MEPS (kWh/day)	New USA 2004 MEPS (kWh/day)	% Aus MEPS Exceeds USA New MEPS
90	80	1.67	1.14	-31%
110	100	1.81	1.30	-28%
135	125	1.95	1.50	-23%
180	160	2.16	1.85	-15%
225	200	2.37	2.20	-7%
270	250	2.58	2.55	-1%
360	315	2.86	3.25	14%
450	400	3.07	3.95	29%

Note: All heat loss values converted to an equivalent heat loss under AS1056.1.

Estimated energy and greenhouse gas emission impacts are outlined in the Appendix.

Chinese Taipei

The Chinese Taipei minimum efficiency levels do not represent very stringent MEPS levels compared to other countries. The structure of the minimum efficiency levels result in requirements that are more focused on performance and hot water delivery than energy consumption and efficiency.

Canada

The Canadian requirements are similar to but slightly less stringent than current US requirements for most water heater sizes. Canadian heat loss requirements are significantly less stringent than Australian 1999 MEPS for all tank sizes. However, it is expected that Canada will adopt the new US 2004 MEPS levels in due course.

New Zealand

The NZ requirements are somewhat more stringent than Australian MEPS requirements for all tank sizes up 270 litres, and then they tend to converge for larger sizes. However, it is important to note that these levels are not yet mandatory and may only apply to installations in new dwellings if and when these requirements are implemented.

European Union

French requirements are slightly more stringent than Australian MEPS requirements for tanks sizes up to about 70 litres and then the Australian 1999 requirements are significantly more stringent for larger tanks. The Swiss/German requirements are somewhat more stringent than Australian MEPS requirements for tanks sizes up to about 90 litres, they are roughly equivalent from about 90 to 150 litres and the Australian 1999 requirements are more stringent for tanks over 150 litres. It is important to note that the bulk of the German market is smaller units under 100 litres, while about 40% of the Australian electric water market is estimated to be under 125 litres. The English requirements (BS699) are very weak by world standards. The Economy 7 requirements are similar to, but weaker than, the Canadian requirements, which are significant less stringent than the Australian 1999 requirements for all tank sizes.

POLICY OPTIONS - SUMMARY

As at May 2001, the most stringent MEPS levels in force for electric storage water heaters in the world are as follows:

- ***For tank sizes of 250 litres and above***: Australia currently has the most stringent requirements;

- ***For tank sizes of 80 litres to 250 litres***: New US requirements for 2004 are the most stringent requirements;

- ***For tank sizes below 80 litres***: Swiss/German requirements are the most stringent by a significant margin, with French requirements also slightly more stringent than the Australian requirements.

When considering the development of new policy options for electric storage water heaters in Australia, the following points need to be borne in mind:

- For small tanks (< 80 litres) a process to revise the current MEPS levels has been under way in Australia since 1999 and improvements will be made as a result (possibly implemented in 2004). Given this situation, it is premature to propose any further options in this paper for these sizes of water heaters. The Australian Greenhouse Office has previously advised industry that the proposed MEPS levels for units in this range will be identified and finalised no later than October 2001.

- For intermediate tanks sizes (80 to 250 litres), the new US MEPS levels, released on 17 January 2001 and which come into force from 20 January 2004, are more stringent than current MEPS levels in Australia. This does provide a trigger to review the MEPS level in Australia for these sizes of water heaters. The greenhouse and energy saving impacts for adopting this option are estimated in the Appendix. However, the issue of cost effectiveness of implementing a new MEPS level for Australia that is only marginally more stringent needs to be addressed, especially as tank sizes approach 250 litres (small savings in emissions and energy, counterbalanced by engineering and other development costs).

- The USA rule does provide a new category of "tabletop water heaters" – the MEPS level for these types remain at the 1991 level. However, it should be noted that there is no product that is directly equivalent on the Australian market. The problem with tabletop models is that there is only limit installation space under benchtops. The DOE considered this issue and the USA rule addressed this with the inclusion of this new category which has the MEPS level unchanged. This issue is more applicable in Australia to the small tank sizes (< 80 litres), where this issue is being specifically addressed.

If regulations were to come into force in New Zealand, following on from the recent introduction of energy efficiency laws in May 2000, this could provide another trigger for a review in the Australian context. If such water heater MEPS regulations were enacted, Australia should review its MEPS levels as a response (noting that the NZ government may choose not to implement the current MEPS levels in the NZ standards and the scope of such regulations is also unknown).

In summary, it appears current Australian MEPS levels for mains pressure electric storage water heaters are currently at or close to world's best practice for sizes of 250 litres and above. However, in the range 80 – 250 litres, the new USA MEPS levels are more stringent then Australia (30% better at the 80 litre size, equivalent at 250 litres). German/Swiss MEPS levels are most stringent for small water heaters. MEPS for other types of electric storage water heaters (non mains pressure) in Australia are not currently mandatory and the advisory levels in AS1056.1 (see Table 3) are considerably less stringent than those for mains pressure systems.

Final Recommendations

The following recommendations are proposed for consideration by government and industry:

1. Developments in the USA with regard to the announcement of new 2004 MEPS level for electric storage water heaters should be considered in the Australian context as a trigger to commence a new MEPS assessment process for larger water heaters (>80 litres).

2. The new MEPS levels to be implemented in the USA, as well of a range of alternative scenarios for different tank sizes, should be examined in the Australian context with regard to the estimated additional greenhouse and energy savings, and the cost of this to industry/consumers.

3. In accord with previous commitments by governments, the process should commence to determine MEPS levels for non mains pressure electric storage water heaters. These levels should be made mandatory and harmonised with current requirements for mains pressure systems (with the possible option of an additional 0.3 kWh/day allowance for systems with an attached feed tank).

Comments or questions should be directed to Shane Holt, Sustainable Energy Group, Australian Greenhouse Office; (02) 6274 1825; <shane.holt@greenhouse.gov.au>

APPENDIX: IMPACT OF US 2004 MEPS

The basis calculation for the Greenhouse Gas impact is described below:

- ***MEPS Levels*** – The new USA 2004 MEPS levels could be applied to AS1056 minimum Heat Loss requirements for water heaters with a delivery capacity in the 80 – 250 litres inclusive. Electric waters heaters in this range are covered by the USA standard and the new MEPS levels for the USA are more stringent then those in Australia.
- ***Market share*** – of various size water heaters for 2000 is estimated from the 1992 figures found in Table 2.
- ***New installations*** – of water heaters are estimated to be 420,000 pa from 2004 with a estimated growth rate of 3%, based on the BIS Shrapnel historical and forecast domestic supply. The total of 420,000 is based on sales in the period up to 1999, and excludes the forecast for 2000 (which is significantly higher then previous years due to pre-GST expenditure).
- ***Energy Savings*** – per annum and per unit are estimated by determining the difference in heat loss from the USA MEPS levels and the current Australian MEPS levels and multiplying these by 365 days.
- ***Total CO_2-e reductions*** – of greenhouse gas emissions are estimated by using an average conversion rate of 0.897 kg/kWh
- ***Cumulative CO_2-e reductions*** – of emissions are based on a 15 year time frame.

The total energy savings for the base year (assumed to be 2004) are 17.6 GWh pa. Total annual greenhouse gases (CO_2-e) are approximately 15.8 kt in the first year and 295 kt CO_2-e after 15 years. The cumulative estimated greenhouse gas reductions over a 15 year period are 2.2 Mt CO_2-e. Table 11 shows the calculation for estimating the greenhouse gas impacts in the base year.

Table 11: Estimated Energy Savings and Greenhouse Impacts of USA MEPS in Australia

Delivered Capacity	Estimated Share in 2000	Heat loss 1999 MEPS (kWh/day)	Heat loss USA NEW MEPS (kWh/day)	Units Installed/year	Estimated Heat Loss Savings GWh/year	Estimated CO_2 Reduction pa (kt)
18	10%		NA	42 000	NA	NA
25	5%	1.60	NA	21 000	NA	NA
50	5%	1.90	NA	21 000	NA	NA
80	7%	1.67	1.14	29 400	5.64	5.06
125	12%	1.95	1.50	50 400	8.36	7.50
160	5%	2.16	1.85	21 000	2.40	2.16
250	26%	2.58	2.55	109 200	1.26	1.13
315	20%	2.86	2.86	84 000	-	-
400	10%	3.07	3.07	42 000	-	-
Total	100%			420 000	17.67	15.85

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