Comparison of Household Refrigerator Efficiency Standards in the USA with those Proposed for Australia and Europe.

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Background

The USA first introduced federal energy efficiency standards (also called minimum energy performance standards and referred to as MEPS in this paper) for household refrigerators in 1990 under the National Appliance Energy Conservation Act (NAECA). The MEPS levels were set for this initial round by undertaking a statistical market analysis and selecting cut-off lines for each "class" of unit based on the availability of a range of units of varying efficiency within the market. A market based statistical approach eliminates less efficient models, while leaving more efficient models to take their place. (Of course, manufacturers generally alter their products to conform with new MEPS requirements, so this analysis is necessarily conservative). Subsequent MEPS levels introduced in the USA in 1993 were based on engineering and economic analyses undertaken by Lawrence Berkeley Laboratories (California). The engineering analysis examined what was both feasible and cost effective in terms of manufacturing cost and resulting energy savings. It also examined a range of other issues such as market competition and financial viability of manufacturers after MEPS. MEPS levels for refrigerators in the USA are again scheduled for revision under NAECA by 1998.

Australia first began to review the potential for refrigerator MEPS in early 1992, with a consultant report in July 1993 recommending cutoff levels based on a statistical market analysis (GWA 1993). The final cutoff levels have been negotiated between government, local manufacturers and importers and are now due for implementation by 1 January 1998, following Ministerial approval in March 1995. It is now possible that the same cutoffs will be adopted in New Zealand, which has a virtually identical product range.

The European Community has also been looking closely at MEPS for household refrigerators for a number of years. In March 1993 they too published a report which recommended refrigerator MEPS cutoff levels based on a statistical market analysis (CEC 1993). This report also made recommendations regarding longer term MEPS cutoffs based on engineering analyses. Negotiations between the EC and manufacturers are ongoing during 1995. While the introduction of MEPS for household refrigerators appears to be likely in the EC, the precise cutoff levels are somewhat uncertain and the time for introduction could be between 1998 and 2000.

This brief paper attempts to compare and contrast the current and proposed MEPS cutoff levels for USA, Australia and Europe.

Australian Background

Most Australian households own a refrigerator. In 1986 all but 0.3% of households did not own any type of refrigeration. About 25% of households own 2 refrigerators as either additional storage or as a drinks/bar fridge. In addition nearly 50% of households also own a separate freezer unit.

Refrigerator and freezer sales in Australia are currently about 700,000 per annum, with some 75% of supply provided by three local manufacturers (based in Australia and New Zealand). Imports are from a range of countries, primarily Asia (Japan, Korea and Thailand), Europe (Slovakia and Russia) and North America.

The bulk of refrigerators sold are in the size range 200 to 500 litres in capacity and include a freezer compartment. The sales weighted average for all refrigerators is 260 litres of fresh food and 85 litres of freezer space. Average unit sizes in the USA tend to be much larger (generally over 600 litres), while the average sizes in Europe tend to be much smaller, at around 250 to 300 litres.

Most separate freezers in Australia are in the size range of 150 to 400 litres. The sales weighted average for all separate freezers is 260 litres. There is a large range of other sized units available ranging from 50 litre bar fridges to refrigerator-freezers and freezers that have a capacity of more than 700 litres. The largest refrigerator-freezer models are imported from the USA.

Comparing MEPS Levels

Comparing MEPS levels between the USA and Australia is relatively straight forward, as test conditions for the measurement of energy consumption are very similar. In Australia these are 32^{o}C ambient (cf USA at 32.3^{o}C), fresh food temperatures at 3^{o}C (cf USA at 3.3^{o}C for all refrigerators, but <7.2^{o}C for refrigerators and refrigerator-freezers) and a typical freezer temperatures at -15^{o}C (USA - same for refrigerator freezers, but -17.8^{o}C for stand alone freezers). Comparison with European data is more difficult due to the differences in both internal and external test temperatures (ambient 25^{o}C, fresh food at 5^{o}C and freezer temperature generally at -18^{o}C, but some units are tested with higher freezer temperatures). Tables 1 to 3 describes the basic differences in test conditions between the groups and also shows current and proposed MEPS levels for refrigerators and freezers for Australia, USA and Europe. The MEPS cutoff formulae consist of two components:

- a fixed allowable energy consumption at zero volume (y intercept)
- an additional energy consumption allowance per litre of adjusted volume (slope)

Table 1 - Proposed Australian Refrigerator MEPS Cutoff Formulae Class Descriptions and Operating Temperatures

Australian Standard Class	Fresh Food ^{o}C	Freezer temp ^{o}C	MEPS intercept kWh	MEPS Slope kWh/litre adjust. Vol.	Freezer Adjustment Factor	Description
1	3	N/A	368	0.892	N/A	all refrigerator *
2	3	-2	300	0.728	1.2	cyclic defrost (one door) *
3	3	-9	330	0.800	1.4	cyclic defrost (one door) *
4	3	-15	424	1.020	1.6	cyclic defrost (two door) *
5T & 5B	3	-15	424	1.256	1.6	no frost (top/bottom freezer)
5S	3	-15	465	1.378	1.6	no frost (side by side)
6C	NA	-15	248	0.670	1.6	separate freezer (chest)
6U	NA	-15	439	0.641	1.6	separate freezer (upright)
7	NA	-15	439	1.020	1.6	no frost separate freezer

Source: GWA 1994

Notes: Fresh food and freezer temperatures are target temperatures. Note all tests are performed at an ambient temperature of 32^{o}C. Class 5 units have an additional allowance of 120 kWh for a through the door ice dispenser where provided. Additional doors in all classes have an allowance for extra throat losses based on liner width. Anti-sweat heaters are operated on their maximum setting for all tests. Classes are determined by freezer operation (cyclic/no frost). * Forced air fresh food compartments are possible but rare.

Table 2 - USA 1993 Refrigerator MEPS Cutoff Formulae
Group Descriptions and Operating Temperatures

Group	Fresh Food ^{o}C	Freezer temp ^{o}C	MEPS intercept kWh	MEPS Slope kWh/litre adjust. Vol.	Freezer Adjustment Factor	Description
1	3.3/7.2	-9.4	299	0.477	1.44	refrig. & manual def. R-F
2	7.2	-15	398	0.367	1.63	partial auto defrost R-F
3	7.2	-15	355	0.565	1.63	no frost - top w/o ttd ice
4	7.2	-15	501	0.417	1.63	no frost - side w/o ttd ice
5	7.2	-15	367	0.583	1.63	no frost - bottom w/o ttd ice
6	7.2	-15	391	0.622	1.63	no frost - top with ttd ice
7	7.2	-15	527	0.576	1.63	no frost - side with ttd ice
8	NA	-17.8	264	0.364	1.73	cyclic freezer (upright)
9	NA	-17.8	391	0.526	1.73	no frost freezer (upright)
10	NA	-17.8	160	0.388	1.73	chest freezers + others

Sources: US Department of Energy 1989, 1990 & 1993.

Notes: Fresh food and freezer temperatures are maximums allowable. All tests are performed at an ambient temperature of 32.2^{o}C. Standardised temperatures are 38^{o}F (+3.3^{o}C) for an all refrigerator, 15^{o}F (-9.4^{o}C) for a refrigerator (freezer compartment), 5^{o}F (-15^{o}C) for a refrigerator-freezer (freezer compartment) and 0^{o}F (-17.8^{o}C) for a freezer. Only target temperature specified for the fresh food compartment of refrigerators and refrigerator-freezers is a maximum of 45^{o}F (+7.22^{o}C). Conversion factor of 28.3 litres/cu ft. is used. R-F = refrigerator-freezer. Note that "K factors" are used to adjust the tested energy consumption of separate freezers. K = 0.7 for chest freezers and 0.85 for upright freezers.

Table 3 - Proposed Initial European Refrigerator MEPS Cutoff Formulae
Category Descriptions and Operating Temperatures

Category	Fresh Food ^{o}C	Freezer temp ^{o}C	MEPS intercept kWh	MEPS Slope kWh/litre adjust. Vol.	Freezer Adjustment Factor	Description
1	5	* 0	237	0.225	* 1.25	no frozen food compartment
2	5	-6	178	0.599	1.55	refrigerator with 1 ✳ freezer
3	5	-12	238	0.437	1.85	refrigerator with 2 ✳ freezer
4	5	-18	221	0.616	2.15	refrigerator with 3 ✳ freezer
5	5	-18	303	0.778	2.15	refrigerator with 4 ✳ freezer
6	5	** +10	237	0.225	** 0.75	refrigerator - chiller
7	NA	-18	195	0.480	2.15	chest freezer
8	NA	-18	289	0.478	2.15	upright freezer
9	5	-18	394	1.011	2.15	no frost with 4 ✳ freezer
10	NA	-18	376	0.621	2.15	no frost upright freezer

Source: CEC 1993

Notes: Fresh food and freezer temperatures are maximums allowable. All tests are performed at an ambient temperature of 25^{o}C (extended, temperate and sub-tropical zones. Allowable energy consumption for no frost systems are 1.3 times the cyclic equivalent.
* Adjustment factor of 1.25 applies only to 0^{o}C compartments and 0 ✳ compartments.
** Temperature of chiller (cellar) compartment, which is not a freezer.

Methodology

A total of 5 currently enforced or proposed MEPS levels were examined for this paper. These were:

- USA 1990 Refrigerator and Freezer Standards - (NAECA 1987)
- USA 1993 Refrigerator and Freezer Standards - (US DOE 1989 & 1990)
- Australian Proposed Refrigerator and Freezer MEPS (GWA 1994)
- European Proposed Short Term Refrigerator and Freezer MEPS (CEC 1993)
- European Proposed Long Term Refrigerator and Freezer MEPS (CEC 1993)

It should be noted that the USA 1990 MEPS standards, the proposed Australian and European Short Term MEPS standards were derived from a statistical analysis of their respective markets. The USA 1993 MEPS and the proposed European Long Term MEPS standards were both based on an engineering analysis. Statistical analysis necessarily results in a less stringent efficiency standard.

It is not possible to develop uniform adjustment factors to harmonise all of the MEPS cutoff lines, as the ratio of fresh food to freezer volume may change within a class with increasing size. This together with variations in compartment temperature and ambient temperature make a single conversion factor impossible.

The volume used to calculate the MEPS cutoff is the adjusted volume, which is the sum of the gross volume of each separate compartment times an adjustment factor for each compartment based on its temperature of operation. Adjusted volume provides a measure of an equivalent gross volume which is "normalised" to a fresh food and ambient operating temperature. The freezer adjustment factors (FAF) used within each of the standards is shown in Tables 1 to 3. The FAF changes according to both the cabinet operating temperature and the ambient test temperature. The impact of the FAF also depends on the relative size of the freezer compartment which varies between models and classes.

The methodology used in this paper was to select two typical models for each of the main 9 MEPS cabinet classes for Australia. An Australian MEPS cutoff to Australian Standard AS2575.2 was calculated for each cabinet. These cabinets were selected as typical of the smaller and larger units available on the Australian market in 1994. The small model in each class is more typical of European products while the large ones are more similar to those in the USA. A maximum allowable energy use (MEPS level) for each cabinet under each standard was then estimated under the equivalent conditions of operation for the USA and Europe. It was not always possible to get a direct correspondence of classes (particularly in ISO/Europe), but the match in most cases was relatively close.

These MEPS energy values related to a maximum allowable energy consumption under each relevant standard (US Federal Regulation for the USA and EN153 for Europe). These allowable MEPS cutoffs were then normalised back to an equivalent energy consumption under the joint Australian Standard & New Zealand AS2575.2/NZS6205.2 which is used to determine energy consumption of refrigerators in Australia.

This normalisation process is an attempt to estimate the energy use of each model when tested according to other standards. It involves a correction for the expected heat flow into each cabinet compartment based on its temperature of operation, its volume and the ambient temperature. Additional factors were also introduced which accounted for the non linear nature of tested energy consumption under different conditions (such as an allowance for fixed heat gains and auxiliaries, shifts in compressor cop as a result of changes in operating temperatures). These have been developed empirically from a range of test data collected in Australia and New Zealand which compares energy consumption figures for the same cabinets tested to Australian, USA and European (ISO) standards. No additional correction factor was

required to convert from US standards to Australian and New Zealand Standards (which is expected as the conditions are very similar), except in the case of freezers, where the tested energy consumption is adjusted by a "K factor" in the US Federal Regulations.. The correction factors to convert from EN153 (ISO) to Australian and New Zealand Standards changed with cabinet size and type. No frost cabinets in particular used less additional energy when tested to Australian and New Zealand Standards in comparison with ISO Standards than would be expected from differences in heat flows alone, due to a significant component of fixed energy auxiliaries. Cyclic units, where these had large defrost heaters, also had a larger fixed component of energy consumption.

Summary of Results

Although equivalent cabinets were analysed for every MEPS class for Australia, USA and Europe, it was only possible to directly compare equivalent cabinet classes which existed in all three markets. A side by side cabinet was also included for comparison between Australia and the USA, even though the European MEPS analysis did not specifically consider this configuration. The results of the analysis are shown in Tables 4 and 5.

Table 4 - Comparison of Various Refrigerator and Freezer MEPS Levels
Equivalent AS2575.2 Annual Energy Consumption for Various Cabinets

Cabinet Description	Size	Fresh Volume litres	Freezer Volume litres	USA 1990 kWh/yr	USA 1993 kWh/yr	Australia Proposed kWh/yr	Europe Short term kWh/yr	Europe Long term kWh/yr
All refrigerator - no freezer	small	135	0	396	366	488	474	220
All refrigerator - no freezer	large	420	0	561	503	743	588	273
Refrigerator-freezer - cyclic *	small	180	25	681	544	648	537	355
Refrigerator-freezer - cyclic *	large	309	98	882	637	899	773	510
Refrigerator-freezer - no frost (top mount, without TTD)	small	170	35	727	533	708	883	480
Refrigerator-freezer - no frost (top mount, without TTD)	large	361	115	1013	727	1109	1366	743
Refrigerator-freezer - no frost (side by side, without TTD **)	small	350	125	1123	798	1223	N/C	N/C
Refrigerator-freezer - no frost (side by side, without TTD **)	large	450	250	1431	925	1636	N/C	N/C
Chest freezer	small	0	160	465	339	420	416	217
Chest freezer	large	0	750	1141	840	1052	1120	584
Upright Freezer - cyclic	small	0	220	593	419	665	595	330
Upright Freezer - cyclic	large	0	420	731	551	870	833	461
Upright Freezer - no frost	small	0	210	874	615	782	748	414
Upright Freezer - no frost	large	0	450	1122	845	1173	1114	617

Notes: * Partial automatic cyclic defrost (Class 4 Australia) 2 door = Europe 3 star (✳)
** Europe 4 star (✳) no frost, no frost allowance assumed to be 1.3.
N/C Not considered as a separate group for MEPS in the European analysis.
TTD is a through the door ice and/or water dispenser unit

Table 5 - Comparison of Various Refrigerator and Freezer MEPS Levels Relative to USA 1993 Refrigerator MEPS

Cabinet Description	Size	USA 1990	USA 1993	Australia Proposed	Europe Short Term	Europe Long term
All refrigerator - no freezer	small	108%	100%	134%	130%	60%
All refrigerator - no freezer	large	112%	100%	148%	117%	54%
Refrigerator-freezer - cyclic *	small	125%	100%	119%	99%	65%
Refrigerator-freezer - cyclic *	large	139%	100%	141%	121%	80%
Refrigerator-freezer - no frost (top mount, without TTD)	small	136%	100%	133%	166%	90%
Refrigerator-freezer - no frost (top mount, without TTD)	large	139%	100%	152%	188%	102%
Refrigerator-freezer - no frost (side by side, without TTD **)	small	141%	100%	153%	N/C	N/C
Refrigerator-freezer - no frost (side by side, without TTD **)	large	155%	100%	177%	N/C	N/C
Chest freezer	small	137%	100%	124%	123%	64%
Chest freezer	large	136%	100%	125%	133%	69%
Upright Freezer - cyclic	small	141%	100%	158%	142%	79%
Upright Freezer - cyclic	large	133%	100%	158%	151%	84%
Upright Freezer - no frost	small	142%	100%	127%	122%	67%
Upright Freezer - no frost	large	133%	100%	139%	132%	73%

Notes: * Partial automatic cyclic defrost (Class 4 Australia), 2 door, Europe - 3 star (✳)
** Europe 4 star (✳) no frost
N/C Not considered as a separate group for MEPS in the European analysis.
TTD is a through the door ice and/or water dispenser unit

Discussion

The introduction of the USA 1993 MEPS for refrigerators saw the allowable energy consumption of most classes fall by around 25% to 40% in comparison with the USA 1990 MEPS. The falls were a little more than this for side by side no frost units and somewhat less for all refrigerators (about 10%).

The proposed refrigerator MEPS for Australia (which, if approved, are scheduled to be implemented in 1997) for cyclic refrigerator-freezers, top mounted no frost refrigerator-freezers and upright freezers are similar to the USA 1990 MEPS for these products, while the MEPS level for side by side units and cyclic upright freezers are only slightly above the USA 1990 MEPS. MEPS for all refrigerator units are about 20% above the USA 1990 MEPS, while MEPS for chest freezers are about 10% below this level. Both analyses were prepared on the basis of a statistical market analysis. At the MEPS which are to be implemented in Australia, about 50% of 1992 models would have been eliminated. The partial automatic cyclic defrost refrigerator-freezer (Class 4), which makes up a very substantial part of the Australian market (about 30%), is approximately equal to the USA 1990 standards. These type of units are relatively uncommon in the USA. The MEPS level for chest freezers, which are also common in Australia, is somewhat better than the USA 1990 MEPS. Altogether, "no frost" units (also called frost free) comprise about 20% of the total market in Australia (includes freezers, top and bottom mount refrigerator-freezers and side by side units).

The proposed European MEPS level (the Short Term Standards) for cyclic defrost refrigerator-freezers is roughly equivalent to the USA 1993 standards at the smaller end of the range (most refrigerator units sold in Europe will tend to the smaller sizes in this analysis). The European MEPS level for no frost freezers is significantly lower than the USA 1990 MEPS (but not quite as stringent as the USA 1993 MEPS). Other proposed European MEPS levels are broadly equivalent to those proposed for Australia. At the European short term proposed MEPS level, some 55% of products on the European market in 1990 would have been eliminated.

Given that the proposed MEPS levels for Europe were based on a similar market analysis to that in Australia at a similar time, it would appear that Europe has started from a slightly higher energy efficiency base for cyclic refrigerator-freezers than is apparent in Australia. This is to be expected, as some of the worlds leading manufacturers of energy efficient refrigerators are located in Europe and the market demand for highly efficient, low environmental impact units is high.

Manufacturers in Australia are quite attuned to energy efficiency, mainly because of the appliance energy labelling program which has been in force since late 1986. A small number of relatively innovative and flexible companies produce some 75% of product for the local market. Most have good links with leading appliance manufacturers in Europe and the USA, so are able to adapt new technology soon after it becomes available, provided they perceive a commercial advantage in doing so. MEPS and energy labelling will continue to drive energy efficiency improvements in refrigerators and freezers in Australia.

Long term MEPS levels proposed for Europe for all units are around 20% to 40% below the current USA 1993 standard. It should be noted that the implementation date for these long term standards is somewhat uncertain (as is the date for the short term standards, which currently could be as late as 2000, if adopted at all). The USA refrigerator and freezer MEPS levels are scheduled for review and implementation by 1998, so these may well be reduced to a level comparable or lower than the European long term standards, but within a shorter time frame. If implemented, it is also envisaged that the Australian MEPS will be reviewed regularly, with the possibility of more stringent levels to take place in 2003.

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EN153 is a CEN/CENELEC standard which is based on ISO7371, ISO8187 ISO5155 & ISO/DIS8561

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