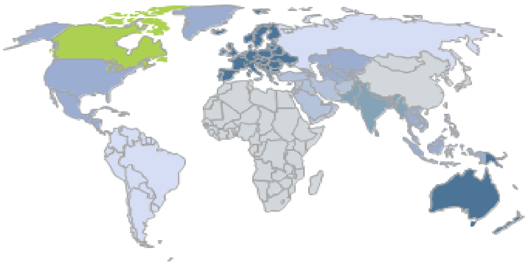
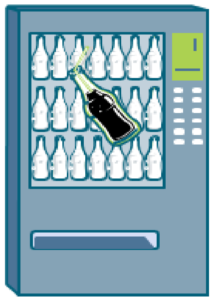
**Technology:** Vending Machines





**Participating countries:**
Australia, Canada, USA

**Other funding countries:**
Netherlands, Austria, Denmark, Japan, Republic of Korea, South Africa, Switzerland, Sweden, UK

**Other regions covered:**
EU

# Benchmarking report for refrigerated vending machines

## Issued: December 2012

***For further information refer to*** ***http://mappingandbenchmarking.iea-4e.org/*****matrix**
***or email operating.agent@mapping.iea-4e.org***



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# 1 Summary

This benchmarking report by the IEA 4E Mapping and Benchmarking Annex covers refrigerated beverage vending machines[1], including those with glass and opaque fronts. It includes data submitted by Australia, Canada, EU, USA (California energy commission and ENERGY STAR datasets) which was collated between February and July 2011. All of these data sets are deemed to be reasonably representative of their markets, including ENERGY STAR because the criteria had not been revised since 2007 and so the included products were likely to represent the majority of the market.[2] The majority of data covers machines available from 2007 to 2010 (although some data was available covering years before that). Mapping documents on machine performance in each of the separate participating countries/regions were published in September 2011.

The datasets contained between 10 and 90 machines in any given year[3] and cover a good proportion of these markets since the total number of different machines available is probably no higher than 300 globally[4] (excluding variants). The EU dataset is small compared to the others and should be treated with particular caution. No sales weighted data was available for any countries.

The ASHRAE test methodology[5] was adopted as the basis for this analysis, being that used by the ENERGY STAR, US and Australian federal requirements. The consumption metric used is kWh per 24 hours (day), with a 'specific consumption' metric used in this analysis of kWh per 300 cans per day. The only normalisation adjustment carried out was to convert data from machines tested at indoor ambient conditions to be comparable with those tested at outdoor conditions, which required an adjustment of around 40% on energy consumption for affected products.

As shown in figure S1, the EU and Californian datasets have nearly 60% 'small' size category machines each, with the Canadian and EU ones both having very few large size machines. Australia and the US ENERGY STAR datasets contain a majority of medium and large sized machines. It is possible that the US ENERGY STAR data set is not representative of the whole market, particularly if smaller machines are less likely to meet the requirements.

In line with their generally larger size, Australian machines have higher energy consumption (Figure S2). The average European machine is 25% smaller than the Australian one but has only 4% lower consumption per day; the ENERGY STAR average machine is almost as large as the Australian machine but has a 25% lower average consumption per day.

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[1] Food/snack vending machines are included in the mapping document for the EU but being the only region with data, no benchmarking of those products could be carried out.
[2] ENERGY STAR criteria Version 3 for beverage vending machines are due to come into effect in 2013.
[3] This is the count of products in any given country/year data bin, after carrying forward products from previous years (products were not carried forward into year bins for which no additional data was available).
[4] Estimate by market expert.
[5] ASHRAE 32.1-2004, Methods of Testing for Rating Vending Machines for Bottled, Canned, and Other Sealed Beverages.



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The only significant change over time seen in this data is in average consumption for the US ENERGY STAR set between 2006 and 2007. This coincides with introduction of the version 2 criteria, at which many poorer performing machines were removed from the dataset. This may not necessarily represent a big change in the efficiency of products available on the market, just in those qualifying for ENERGY STAR, which would in due course influence availability on the market. It is worth noting, however, that the major bottling companies tend to favour products registered for ENERGY STAR.

Figure S3 shows average specific energy consumption. As with the consumption graph, the only significant change occurs between 2006 and 2007 for the ENERGY STAR dataset, coinciding with the introduction of version 2 criteria. The best performing machine overall in each year is from the US ENERGY STAR dataset. Figure S4 shows a scatter plot of machines from the most recent data set from each country, showing the very high degree of overlap in the data sets. EU and Australian machines are more prominent towards the top of the cloud (higher energy consumption); US ENERGY STAR machines dominate at the lower consumption area.

The average ENERGY STAR machine uses just over half the energy per can of the average EU machine. EU machines appear to have the worst average specific consumption, but when comparing the EU average to those of other regions it is important to bear in mind the differences in market and in type and size of machines that are in use there:

- The majority of machines in the EU are glass fronted merchandisers with higher heat gains.
- EU machines tend to contain snack or food items as well as beverages and so the whole contents are refrigerated to the same temperature (rather than the majority of stock being held at a slightly higher temperature until it is close to the front of the queue to be vended).
- EU machines tend to be smaller which is inherently less efficient per can (they stock fewer cans/bottles as delivery visits are more regular).

Australian and US ENERGY STAR machines are predominantly opaque fronted and larger than the EU machines and some have significantly better specific consumption.

Regarding policies, only Canada and the USA have mandatory maximum energy consumption requirements at a national level, amongst participating countries (Canada since 2007, USA from August 2012). The ENERGY STAR voluntary label operates in the USA, Canada and Australia; version 2 of the criteria came into force in 2007 and Version 3 of the criteria have been developed and are due to go into effect on 1 March 2013.[6] In addition, the US state of California has had minimum energy performance standards (MEPS) since 2006 aligned with ENERGY STAR Version 2 Tier 1 requirements.

There appears to be considerable scope to apply and tighten MEPS, since the best machines (usually large machines) use between 33% and 50% of the energy per bottle/can

[6] See http://www.energystar.gov/index.cfm?c=revisions.vending_machines



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compared to the average in each market[7]. In particular, there is scope to eliminate poor performers for small and medium sized machines.

For future policy development, it may be worth considering whether the different implicit stringencies for indoor and outdoor rated products (around 40% higher consumption – see Appendix 1) as found in the ENERGY STAR Tier 2 criteria, are justified, or whether the approach now taken by the US Federal MEPS is perhaps more appropriate than other ways to split the market based on functionality – i.e. to set different volumetric MEPS depending upon whether the machine chills the whole internal space (and so could be used for storage of perishable food/drink) or focuses on chilling only the nearest products to be vended (suitable for non-perishable drinks). Similarly, different MEPS may also be required for some regions based on whether the machine must (or is able to) meet stringent food safety storage temperature requirements. And finally, whether the energy consumption data from the standard test carried out at 'outdoor conditions' of 32.2°C±1°C and 65%±5% relative humidity is potentially misleading for users and for policy-makers since no countries have this high temperature as an average[8].

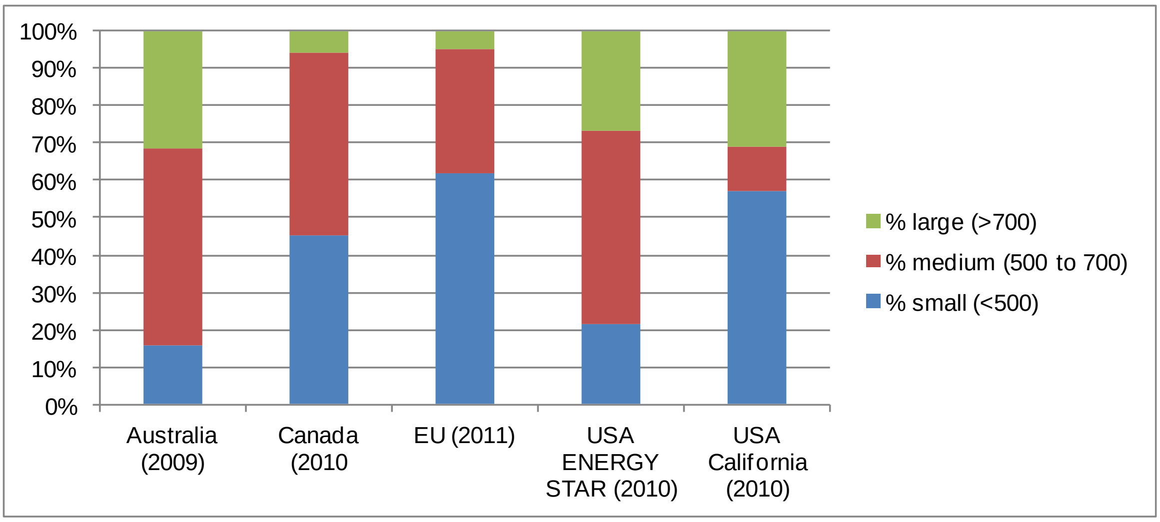


**Figure S1. Breakdown of the most recent data set into large, medium and small capacity units, by number of cans.**

[7] Note that these significant differences between average and best occur within the datasets for each separate market; this is not (for example) comparing EU with US.
[8] It may be necessary to ensure that the machines are capable of maintaining temperature under high ambient conditions (although failing this only incurs a food safety risk for cabinets designed for perishable foods) but this capability test should be entirely separate to the energy rating.



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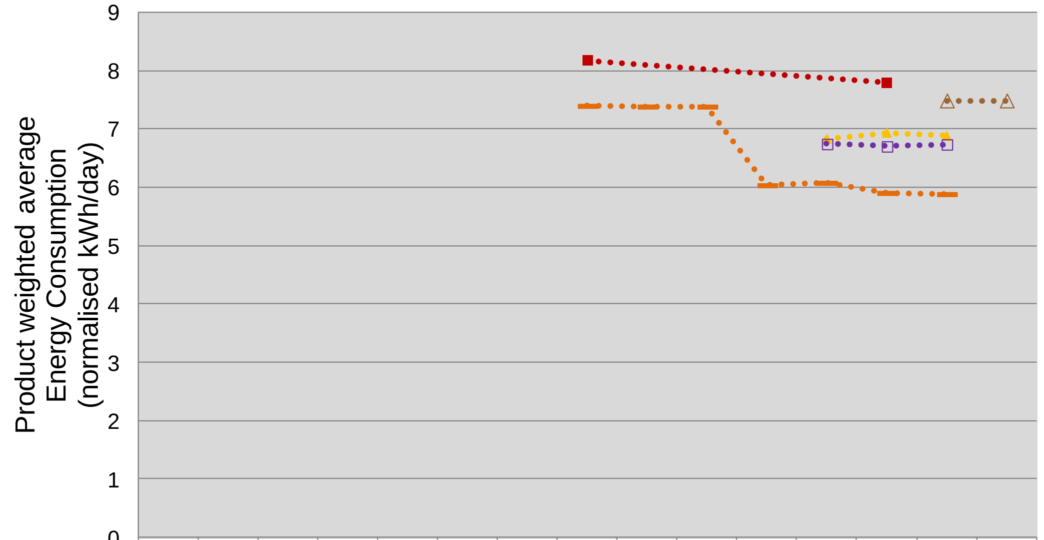
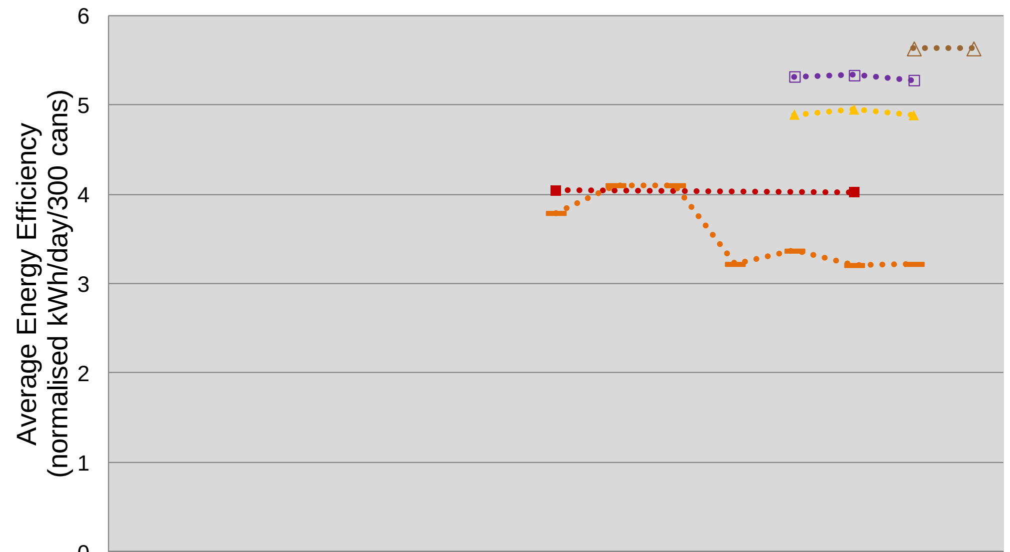



| | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Australia | | | | | | | | 8.17 | | | | | 7.79 | | |
| Canada | | | | | | | | | | | | 6.84 | 6.94 | 6.88 | |
| USA CEC | | | | | | | | | | | | 6.74 | 6.70 | 6.73 | |
| EU | | | | | | | | | | | | | | 7.49 | 7.49 |
| USA ENERGY STAR | | | | | | | | 7.40 | 7.38 | 7.38 | 6.04 | 6.08 | 5.90 | 5.88 | |

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

**Figure S2. Average energy consumption (normalised) in kWh per day.**

*For definitions of what is meant by robust, indicative and illustrative, see section 3.1.*




| | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Australia | | | | | | | | 4.04 | | | | | 4.02 | | |
| Canada | | | | | | | | | | | | 4.89 | 4.95 | 4.89 | |
| USA CEC | | | | | | | | | | | | 5.32 | 5.33 | 5.28 | |
| EU | | | | | | | | | | | | | | 5.63 | 5.63 |
| USA ENERGY STAR | | | | | | | | 3.79 | 4.10 | 4.10 | 3.22 | 3.37 | 3.21 | 3.22 | |

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

**Figure S3. Average specific energy consumption in kWh per day per 300 cans of internal capacity.**

*For definitions of what is meant by robust, indicative and illustrative, see section 3.1.*



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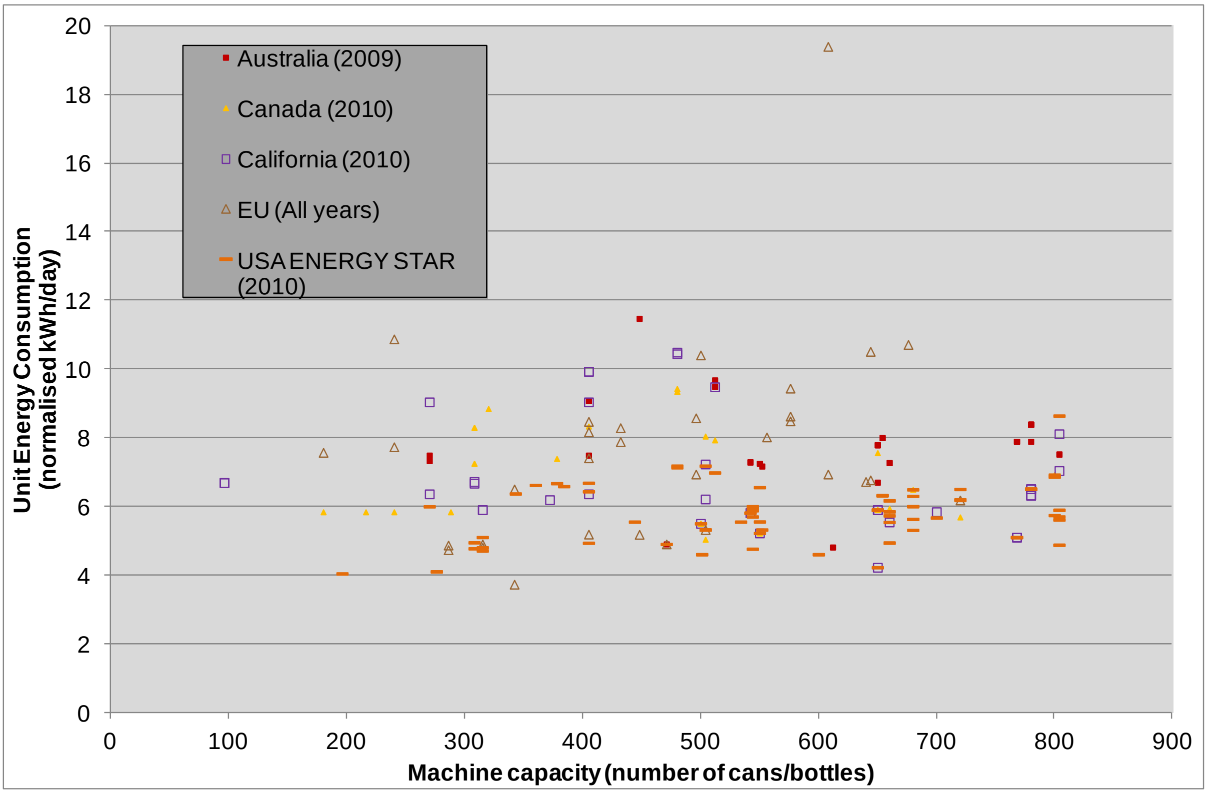


**Figure S4. Scatter graph of energy consumption (kWh per day) against machine capacity (number of cans/bottles).**

*For definitions of what is meant by robust, indicative and illustrative, see section 3.1.*



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# Contents





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## 2 Introduction

This report is the result of analysis of data collated between February and July 2011. Mapping documents for the participating countries were mostly published in September 2011. This benchmarking report was compiled in July 2012 (delayed due to project scheduling).

This benchmarking covers beverage vending machines both with glass fronts and opaque fronts. The original plan was to also cover food/snack vending machines but data for these was only received from the EU and so no benchmarking was possible for that machine type. This does appear to correspond with the different proportion of food/snack versus can/bottle machines in the US and EU markets.[9] Average efficiency results for EU food/snack vending are given in the EU mapping document.

For a full definition of scope and performance metrics considered, see *Product Definition: Vending Machines, Version 1.7: 11 May 2011.*[10]

Data was submitted by Australia, Canada, EU, USA (California energy commission and ENERGY STAR datasets). The datasets submitted include individual machine data for machines that were on the market between 2002 and 2011, although the majority of data covers 2007 to 2010.

[9] Directly comparable data was not available, but the US National Automatic Merchandising Association (personal correspondence, July 2012) indicated that food vending in the USA accounts for only 7% to 10% of sales, whereas the 2008 census of vending machines by the UK Automated Vending Association suggests that there were 108,000 snack/food machines in the UK stock, compared to only 88,000 can/carton/bottle machines – or 55% food/snack.
[10] See http://mappingandbenchmarking.iea-4e.org/matrix.



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# 3 About the data used and analysis method

Data was invited from 11 IEA 4E Mapping and Benchmarking Annex participating countries in February 2011. The request yielded data from Australia, Canada, EU, USA (California energy commission and ENERGY STAR datasets). Details of each dataset and results for each country separately are included in the individual country mapping documents which are available from http://mappingandbenchmarking.iea-4e.org/matrix.

## 3.1 Types of vending machine included

This benchmark analysis covers 2 basic types of vending machine shown in Figure 1:

a) The dedicated can/bottle vending machine with an opaque front that might sell between 1 and 5 types of drink. Cans/bottles are often held in a stack and gravity fed to the dispensing mechanism. Whilst the whole stock may be partially cooled, in many designs only those at the bottom third of the stack are cooled to the dispensing temperature. Usually rated for location outdoors or combined rating for indoors/outdoors and hence capable of performing in higher ambient temperatures, this type of machine is generally subject to testing at 32.2°C ambient temperature.

b) The glass fronted vending machine with a more flexible vending space that can be used to serve 20 or more different types of can/bottle and/or various snacks or food. Products are often queued in lines on several shelves (sometimes of the spiral vend design with rows of chrome spirals with one product between each turn of the spiral which is pushed forward as the spiral is rotated). The whole of the internal storage space is cooled to the same temperature. These are also called 'multi-package' vending machines in Canadian and Californian definitions. More usually rated for indoor use only and generally subject to testing at 23.9°C ambient temperature.



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**Figure 1. Dedicated can/bottle machine with an opaque front (left); glass fronted vending machine for cans/bottles and/or snacks/food (right).**

## 3.2 Important cautions for interpreting and using mapping and benchmarking information

Considerable efforts have been taken to ensure the integrity of the data supplied and the subsequent data manipulation and analysis. The generic approaches are detailed in the overall Mapping and Benchmarking Framework[11] and in the Vending Machines Product Definition.[12] However, to ensure that readers are fully aware of the reliability of particular sets of data and any associated assumptions or transformations that have been necessary, a *Framework for Grading Mapping and Benchmarking Outputs* has been developed that is used across all of this project's outputs. These gradings are based on a scale as follows:

- **Robust**: Datasets are representative of the full market and there is significant confidence in the transformation used to make the dataset comparable with others. Comparisons within and between such datasets are as reliable as reasonably possible.
- **Indicative**: Datasets are not fully representative of the market and/or there are minor concerns with the reliability of the transformation used to make the dataset comparable with others. Hence indicative data provides meaningful but qualified comparisons.

[11] Refer to Annex framework at http://mappingandbenchmarking.iea-4e.org/, accessed 23 July 2012.
[12] Refer to detailed product definition at http://mappingandbenchmarking.iea-4e.org/shared_files/174/download, accessed 23 July 2012.



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- **Illustrative**: Datasets poorly represent the market and/or there is significant concern with the reliability of the transformation used to make the dataset comparable with others. Hence any associated results and conclusions must be treated with caution.

## 3.3 About the datasets used

### *3.3.1 Sources and quality grading*

Table 1 provides an overview of the datasets and their quality gradings according to the categories described in section 3.2. Note that quality gradings are considered the same for declared and normalised data since normalisation is straightforward and reasonably robust. Statistical considerations imply that the EU dataset is the least robust of the group and is only retained as indicative (rather than illustrative) due to reassurances from the data providers that the machines account for a significantly higher proportion of the EU market than their count might indicate. Comparisons involving EU data should nevertheless be treated with particular caution. No data sets could be considered robust as none are sales-weighted.

**Table 1. Summary of the type and assigned quality for each dataset (for both declared and normalised data).**

| Country | Assigned quality | Source |
|---|---|---|
| **Australia** | **Indicative** | Mandatory government database (but not sales-weighted) |
| **Canada** | **Indicative** | Mandatory federal database (but not sales-weighted) |
| **EU** | **Indicative** | Data provided by individual EU manufacturers.<br>*Note: this is the smallest of the data sets* |
| **USA ENERGY STAR** | **Indicative** | Federal government-run endorsement scheme for better performing machines on the market |
| **USA California Energy Commission** | **Indicative** | State government-run mandatory database for the state of California |

### *3.3.2 Sales weighted data and market coverage*

No sales weighted data was available for any countries. For most product categories under the US ENERGY STAR programme, it generally aims to include only the best 30% or so of products on the market but For vending machines the proportion of market covered by qualifying products is likely to be significantly higher since the major bottling companies tend to specify ENERGY STAR qualifying products. The current ENERGY STAR criteria for vending machines (version 2) came into force in 2007 (and will be superseded by Version 3 in March 2013). It is therefore likely that the majority of US dedicated beverage machines qualified during the period examined, but this cannot be known for certain due to the



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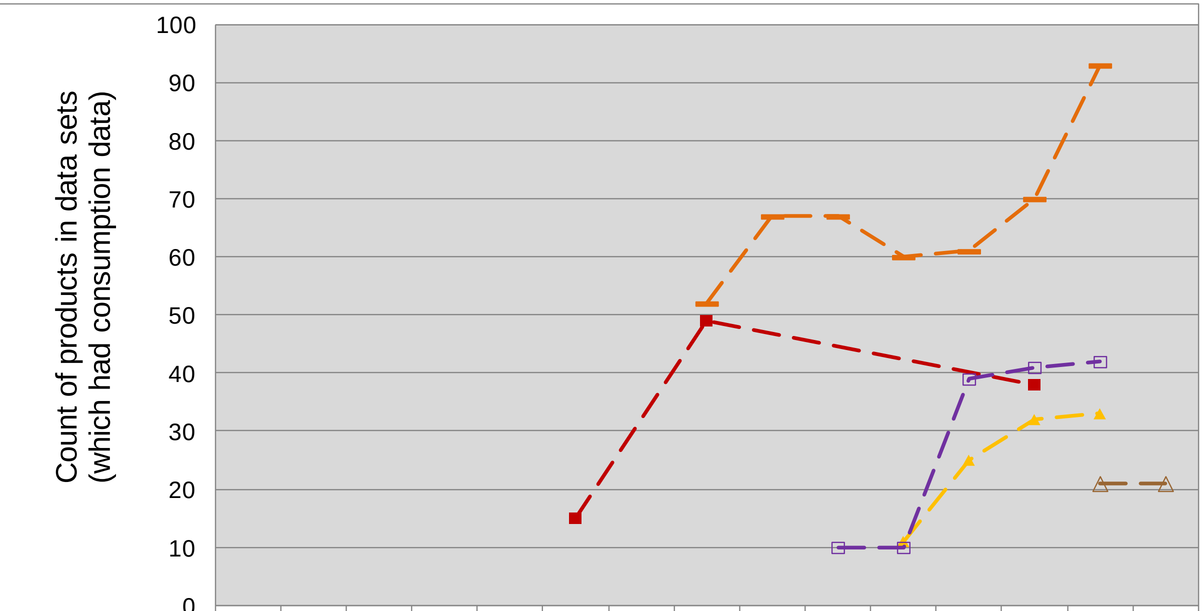
absence of sales data. However, there is another respect in which the ENERGY STAR dataset is not fully representative of the US market: it excludes any machines which are not dedicated for can/bottle or other sealed beverages. The size of this misrepresentation is not major since food/snack machines account for less than 10% of the US market anyway[13]. The EU data set is relatively small and should be treated with particular caution. All of the data sets in this benchmarking analysis have therefore been considered reasonably representative of the markets, subject to the cautions observed above.

### *3.3.3 Count of machines included*

The count of machines in each dataset is shown in Figure 2. The counts show that the number of machines varies significantly between countries and also between years within each country dataset. Data bins[14] with 15 or fewer machines were discounted from the analysis as being unreliable. Nevertheless, trends must be treated with caution and examined to check that they are not simply a result of a very different size of dataset, perhaps introducing a different mix of machine types in the dataset. See also section 3.3.4.




| | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Australia | | | | | | 15 | | 49 | | | | | 38 | | |
| Canada | | | | | | | | | | | 11 | 25 | 32 | 33 | |
| USA CEC | | | | | | | | | | 10 | 10 | 39 | 41 | 42 | |
| EU | | | | | | | | | | | | | | 21 | 21 |
| USA ENERGY STAR | | | | | | | | 52 | 67 | 67 | 60 | 61 | 70 | 93 | |

Solid line = robust data    Dashed line = indicative data    Dotted line = illustrative data

**Figure 2. Count of machines included in each data set for each year. Data bins with 15 or fewer machines were later deleted from the analysis.**

---

[13] Estimate by market expert based on feedback from US manufacturers.

[14] A data bin is a sub-set of the data set containing the machines of a certain type available in a particular year in a particular country. For example, in figure 2 above, the data bin for the USA Californian dataset in 2006 contains 10 products (and so was deleted from the subsequent analysis since it contained less than 15 machines).



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### 3.3.4 Number of brands

Another important change noted between different years and between different countries' datasets was the number of brands included. A sudden change in brand mix in a data set can change the mix of machine types, consumption and efficiency. This introduces a risk that a false market trend or step change in performance could be shown in the graph, because the change arises only as a result of the change in data in the set, not reflecting any change in the market. Not surprisingly, data bins[15] with low machine counts coincided with those having a very limited number of brands included. Globally there are probably only around 20 manufacturers of vending machines and perhaps 300 machines (excluding variants). The number of brands available on any market is very unlikely to change much from year to year but representation in data sets can change for reasons which are nothing to do with machine availability. Exclusion of the data bins containing 15 or fewer machines also removed the big steps in number of brands shown in Figure 3 to Figure 7. Note that each colour in any figure represents a different brand but colours do not correspond between the different figures.

[15] A data bin is a sub-set of the data set containing the machines of a certain type available in a particular year in a particular country.



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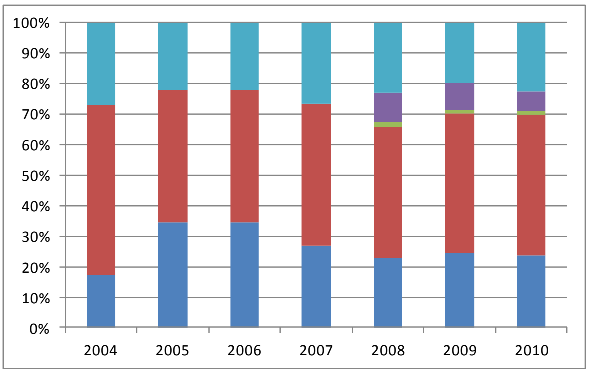


**Figure 3. Mix of brands amongst US ENERGY STAR datasets (all datasets were retained).**

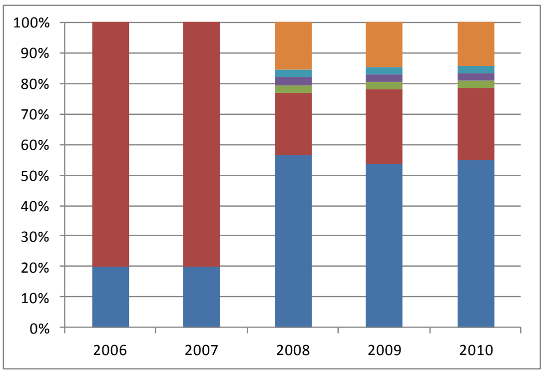


**Figure 4. Mix of brands amongst US California energy commission datasets (2006 and 2007 datasets were excluded from the later analysis).**

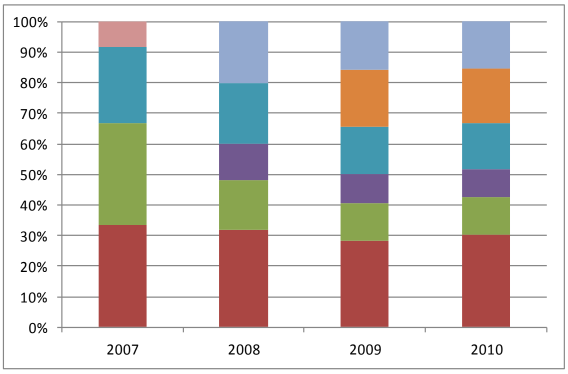


**Figure 5. Mix of brands amongst Canadian datasets (2007 dataset was excluded from the later analysis).**

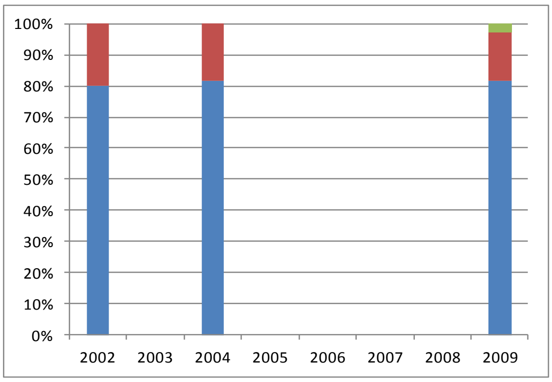


**Figure 6. Mix of brands amongst Australian datasets (2002 dataset was excluded from the later analysis due to low count).**

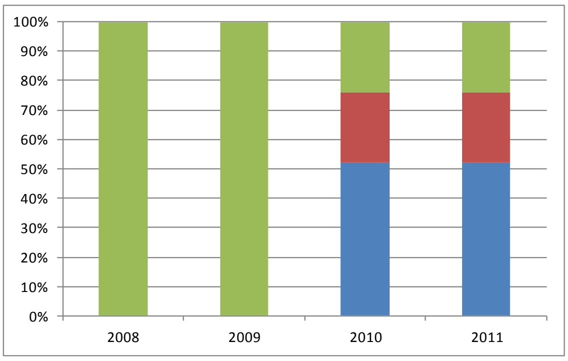


**Figure 7. Mix of brands amongst EU datasets (2008 and 2009 datasets were excluded from the later analysis).**



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## 3.4 Test methodologies, characteristics and metrics

### 3.4.1 Test methodologies

Two test methodologies have been identified.[16]

1. ASHRAE Standard 32.1-2004, Methods of Testing for Rating Vending Machines for Bottled, Canned, and Other Sealed Beverages (as used by ENERGY STAR and US DOE MEPS ).
2. Test Protocol for the Measurement of Energy Consumption in Vending & Dispensing Machines, Version 2.0 – June 2008, European Vending Association, Brussels, http://www.vending-europe.eu (as proposed by this manufacturers' association for use in presenting performance data to customers, and also for a voluntary energy labelling scheme in Europe).

The ASHRAE test methodology has been adopted by the US EPA for ENERGY STAR, California Energy Commission for state MEPS And for US federal MEPS, Canada and Australia. The European Vending Association methodology has not been adopted by any national schemes, nor is there much public domain machine performance information available that is based upon this methodology (based on UK research for Defra during 2009). Hence the ASHRAE test methodology was adopted as the basis for this mapping and benchmarking analysis.

### 3.4.2 Operational modes

Energy consumption could be measured during the following operational modes:

- Normal idle mode, i.e. waiting for the next customer during normal operating hours. This is by far the most dominant mode and is considered typical of the annual performance.
- Vending mode is transitory during actual delivery of a sale. The actual vending operation is transient and infrequent when averaged over the whole year for machines that are mostly operational 24 hours per day, 365 days per year.
- Reloading and pulling down phase after refill. This is also a transitory phase and is ignored when characterising typical performance.
- Low-power mode, in which lighting and refrigeration may be off or running at a reduced level. The internal temperature may be allowed to rise.

The mode of most significance to this analysis is the normal idle mode and this is used as the basis for the ENERGY STAR criteria and MEPS in Australia and Canada.

[16] Note that subsequent to the research stage of this analysis, the US DOE published their Final Rule for vending machines and ENERGY STAR criteria Version 3 which refer to a modified version of the ASHRAE Standard 32.1 test method, published as 10 CFR Part 431 Subpart Q, 10 CFR Part 431.294. This is based upon a volumetric efficiency, rather than according to capacity (number of beverages).



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### 3.4.3 Consumption metric – kWh/24 hours

The consumption metric generally used for these machines is kWh per 24 hours (day).

### 3.4.4 Efficiency metric (specific consumption) – kWh/300 cans/day

Energy efficiency metrics rarely feature in the technical data published by suppliers at the time of this analysis. However, a specific consumption metric was defined for the purposes of this analysis in kWh per day per 300 cans internal capacity. This allows comparison of all capacities of machine on one set of axes and used the lowest likely capacity of machines (300 cans) as the baseline unit. Note that the US DOE MEPS and ENERGY STAR Criteria Version 3 use performance calculated from volumetric efficiency (kWh/ft$^3$) rather than from beverage capacity (number of cans/bottles).

### 3.4.5 Vending machine capacity

The capacity of beverage (bottle/can) and snack/drink vending machines is generally measured in number of cans/bottles or packets of food/snack that the machine can store. For example a beverage machine may hold 650 cans.

It would have been preferable to note the size of the bottle/can that can be accommodated – whether 355 ml (common in USA), 330 ml (Europe), 0.5 litre bottles or other – and adjust volume measurements to compensate where applicable since the same number of bottles/cans capacity could mean a different internal volume in some cases. But insufficient data was available to enable this. Note that the energy consumption test is undertaken after steady state is reached and so does not take into account the energy consumed to pull the contents down to temperature, and so the volume of drink within the machine (product of bottle/can volume and count) is less important than the heat gain through insulation and efficiency of refrigeration pack etc.

### 3.4.6 Beverage storage temperature

This analysis includes only machines intended for refrigerated vending operating at around 0°C to 5°C. Frozen, ambient and mixed temperature storage machines are excluded. In practice, the major soft drink suppliers who dominate the market specify a certain optimum temperature for serving from their machines which is the same the world over[17], and hence have had a useful normalising effect. The average beverage temperatures for test situations in test standard ASHRAE 32.1 are between 0.6°C to 4.4°C. The standard also requires that

[17] For example, one major global brand specifies that all drinks in the measured portion of the test must achieve 0°C (32F) to 7.2°C (45F) with an average of 3.3°C (38F) or below. For a stack vending machine, this is tested on the front 1st and front 4th product of each stack, measured from the bottom (meaning all drinks likely to be dispensed soon).


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the 'next to be vended' temperature shall be stabilised to 2.2±0.5°C during the energy consumption test and the vending test shall continue until product is coming out at 4.4°C or until half the product is vended. Beverage machines are often designed to vend product at the required 2.2°C but to store the bulk of the cans at a temperature a couple of degrees higher. The cans closest to the 'head of the queue' get chilled further as they approach vend, which saves energy by allowing a higher storage temperature for the majority of the stock. The storage temperatures of beverage machines are therefore likely to be highly comparable and no normalisation was carried out for storage temperature in this analysis.

This raises another important cause of different specific energy consumption between dedicated beverage vending machines and snack/food vending machines that are also used to vend beverages:

- Dedicated beverage vending machines store the majority of their stock at a slightly higher temperature which will require lower energy consumption. Beverages are chilled further to the serving temperature only shortly before they reach the front of the queue to be vended.
- Snack/food vending machines which are also used for beverages have to keep all contents chilled to the same serving temperature because some of their content may be subject to food safety regulations regarding storage temperature. A lower storage temperature requires more energy to retain temperature (if insulation levels are the same).

This must be borne in mind when comparing average products from different markets.

### *3.4.7 Ambient temperature and humidity during test*

Some vending machines are designed to be placed outside and are fully weatherproof, others can only be used indoors. Its location will affect the energy consumption of a machine, depending on by how much the average external ambient temperature is higher or lower than the internal storage temperature. The ENERGY STAR criteria for vending machines use the same numerical energy efficiency criteria for both indoor and outdoor machines, but provide for different ambient rating conditions. Indoor and outdoor machines are grouped together for this analysis, but a normalisation adjustment is made to those tested at indoor conditions, see section 3.5.

The ASHRAE test methodology offers two sets of possible ambient conditions for testing:

- 32.2°C±1°C and 65%±5% relative humidity (RH) for machines specified as suitable for outdoor use[18]; and
- 23.9°C±1°C and 45%±5% RH for indoor machines.

[18] Use of this high test temperature was probably driven by the desire to ensure that the machine can deliver product at the required temperature even under extreme conditions – i.e. it is part of a 'fitness for purpose' test, rather than attempting to derive indicative energy consumption under typical conditions for users.



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The European Vending Association Energy Measurement Protocol requires:

- 32°C and 65% RH for outdoor machines; and
- 25°C and 60% RH for indoor.

Data was normalised to the outdoor machine conditions required in ASHRAE 32.1, i.e. 32.2°C±1°C and 65%±5% relative humidity. 'Outdoor' was chosen because the majority of machines were declared for outdoor conditions. Machines identified as suitable for both indoor and outdoor usage were treated as if they were tested at the outdoor conditions (in line with the ENERGY STAR criteria).

The effect of ambient humidity on machine performance is less pronounced, especially as differences are small, and no empirical evidence for normalisation is available so this difference was ignored.

## 3.5 Data normalisation calculations

As discussed in section 3.4, the only factor for which normalisation was decided to be necessary was for the ambient temperature during test. Testing is carried out at either 32.2°C for outdoor machines or indoor/outdoor machines, or at 23.9°C for indoor machines. All data was normalised to be comparable as if testing was carried out at 32.2°C, i.e. to outdoor test temperature.

Normalisation was carried out for machines tested at the indoor ambient conditions using this equation (see Appendix 1 for its derivation):

$$\mathbf{E_{32.2°C} = 1.588 \times E_{23.9°C} - 1.088}$$

Where:

$E_{32.2°C}$ = Energy consumption tested at 32.2°C
$E_{23.9°C}$ = Energy consumption tested at 23.9°C

## 3.6 Approach to analysis

Analysis of the machine data was straightforward:

1. Machine type descriptions were used to identify machines as either beverage vending machines or snack/drink vending machines. Machines quoted as food, spiral or snack were counted as snack/drink vending.
2. Machines with a capacity of fewer than 500 bottles/cans were identified as small, 500 to fewer than 700 as medium, and over 700 as large.



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3. Machine descriptions were used to identify machines as either glass fronted or closed. The description 'live display' (relevant to around 5% of the US dataset) was interpreted as being a glass front.[19]
4. Data bins with 15 or fewer machines were deleted from the analysis as providing unreliable averages.
5. Machine descriptions were used to determine if the machine was tested at indoor or outdoor conditions, depending on the stated description or local test methodology. Those tested at indoor conditions were normalised as described in section 3.4.7.
6. Normalisation was carried out as described in section 3.5.
7. Some models were identified in their descriptions as rebuilt (as opposed to new). It was assumed that these machines would perform as equivalent to new machines and so this was ignored. A high proportion of vending machines are rebuilt during their lifetimes, often including a complete replacement of cooling equipment and controls.
8. To take account of machines being available on the market for an average of 6 years after first release, machines were carried forward into the following 6 yearly datasets. The effect of this decision for most of the data sets (except Australia for which adequate data was only available for 2002, 2004 and 2009) is that the number of machines in the sets rises significantly over successive years but this is primarily a reflection of the data set coverage, not of the market itself. It is assumed that as the count of products rises, so the data set becomes more representative of the market. This carrying forward of products to later years also smoothes out the impact of changes in efficiency of the new products, as their impact is diluted by carry-over products. This is as close to an accurate reflection of what occurs in the market as is possible without sales data (assuming that the average period for which a product continues to be available on the market is accurate).

[19] Comments from the US team in September 2012 indicated that the term 'live display' is generally used to describe an opaque front machine with a small window showing specific products that are dispensed from the machine. The glass front therefore may only constitute a small proportion of the front area.


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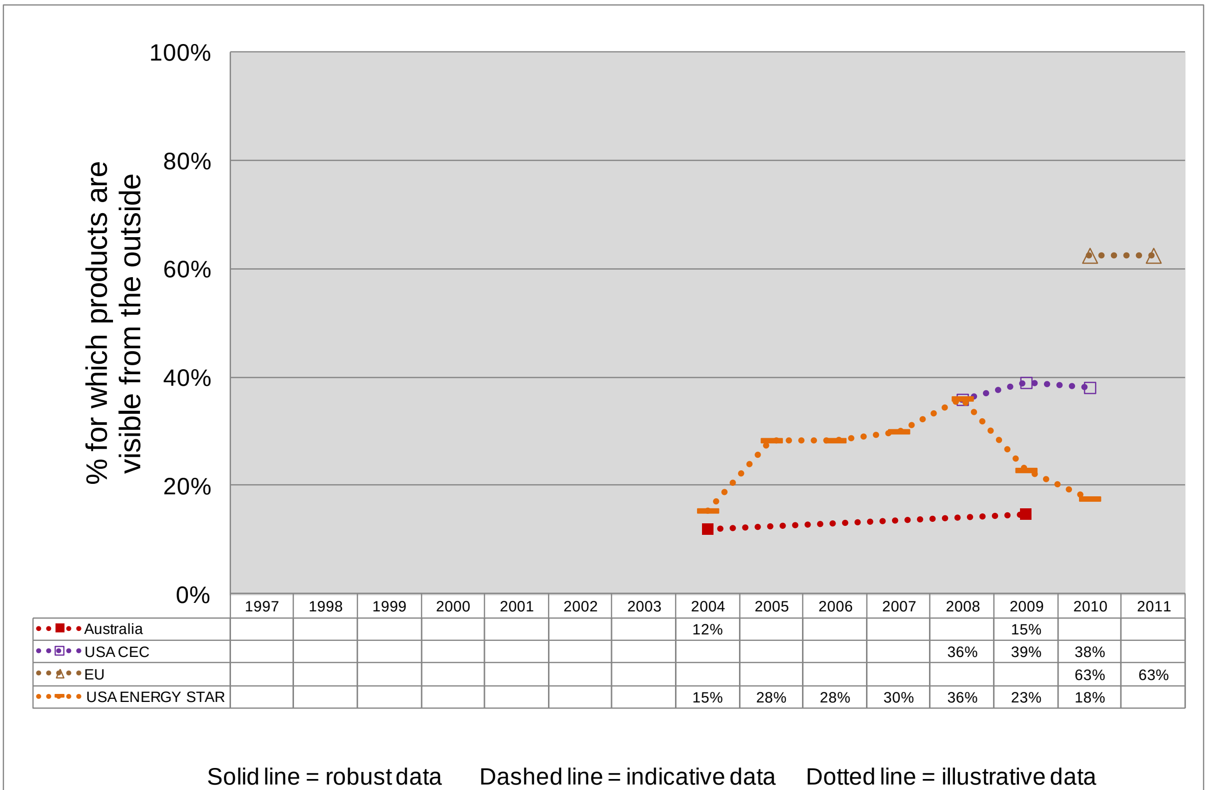
# 4 Types of machines on the market and trends

## 4.1 Glass versus opaque fronted

For the majority of dedicated beverage (can/bottle) vending machines, the contents are not visible from the outside, which is usually covered in illuminated advertising over the insulation. If the product is to be visible from the outside, glass is required, which generally allows more heat ingress than solid insulation and so consumption would be higher. For beverage vending, it makes no difference to functionality from the user's point of view as to whether the product is visible or not. For food/drink vending, visibility of the product could be important.

Figure 8 shows how this varies between country datasets: the EU market is just over 60% glass fronted; US less than 40% glass fronted and Australia less than 20% glass fronted. This also reflects feedback received from EU manufacturers that EU machines tend to be of the flexible vending type which can be used for vending both drinks and snacks within one machine. Figure 9 shows an alternative presentation of these proportions for the most recent data set.

The Canadian dataset did not indicate whether machines were glass fronted or not.




| | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Australia | | | | | | | | 12% | | | | | 15% | | |
| USA CEC | | | | | | | | | | | | 36% | 39% | 38% | |
| EU | | | | | | | | | | | | | | 63% | 63% |
| USA ENERGY STAR | | | | | | | | 15% | 28% | 28% | 30% | 36% | 23% | 18% | |

**Figure 8. Proportion of data sets for which products are visible from the outside.**



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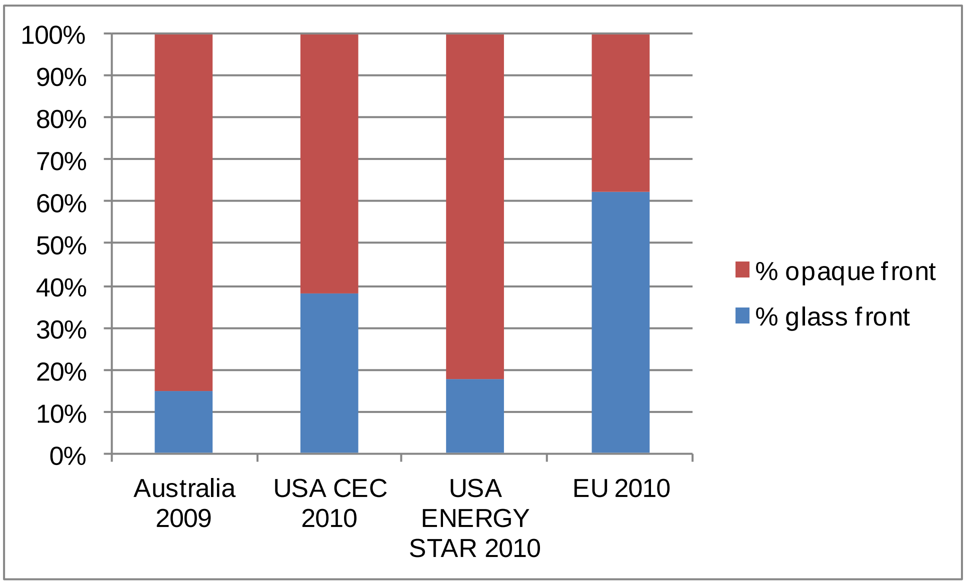


**Figure 9. Breakdown of datasets into those with opaque front and glass front for the most recent data set.**

## 4.2 Capacity of vending machines

Figure 10 shows how capacity varies between countries' datasets. EU has an average of 450 can capacity whereas Australia and US ENERGY STAR are generally around or above 600. This has implications for the efficiency that is achievable in terms of kWh per 300 cans per day, due to the increased surface to volume ratio for smaller machines (see section 5.3).

Figure 11 shows how the datasets break down into categories of small, medium and large capacity units. The EU and Californian datasets have nearly 60% 'small' category machines each, whereas Australia and the US ENERGY STAR datasets have only around 20% in the 'small' category. The EU and Canada have less than 10% in the 'large' category.

Anecdotal evidence from an industry expert confirms that there are fundamental differences in the business model used by vending machine operators in Europe compared to that in the USA. Operators in Europe tend to offer complete drinks and snacks services for which hot drinks machines have to be visited on a regular basis to keep them clean. The accompanying cold beverage machines can therefore be refilled at the same time as these frequent visits and therefore smaller machines can be guaranteed to remain stocked and less money is tied up in that stock. The major operators in the USA operate machines which are filled on an 'as-required' basis and the machine has telemetry installed that informs the delivery driver when it needs restocking. The economics of this model favour larger machines with fewer visits. These differences between the types of markets in different countries result in the use of machines that are unlikely to be able to achieve comparable energy efficiency and should be borne in mind when comparing the graphs, since energy efficiency policy is unlikely to be able to bridge the gap.



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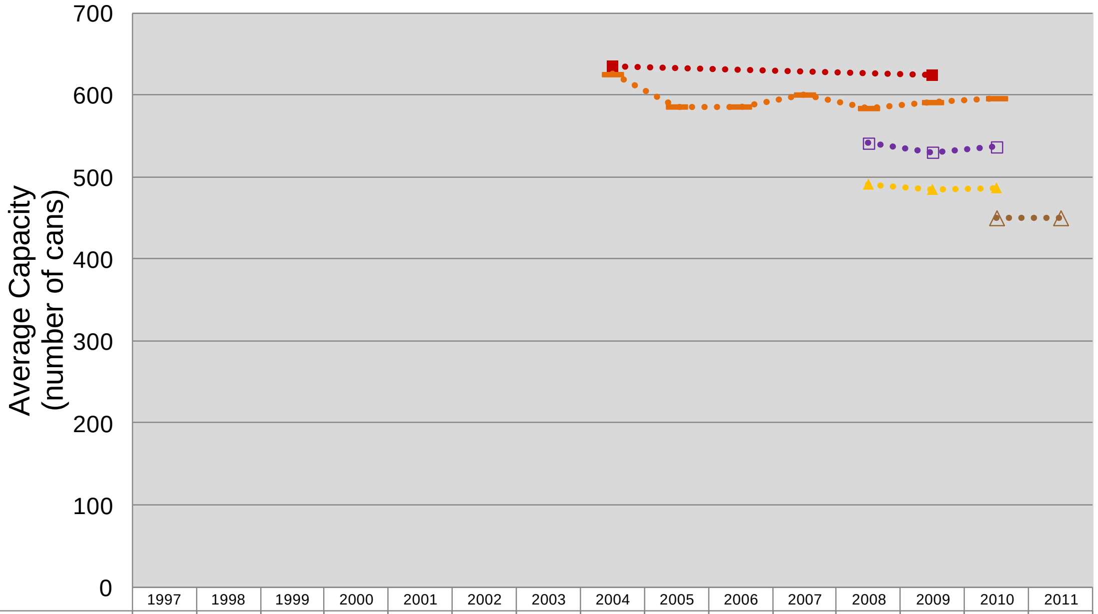


| | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Australia | | | | | | | | 635 | | | | | 624 | | |
| Canada | | | | | | | | | | | | 491 | 485 | 487 | |
| USA CEC | | | | | | | | | | | | 542 | 530 | 537 | |
| EU | | | | | | | | | | | | | | 451 | 451 |
| USA ENERGY STAR | | | | | | | | 626 | 586 | 586 | 601 | 584 | 592 | 596 | |

Solid line = robust data   Dashed line = indicative data   Dotted line = illustrative data

**Figure 10. Average capacity of vending machines measured in number of cans.**

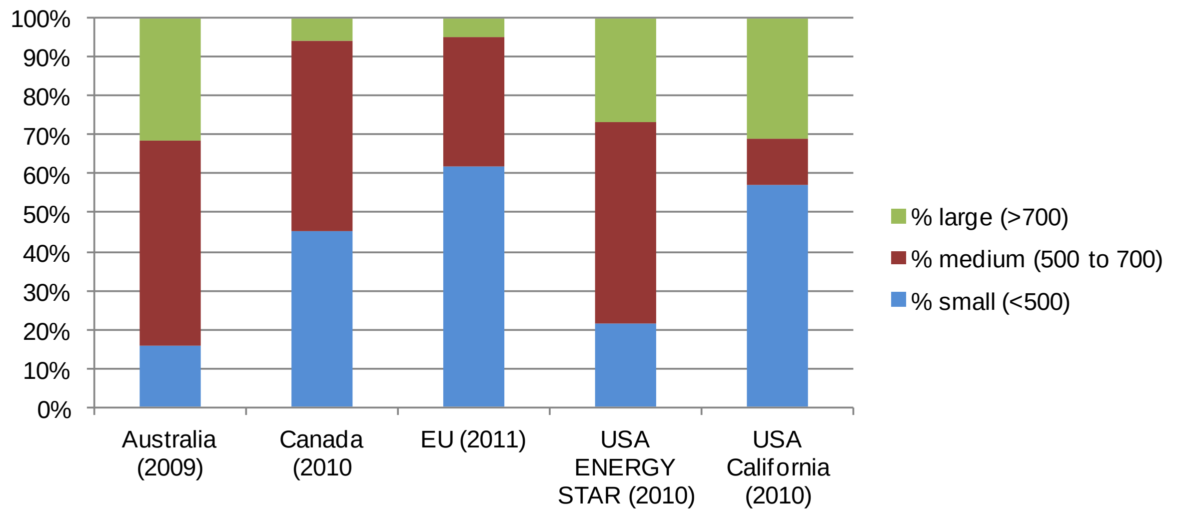


**Figure 11. Breakdown of the most recent data set into large, medium and small capacity units, by number of cans.**



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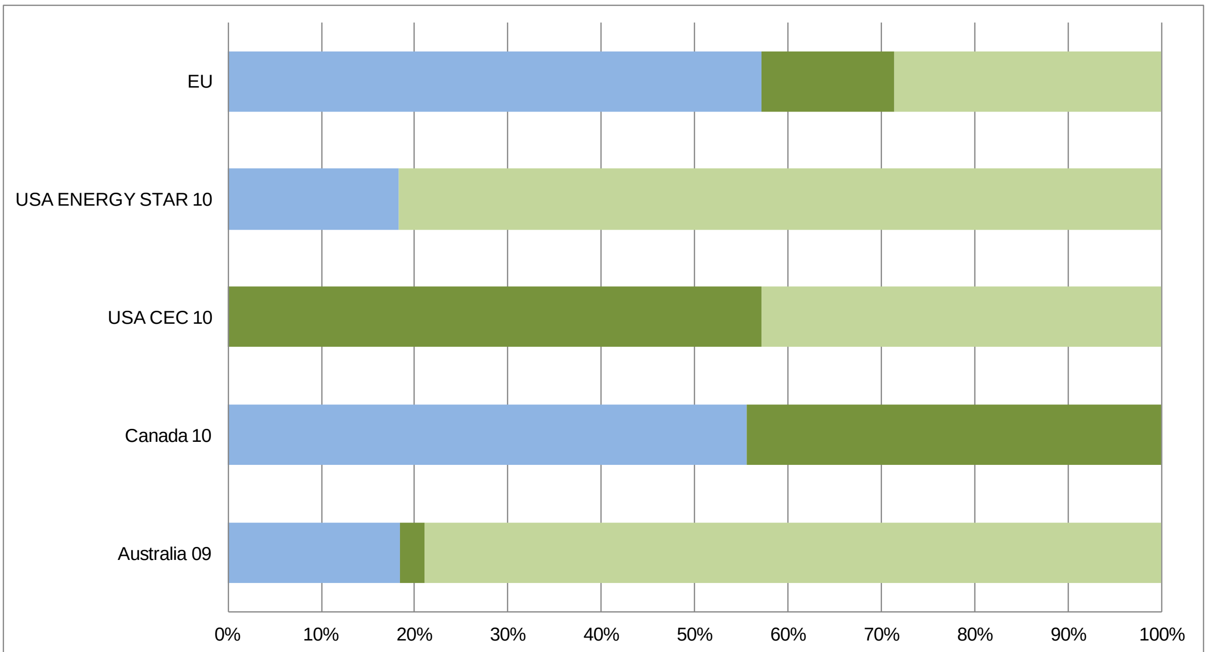
## 4.3 Indoor and outdoor rating

Figure 12 shows how the proportion of machines rated for indoor, outdoor or both ambient conditions varies between data sets. US and Australian machines tend to be predominantly rated for outdoor or both conditions. Just over half of Canadian and EU machines are rated for indoor conditions only. The machines rated at indoor conditions have been subject to normalisation, i.e. adjusted to a level as if tested at outdoor conditions.

In line with ENERGY STAR criteria, machines rated at both conditions are tested at outdoor ambient conditions.

Note that the Californian and Canadian standards refer to multi-package vending machines, which appear to correspond directly with being glass fronted machines and also correspond with being machines dedicated to indoor usage.




| | Australia 09 | Canada 10 | USA CEC 10 | USA ENERGY STAR 10 | EU |
|---|---|---|---|---|---|
| % used indoors | 18,4% | 55,6% | 0,0% | 18,3% | 57,1% |
| % used outdoors | 2,6% | 44,4% | 57,1% | 0,0% | 14,3% |
| % used in and out | 78,9% | 0,0% | 42,9% | 81,7% | 28,6% |

**Figure 12. Proportion of each data set that is rated at indoor, outdoor or both ambient conditions (data shown for most recent substantial data set).**



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# 5 Energy performance

## 5.1 Important differences between machines used in each market

When comparing the average energy consumption or specific energy consumption of machines across different countries/regions in this section, it is important to bear in mind the significant differences between the dominant machine types in each market as described in section 4 *Types of machines on the market and trends*. The EU market is dominated by glass fronted merchandisers that vend snacks/food and/or beverages (over 60%) whereas US and Australian data sets have fewer than 20% and the Californian data set has fewer than 40%. This is very important for energy consumption because:

- A glass front allows more heat ingress than an opaque insulated front (see section 4.1);
- Dedicated beverage vending machines store the majority of their stock at a slightly higher temperature which will require lower energy consumption; snack/food vending machines have to keep all contents chilled to the same lower serving temperature which requires more energy (if insulation levels are the same) (see section 3.4.6);
- A significant proportion of EU machines are designed as capable of also storing fresh food and so subject to food safety regulations that require them to be able to maintain a given temperature by law. To ensure compliance, the machines are designed with a higher refrigeration capacity than would be necessary for non-perishable goods. This could result in a higher consumption per unit capacity than, for example, dedicated beverage machines that are typical in the US market and subject only to consumer/supplier preferences for temperature, rather than food safety law;
- Smaller/lower capacity machines (as present in the EU market) will have a higher surface area to volume ratio than larger machines and so suffer more heat ingress per unit beverage capacity for the same insulation levels; and
- Anecdotal evidence from the European trade association[20] indicates that EU 'indoor' machines are generally designed to operate in a wider range of ambient temperatures than typical US machines since they typically have to operate without air-conditioning in summer[21]. This could result in typical EU machines having a higher refrigerating capacity (kW of cooling power) than equivalently sized US machines and so the EU machines may have proportionately larger energy consumption.

It was not considered feasible or appropriate to normalise for these issues: Not feasible due to inadequate data in each data set to allow normalisation; and not appropriate because this analysis is mainly focused on beverage vending and in that respect the same utility is being

[20] Personal correspondence.

[21] One EU source suggested that US specifications typically achieve a consistent 7°C temperature drop below ambient, rather than being able to achieve the target temperature regardless of ambient but this was not confirmed by any other sources (which in summer requires more than 7°C temperature drop, and so a higher refrigerating capacity).



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provided whether the machine is glass or opaque fronted.[22] It is useful that policymakers understand the differences in specific consumption but also realise that energy efficiency regulation would have to force a significant change in the typical EU product functionality in order to match the much better performance levels achieved in Canada and the US for example.

## 5.2 Average energy consumption (kWh per day)

Figure 13 shows the average energy consumption per day for machines in each dataset. The Australian machines might be expected to have high energy consumption as they have the largest average capacity. The European machines are 25% smaller than the Australian ones but have only 4% less consumption per day (which simply implies that the Australian ones are more efficient per 300 beverages).

The only significant change in average consumption seen in this data is for the US ENERGY STAR set between 2006 and 2007. This coincides with introduction of the version 2 criteria, after which many poorer performing machines were removed from the dataset.

Figure 14 shows a scatter graph derived from the largest dataset for each country (except for the EU for which all data was included due to low data quantities). The US ENERGY STAR machines can be seen to dominate the lower part of the graph. There are a few EU machines with comparatively low consumption, but also many with high consumption.

[22] A separate analysis of glass and opaque-fronted machines could be presented if the scope and aim of the analysis were to be adjusted, but this was not the original objective.



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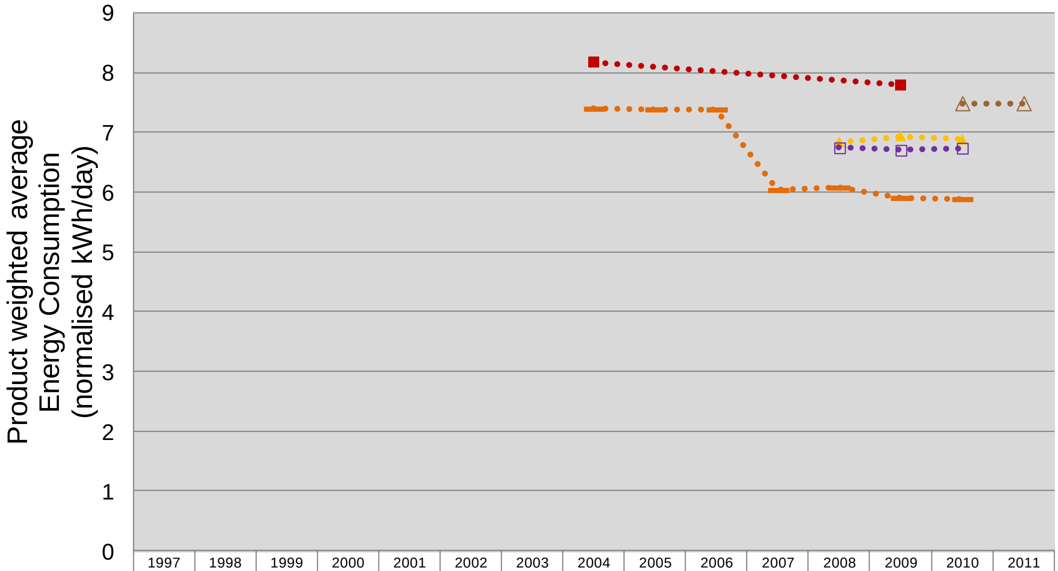


| | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Australia | | | | | | | | 8.17 | | | | | 7.79 | | |
| Canada | | | | | | | | | | | | 6.84 | 6.94 | 6.88 | |
| USA CEC | | | | | | | | | | | | 6.74 | 6.70 | 6.73 | |
| EU | | | | | | | | | | | | | | 7.49 | 7.49 |
| USA ENERGY STAR | | | | | | | | 7.40 | 7.38 | 7.38 | 6.04 | 6.08 | 5.90 | 5.88 | |

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

**Figure 13. Average energy consumption (normalised) in kWh per day.**

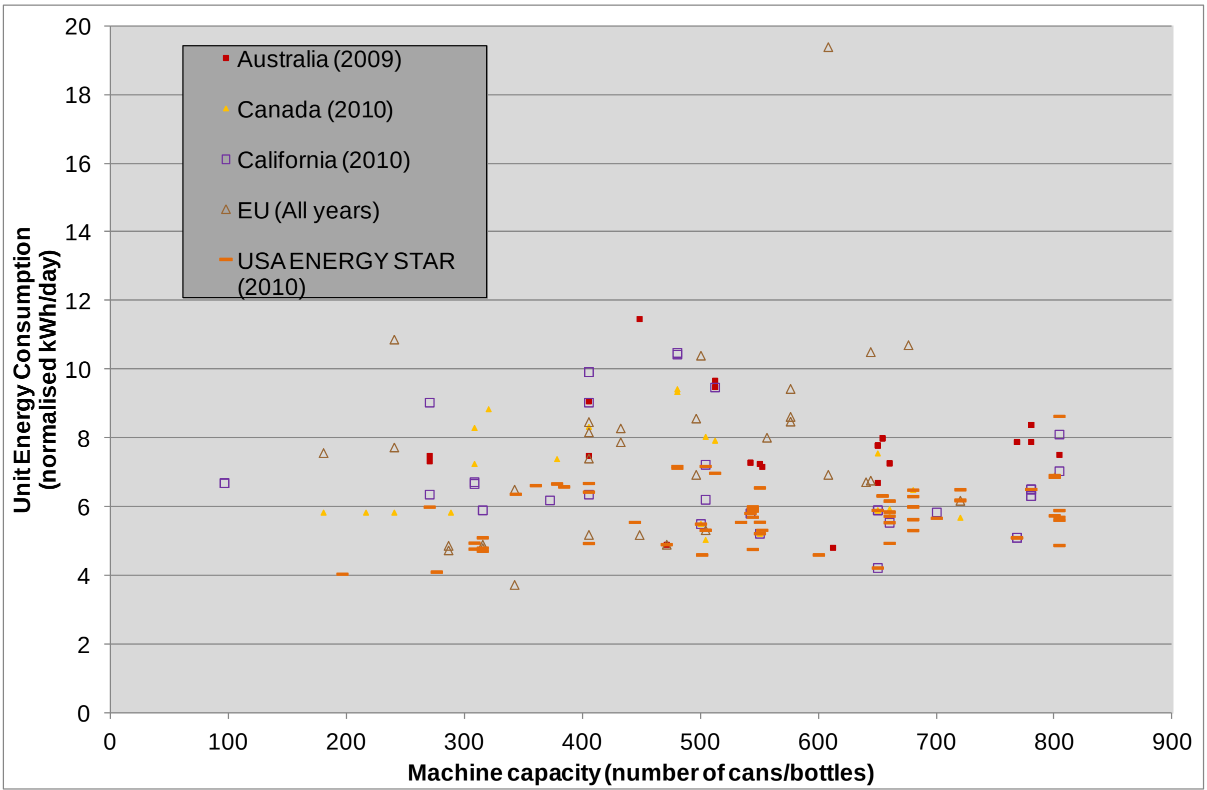


**Figure 14. Scatter graph of energy consumption (kWh per day) against machine capacity (number of cans/bottles).**



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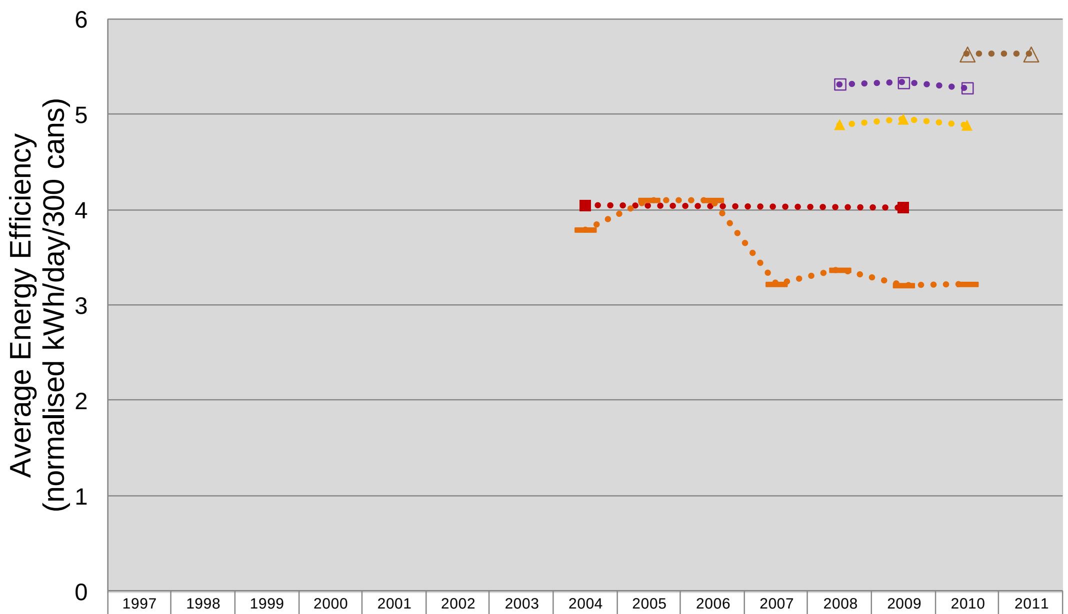
## 5.3 Average specific energy consumption (kWh/300 cans per day)

Figure 15 shows average specific energy consumption. The only significant change occurs between 2006 and 2007 for the ENERGY STAR dataset, coinciding with the introduction of version 2 criteria. It is therefore likely that the deletion of machines at that time gave rise to the step change seen.

EU machines appear to have the worst average specific consumption, most likely due to some or all of the reasons explained in section 5.1. Australian and US ENERGY STAR machines are predominantly opaque fronted and larger than the EU machines and some have significantly better specific consumption. ENERGY STAR machines use just over half the energy per can of those from the EU.

Figure 16 shows how specific consumption varies with capacity, based on the most substantial recent dataset and in the case of EU shows all data combined. The trend line for the EU dataset has a relatively poor correlation to the actual data, most likely because it contains a more varied mix of glass fronted versus opaque fronted machines and range of machine types (spiral vend, beverage etc) and ages. The US ENERGY STAR dataset shows the narrowest spread and best average efficiency. The EU and California have a wider scatter of efficiency levels than other datasets.




| | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Australia | | | | | | | | 4.04 | | | | | 4.02 | | |
| Canada | | | | | | | | | | | | 4.89 | 4.95 | 4.89 | |
| USA CEC | | | | | | | | | | | | 5.32 | 5.33 | 5.28 | |
| EU | | | | | | | | | | | | | | 5.63 | 5.63 |
| USA ENERGY STAR | | | | | | | | 3.79 | 4.10 | 4.10 | 3.22 | 3.37 | 3.21 | 3.22 | |

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data

**Figure 15. Average specific energy consumption in kWh/300 cans per day.**



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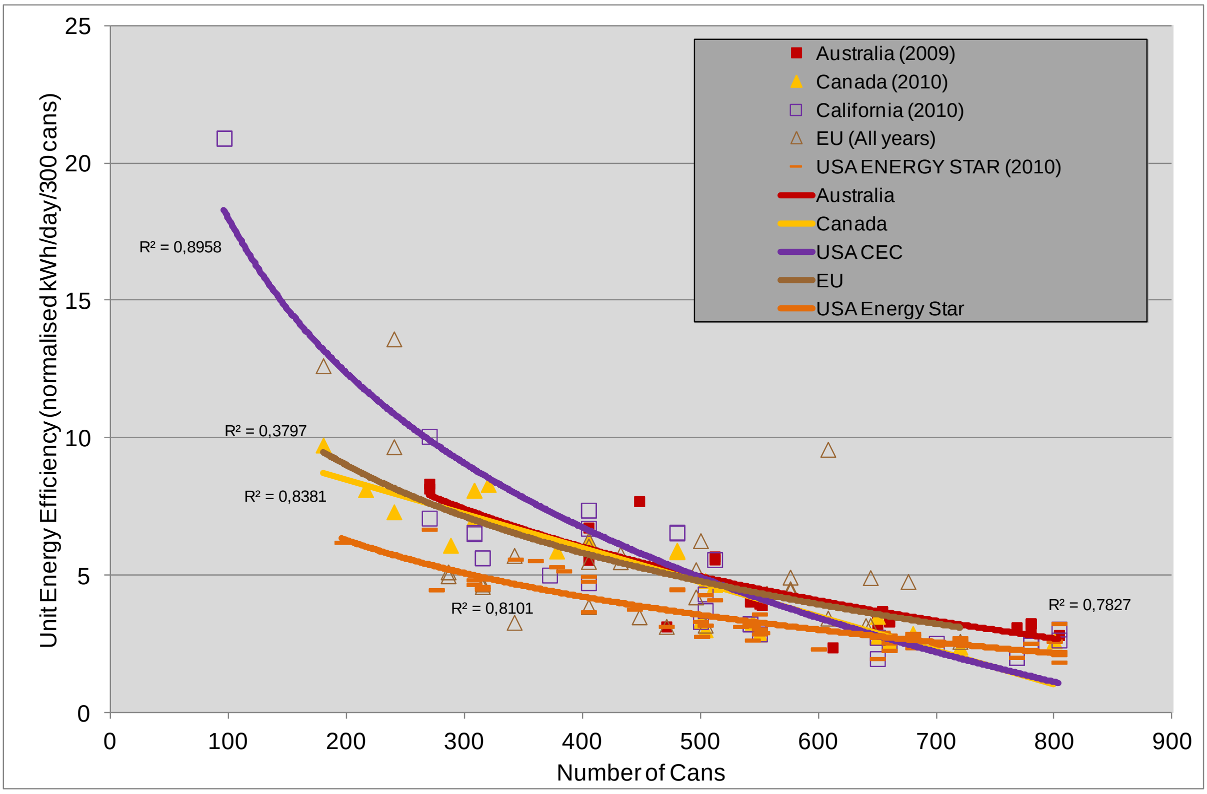


**Figure 16. Plot of specific consumption against capacity showing trend lines for each dataset, including the R-squared value for each.**

## 5.4 Best performing machines

Figure 17 shows that there is much less difference between the best performing machines in each region as compared with the difference between average performances. The best EU machines virtually match the best Canadian and Australian machines; US machines appear to have a top benchmark specific consumption that is 20% lower. The best performing machine overall in every year is from the US ENERGY STAR dataset.

Note that a higher proportion of the EU machines were subject to normalisation adjustment and so relative positioning for EU machines could be skewed by that (see Appendix 1).



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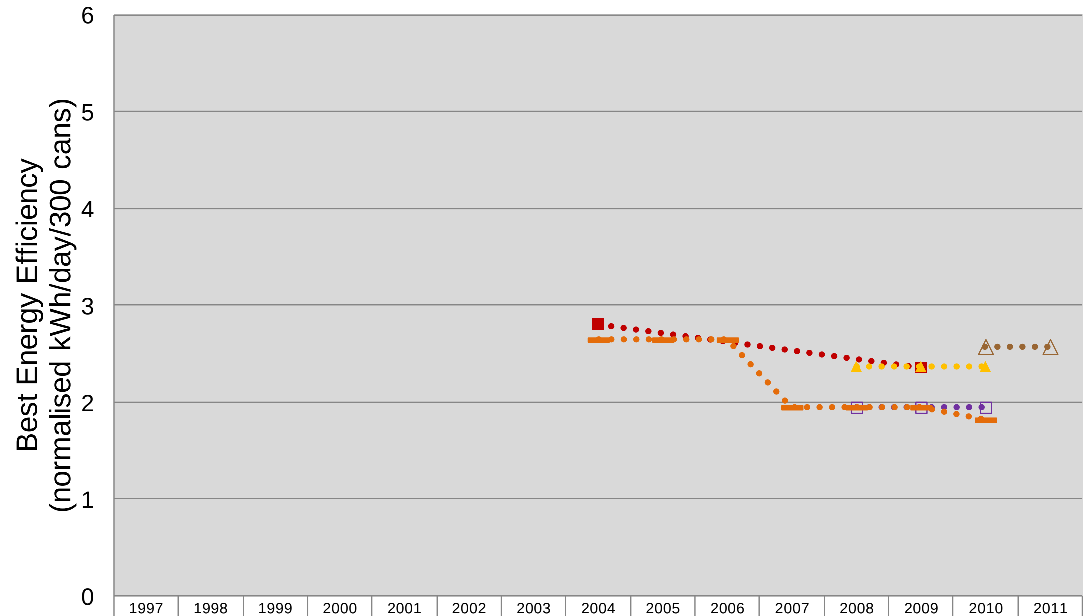


| | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Australia | | | | | | | | 2.81 | | | | | 2.36 | | |
| Canada | | | | | | | | | | | | 2.37 | 2.37 | 2.37 | |
| USA CEC | | | | | | | | | | | | 1.95 | 1.95 | 1.95 | |
| EU | | | | | | | | | | | | | | 2.58 | 2.58 |
| USA ENERGY STAR | | | | | | | | 2.65 | 2.65 | 2.65 | 1.95 | 1.95 | 1.95 | 1.82 | |

Solid line = robust data  Dashed line = indicative data  Dotted line = illustrative data

**Figure 17. Specific consumption of the best performing machine in each data bin.**



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# 6 Stock of machines and national consumption

Time series stock and national consumption data was only made available by Australia[23] and that indicated a stock of 110,000 units in 2004, rising slowly to 113,000 in 2009. Improvements in assumed average efficiency meant that the estimated national consumption fell slightly from 522 GWh per year in 2004 to 520 GWh per year in 2009.

A single figure was available for Canada from a study in 2004 which concluded and estimated stock of 200,000 vending machines and an estimated annual consumption of around 730 GWh per year. For the US, the Final Rule for beverage vending machines[24] indicates a US stock of 2.3 million in 2009. The European Ecodesign study[25] estimated that there were 1.16 million refrigerated vending machines in the EU-25 in 2004.

[23] Draft Regulatory Impact Statement, Minimum Energy Performance Standards and Alternative Strategies for Refrigerated Beverage Vending Machines (Niskin, 2008).
[24] See http://www1.eere.energy.gov/buildings/appliance_standards/commercial/beverage_machines.html
[25] European Commission DG TREN Preparatory Studies for Eco-design Requirements of EuPs [TREN/D1/40-2005/LOT12/S07.56644], Lot 12 Commercial refrigerators and freezers, Final Report December 2007, Bio Intelligence Service S.A.S.



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# 7 Policies

Policies in the participating countries are summarised in Table 2 and the subsequent paragraphs in this section. See the individual country mapping document for full details.[26] Only Canada and the USA have mandatory minimum requirements at a national level, amongst participating countries (Canada since 2007, USA from August 2012). The ENERGY STAR voluntary label operates in the USA, Canada and Australia; version 2 of the criteria came into force in 2007 and version 3 of the criteria will go into effect on March 1, 2013. In addition, the US state of California has had minimum performance requirements since 2006 aligned with ENERGY STAR Tier 1 requirements. These Californian State specific MEPS have been recently superseded by the U.S. Federal MEPS referred to above and so are no longer relevant to the market. Figure 18 compares the normalised minimum requirements for all of the policies or schemes for which data can be made comparable, set against the scatter graph of normalised machine data. The minimum requirements lines for each scheme are explained in the following sections.

**Table 2. Summary of policies for refrigerated vending machines amongst participating countries.**

| Country/ region | MEPS regulation | Label regulation |
|---|---|---|
| Australia | None.<br>(In development, proposed as equivalent to ENERGY STAR Tier 1) | ENERGY STAR voluntary label since 2006 (same criteria as USA) |
| Canada | Since 2007 (extended scope 2008). Equivalent to ENERGY STAR Tier 1 | ENERGY STAR voluntary label for rebuilt machines only |
| EU | None.<br>(eco-design preparatory study completed 2007; no draft regulation forthcoming) | None.<br>(A voluntary scheme developed by the EU trade association is only used by a few suppliers) |
| USA – federal | Came into force August 2012 | ENERGY STAR voluntary label since 2004; updated criteria 2007 and Version 3 criteria come into force in March 2013 |
| USA – California state | Since 2006, equivalent to ENERGY STAR Tier 1 | None |

[26] Available from http://mappingandbenchmarking.iea-4e.org/matrix.



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## 7.1 Policies in the EU

There are no EU-wide policies specifically relating to vending machines in force or in draft at July 2012. An EU Ecodesign preparatory study[27] covering vending machines (amongst other commercial refrigeration products) was published in December 2007 but no regulatory proposals are yet forthcoming. In parallel to this, the European Vending Association (EU trade body covering vending machines) has developed a voluntary methodology for the energy labelling of vending machines according to an A to G label scale similar in nature to EU regulatory energy labels.[28] To date, few machines on the EU market have an associated 'energy label' in their machine data. Vending machines are covered by the US ENERGY STAR programme, but not by the EU ENERGY STAR programme.

## 7.2 Policies in Canada

Canada has MEPS for vending machines and also uses the ENERGY STAR label for rebuilt machines only.

Canada's Energy Efficiency Regulations set minimum energy performance standards applicable to both beverage (can/bottle) and to food/snack machines.[29] The first MEPS came into force in January 2007 and are identical to the ENERGY STAR Tier 1 requirements (which came into force under ENERGY STAR in April 2004). Subsequently, in January 2008 a more stringent consumption MEPS level was introduced for refrigerated beverage vending machines with opaque front which corresponds with ENERGY STAR Tier 2 requirements (which came into force under ENERGY STAR in July 2007).

The Canadian requirements for opaque front beverage vending machines require testing at an ambient temperature of 32.2°C, whereas the ambient temperature for multi-package and snack/beverage (glass front) machines is 23.9°C. Therefore in Figure 18 the MEPS levels for those tested 23.9°C have been normalised in line with the same way as for product data (see section 3.5). It can be seen when these 2 sets of requirements are shown on an approximately comparable basis in Figure 18 that the multi-use or glass door machines for indoor use are subject to a significantly less stringent requirement in relative terms. The Canadian products appearing in Figure 18 above the lower minimum standard line are at least predominantly those for which data has been normalised as they were tested at the lower indoor ambient temperature.

At January 2008, ENERGY STAR in Canada was discontinued for new machines but remains applicable to rebuilt vending machines.

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[27] European Commission DG TREN Preparatory Studies for Eco-design Requirements of EuPs [TREN/D1/40-2005/LOT12/S07.56644], Lot 12 Commercial refrigerators and freezers, Final Report December 2007, Bio Intelligence Service S.A.S.
[28] See http://www.vending-europe.eu/standards/EVA-EMP.html
[29] See http://oee.nrcan.gc.ca/regulations/product/beveragevendmachine.cfm?attr=0



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## 7.3 Policies in Australia

Suppliers can voluntarily use the US ENERGY STAR label in Australia through a reciprocal agreement with the US Government that has been in place since 2006. The three major suppliers in Australia (which account for 80% of sales) supply machines compliant with ENERGY STAR although it is not known if they supply *only* compliant machines.

Regulatory Minimum Standards have been proposed for Australia and New Zealand and a Regulatory Impact Statement has been published[30] but the regulation has not yet been enacted. The test methodology is identical to that of ENERGY STAR/ASHRAE 32.1 and the minimum energy performance requirement is the same as US ENERGY STAR Tier 1 which was in force from 2004 to June 2007. The Australian test methodology AS/NZ 4864 also identifies a high efficiency standard which corresponds with the ENERGY STAR Tier 2 requirement and is effectively a voluntary labelling level.

## 7.4 Policies in the USA

**US ENERGY STAR**

Refrigerated beverage (can/bottle) vending machines have been covered by the US ENERGY STAR voluntary labelling programme since 2004[31]. The ENERGY STAR programme does not include snack or beverage/snack hybrid units. The ENERGY STAR criteria stipulate a design requirement to have a hard-wired automatic low power state for lighting and/or for refrigeration system, combined with two tiers of daily energy consumption requirements. Version 2 Tier 1 covered April 2004 to June 2007; Tier 2 came into force in July 2007. The criteria were updated and Version 3 of the criteria will go into effect on 1 March 2013.

As previously discussed, machines used exclusively indoors have to be tested at 23.9°C whereas outdoor machines and those suitable for both indoor and outdoor are tested at 32.2°C; all of these products are subject to exactly the same minimum requirements. Therefore in Figure 18 both the machine performance data and the ENERGY STAR requirements for indoor type machines are shown normalised, using the method described in section 3.5. It can be seen, when these 2 sets of requirements are shown on an approximately comparable basis in Figure 18 that the products for indoor use are subject to a significantly less stringent requirement in relative terms.

**US Federal MEPS**

Mandatory Federal MEPS apply to all beverage vending machines manufactured for sale in the United States, or imported to the United States, from August 31 2012.[32] This rule is also based on the test standard ASHRAE 32.1 and imposes a maximum daily energy

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[30] Niskin (2008) Regulatory Impact Statement: Minimum Energy Performance Standards and Alternative Strategies for Refrigerated Beverage Vending Machines. Consultation Draft, Equipment Energy Efficiency Committee. Report No 2008/10, September 2008, Niskin Enterprises Pty Ltd.

[31] See http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=VMC

[32] Note that the published date of entry into force in the original final rule was wrong, and corrected in a subsequent final rule to be 31 August 2012, being three years after original publication.



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consumption figure based on testing at 23.9°C±1°C and 45%±5% RH. The limit is a function of the internal refrigerated volume of the unit (in cubic feet). In order to plot these requirements on Figure 18, it would be necessary to be able to convert between internal refrigerated volume in cubic feet and the equivalent number of cans/bottles in machine capacity that correspond to any volume. No data to enable the calculation of this was available since the US, Californian and Canadian datasets do not include any internal volume data for dedicated beverage vending machines. The EU dataset does include some products with both internal volume and product count, but the EU products are significantly different (predominantly glass front machines rather than the opaque front dedicated beverage machines of the USA) and therefore any factor derived from the EU data would be inappropriate for the US products. The US Federal requirements therefore cannot be plotted on the figure.

**California MEPS**

The California Energy Commission has had in place minimum standards for beverage vending machines since 1 January 2006.[33] The requirement in kWh per day coincides with the ENERGY STAR Tier 1 requirements, combined with a design requirement to have a hard-wired automatic low power state for lighting *and* refrigeration system.

The Californian regulation differentiates between normal refrigerated beverage machines (which must be tested at 32.2°C) and what it calls multi-package canned and bottled vending machines. The multi-package machines are basically those with glass front that can vend many different types of product and these must be tested at 23.9°C. The 'multi-package' machines are those that are rated for indoor use only and therefore directly correspond with indoor labelled products under the ENERGY STAR scheme. Therefore in Figure 18 both the machine performance data and the California Energy Commission requirements for indoor type machines are shown normalised, using the method described in section 3.5. These normalised Californian requirements correspond exactly with the normalised requirements for Canadian machines (the upper Canadian line) in Figure 18.

It can be seen, when these 2 sets of requirements are shown on an approximately comparable basis in Figure 18, that the products for indoor use are subject to a significantly less stringent requirement in relative terms. It appears in Figure 18 that some of the Californian products do not quite meet the requirements (purple squares slightly above the upper yellow dotted line); no reason has been identified for these being retained in the dataset.

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[33] See Appliance Efficiency Regulations, (California Code of Regulations, Title 20, Sections 1601 through 1608), dated September 2010 available from http://www.energy.ca.gov/appliances/



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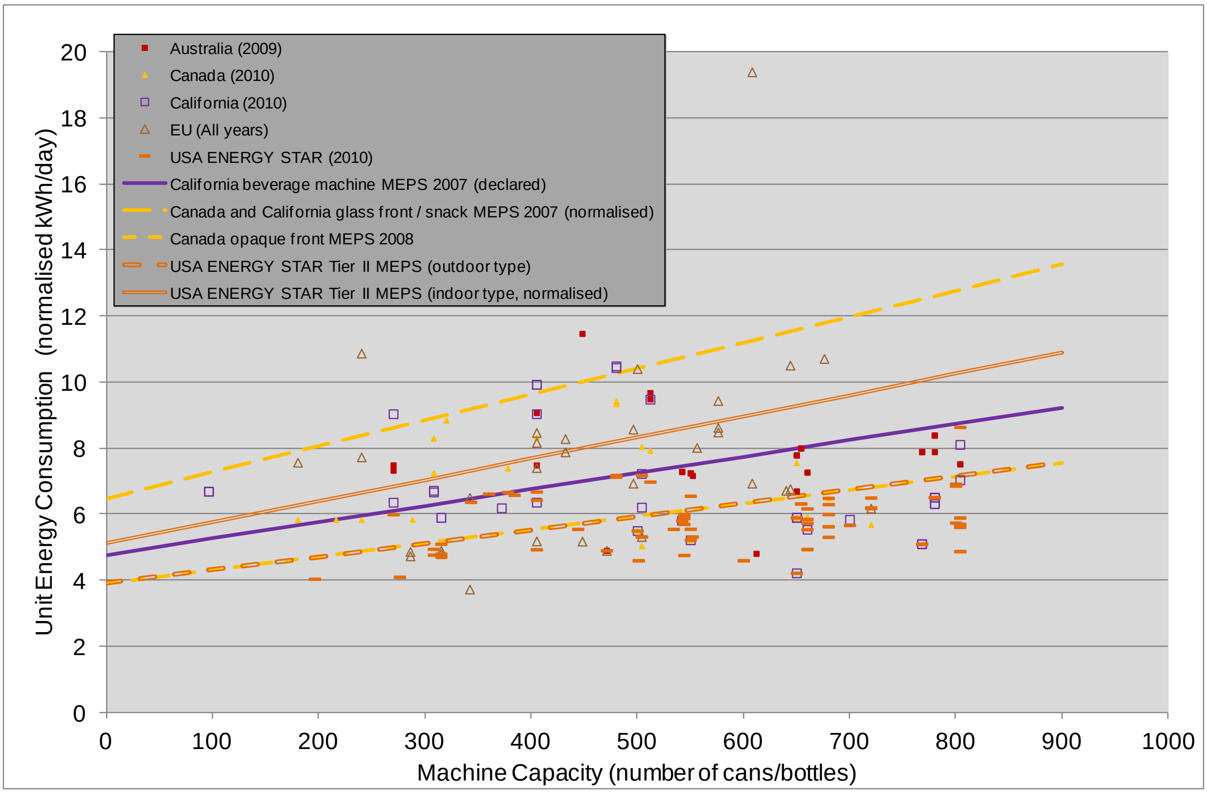


**Figure 18. Minimum energy performance standards (MEPS) and scheme thresholds.**



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# 8 Conclusions

The following overall conclusions have been drawn:

- There appear to be distinct differences in the type of machines used in the EU market compared to other markets. EU refrigerated vending machines are on average at least 20% smaller than US/Canadian/Australian machines and over 60% of them are glass-fronted flexible food/snack and/or cans/drinks machines compared to fewer than 40% glass fronted in US/Canada/Australia.
- The difference in capacity and type of machines used arises due to significant differences in the business model followed for the companies operating the machines. European operators tend to provide and service hot beverage machines as well as cold beverage and snack/food machines and so visit premises more regularly. Machines can therefore be smaller and refilled regularly (attractive as less cash has to be tied up in stock).
- Several factors mean that the glass fronted flexible sales space machines are inherently likely to consume more energy and be less efficient than dedicated bottle/can machines: the glazed area allows more heat ingress than solid insulation; glazed machines hold the entire stock at the serving temperature whereas dedicated can/bottle machines cool only the front few products in the queue down as far as the serving temperature; products capable of storing fresh food will have to meet food safety storage temperature requirements which could mean higher refrigerating capacity.
- There is considerable scope to apply and tighten MEPS, since the best machine (usually a large machine) uses between 33% and 50% of the energy per bottle/can compared to the average in each market. In particular, there is scope to eliminate poor performers for small and medium machines.
- In order for the EU market to match average efficiency levels achieved by US/Canadian markets, there would probably have to be a change in the typical EU product functionality or service.
- The machines registered on the ENERGY STAR programme have an average specific consumption 43% lower than the EU average; Australian machines have an average 30% lower than the EU average. It should be borne in mind that the ENERGY STAR data set excludes any glass fronted products and so should be expected to be more efficient.
- No evidence is apparent for any improving trend, other than when ENERGY STAR criteria have changed.
- There are significant differences in the stringency of energy efficiency requirements for indoor rated products compared to outdoor products, once the data is normalised to account for the 8.3°C difference in ambient test temperature. The indoor rated products are effectively allowed to consume around 40% more energy for delivering a comparable service.



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For future policy development, it may be worth considering:

a) Whether the different stringencies for indoor and outdoor rated products are justified;
b) Whether food safety storage temperature requirements may be an appropriate differentiator in product functionality: Machines usable for perishable food with the whole internal volume chilled which are able to meet strict temperature requirements could be subject to less stringent energy consumption requirements; whereas machines for non-perishable food and drink could be allowed more flexibility on temperature but have to meet more stringent energy consumption requirements. The new US Federal MEPS take a similar approach to the former, with one level for beverage machines chilling the whole internal space and a more stringent level for machines that only chill the next few to be vended products to the serving temperature;
c) Whether consideration is necessary of whether the energy consumption data from the standard test carried out at ‘outdoor conditions’ of 32.2°C±1°C and 65%±5% relative humidity is potentially misleading for users and for policymakers since no countries have this high temperature as an average. The data from this test is not indicative of consumption under typical usage conditions (although is potentially useful as an indication that the machine can achieve the required beverage delivery temperature under extreme conditions). For example, the US MEPS have adopted the indoor temperature class for the requirements, which is much more typical of real usage conditions.



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# 9 References

This section compiles into one place the document, Internet and other source references that are used in the report, for the benefit of those researching this field.

## 9.1 General references

i. IEA 4E Mapping and Benchmarking Annex document: Product Definition: Vending Machines, Version 1.7: 11 May 2011, available from http://mappingandbenchmarking.iea-4e.org/matrix.
ii. Details of each country dataset and results for each country separately are included in the individual country mapping documents which are available from http://mappingandbenchmarking.iea-4e.org/matrix.
iii. Mapping and Benchmarking Framework document, available from http://mappingandbenchmarking.iea-4e.org/.

## 9.2 Australia references

i. Equipment Energy Efficiency Committee, Regulatory Impact Statement Consultation Draft, Minimum Energy Performance Standards and Alternative Strategies for Refrigerated Beverage Vending Machines, Draft Regulatory Impact Statement (Niskin, 2008). See http://www.energyrating.gov.au/wp-content/uploads/Energy_Rating_Documents/Library/Refrigeration/Commercial_Refrigeration/200810-ris-vending.pdf.

## 9.3 Canada references

i. Energy Efficiency Regulations set minimum energy performance standards applicable to both beverage (can/bottle) and to food/snack machines, available from http://oee.nrcan.gc.ca/regulations/product/beveragevendmachine.cfm?attr=0.

## 9.4 EU references

i. European Ecodesign study, European Commission DG TREN Preparatory Studies for Eco-design Requirements of EuPs [TREN/D1/40-2005/LOT12/S07.56644], Lot 12 Commercial refrigerators and freezers, Final Report December 2007, Bio Intelligence Service S.A.S. Available at http://www.ecofreezercom.org/documents_1.php, accessed 3 October 2012.
ii. European Vending Association voluntary methodology for the energy labelling of vending machines, available from http://www.vending-europe.eu/standards/EVA-EMP.html.



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## 9.5 USA references

i. ASHRAE 32.1-2004, Methods of Testing for Rating Vending Machines for Bottled, Canned, and Other Sealed Beverages.
ii. US ENERGY STAR criteria for vending machines, see http://www.energystar.gov/index.cfm?c=revisions.vending_machines
iii. Final Rule for beverage vending machines, available from http://www1.eere.energy.gov/buildings/appliance_standards/commercial/beverage_machines.html. Note that the published date of entry into force in the original final rule was wrong, and corrected in a subsequent final rule to be 31 August 2012, being three years after original publication.
iv. California Energy Commission minimum standards for beverage vending machines, Appliance Efficiency Regulations, (California Code of Regulations, Title 20, Sections 1601 through 1608), dated September 2010 available from http://www.energy.ca.gov/appliances/



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# Appendix 1: Methodology for data normalisation for ambient temperature during test

The ASHRAE test methodology offers two sets of possible ambient conditions for testing: 32.2°C±1°C and 65%±5% relative humidity (RH) for machines specified as suitable for outdoor use and 23.9°C±1°C and 45%±5% RH for indoor machines. The European Vending Association Energy Measurement Protocol requires 32°C and 65% RH for outdoor machines; and 25°C and 60% RH for indoor.

Note that the products rated for 'indoor use only' are often glass fronted machines and this adjustment of their consumption to an equivalent as if tested at outdoor conditions is a totally artificial scenario for these products. These products could not be expected to pass the serving temperature requirements test if they were actually tested under outdoor conditions – but the calculation does provide data with a measure of comparability.

Two possible methods to normalise were considered:

a) Using the generally accepted rule of thumb for refrigeration systems that energy consumption increases by 2% to 3% per degree Celsius of additional temperature lift (i.e. difference between cooling temperature and ambient temperature). This would give rise to an equation: % adjustment to energy consumption = 2.5% x (ambient temp difference from 32.2°C). Which equates to 8.3°C x 2.5% = 21% uplift of energy consumption for 23.9°C to 32.2°C.

b) Using empirical evidence from the Californian Energy Commission data set which quotes energy data tested at both indoor and outdoor conditions. This gave rise to the graph in Figure A1. This data set gives an average uplift of 37%, or 4.4% per degree Celsius.

It was decided to use the empirical evidence which appears reasonably strong. As more products declare performance in outdoor mode, it was decided that data would be normalised as far as possible to the outdoor machine conditions required in ASHRAE 32.1, i.e. 32.2°C±1°C and 65%±5% relative humidity. This derives the equation:

**Equation 1**

$$E_{32.2°C} = 1.588 \times E_{23.9°C} - 1.088$$

Where:
$E_{32.2°C}$ = Energy consumption tested at 32.2°C
$E_{23.9°C}$ = Energy consumption tested at 23.9°C



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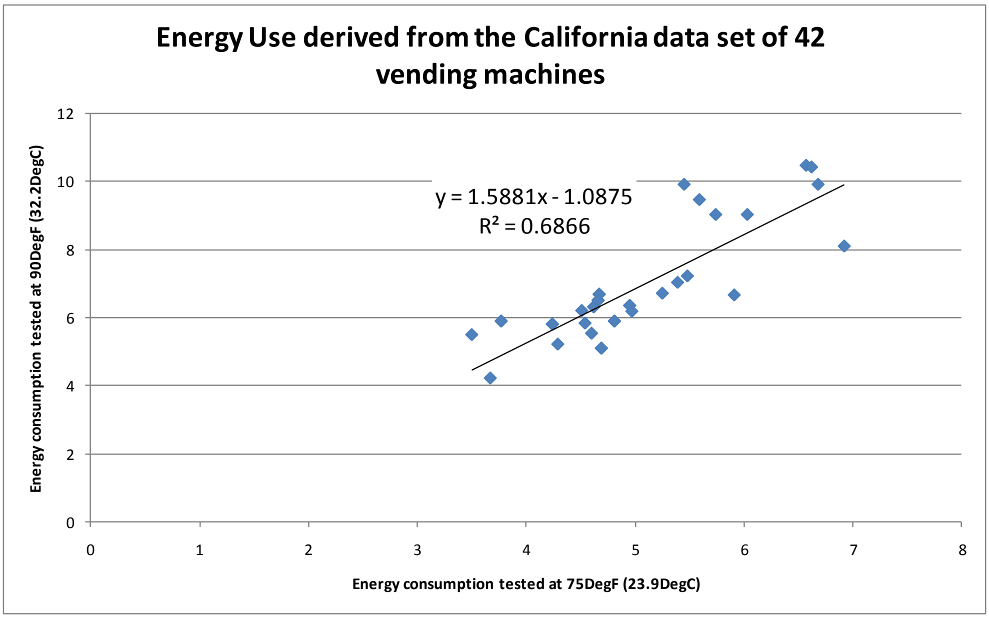


**Figure A1. Scatter plot of energy performance results for vending machines registered with the California Energy Commission.**

For products tested at indoor temperatures, declared energy consumption will be calculated as per Equation 1. It was decided to assume for the purposes of this analysis that results when tested at 25°C (EVA EMP method) would be equivalent to results when tested at 23.9°C (ASHRAE 32.1) and so use the same equation to normalise EVA EMP data tested at indoor temperatures.

*Consequential caution on scope –energy consumption lower limit for validity*

The data set used to derive Equation 1 covers only machines with an energy consumption between 3.5 and 7 kWh/day and the $R^2$ figure (match between data and equation) is 0.6866 which is reasonable. It is prudent therefore to limit the extrapolation used. In particular Equation 1 is inappropriate for machines with low energy consumption: the output (consumption when tested at 32.2°C) is negative for consumptions derived from tests at 23.9°C of below 0.7 kWh/day. A slight extrapolation is considered acceptable. It is suggested that products with an energy consumption of less than 3 kWh per day would fall outside the range for which this normalisation step is valid.

*If ambient temperature is not at standard indoor or outdoor temperature*

When an ambient temperature for test is declared that does not correspond with the standard indoor or outdoor temperature classes (as occurred with four products tested at 20°C) then a linear extrapolation or interpolation of Equation 1 can be used. Equation 1 delivers an energy consumption figure inflated to simulate testing at an ambient temperature 8.3°C higher; by calculating the difference in energy consumption between the lower and higher figures and dividing by 8.3 a change in energy per degree can be calculated – and



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this figure multiplied by the required temperature difference. The required energy consumption estimate can then be derived by adding additional energy for a lower ambient test temperature than 23.9°C; subtracting energy for a higher temperature than 32.2°C; and interpolating for a temperature between the two. Errors from this approach will increase with increasing extrapolation and it would probably be inappropriate to extrapolate by more than 4 or 5 degrees from 24°C or from 32°C.

The temperature used for testing of European products for outdoor use is almost identical to that used under the ASHRAE standard and no adjustment would be required for that; the difference for the indoor products is small and considered negligible in proportion to other differences in comparability between the US and EU products and so no adjustments were made to address this. US, Canadian and EU data were treated in the same way regarding normalisation for ambient temperature during test.

*If ambient temperature is not known*

For a few products, the ambient temperature during test is not known (i.e. the data does not show whether the product is for ‘indoor’ or ‘outdoor’ or ‘indoor/outdoor’ use - which determines the ambient temperature during test). If such a product is assumed to be indoor when it is actually outdoor, then the performance of that product would end up at least 20% (taking the rule of thumb of 2.5% per degree Celsius difference) higher than it should be; and vice versa. Hence if the ambient temperature is not known the error could be significant and such products will have to be removed from the analysis.

*Limitations of normalisation process for ambient temperature*

i. The equation for normalising is based upon empirical evidence which shows an $R^2$ rating of 0.6866 which is reasonable.[34] However, if the machines available in California are not representative of other regions in this respect (variability of consumption with ambient temperature), then the adjustment could be misleading. Analysis of the product lists shows the same product model numbers in US ENERGY STAR and the Australian data set, and some common products between USA and Canada, so this is probably a low risk for those data sets. The EU data set has no products in common with USA, Canada or Australia and so it is possible that the relationship has less validity for this set.
ii. The calculations are based upon the temperatures used in the ENERGY STAR test method. It is possible that manufacturers could use different test temperatures for what they call ‘indoor’ or ‘outdoor’ machines, if they are not involved in ENERGY STAR. In fact, the European Energy Measurement Protocol does use a slightly different temperature for indoor tests of 25°C, rather than 23.9°C which has been

[34] $R^2$ rating is a statistical indicator of strength of relationship (i.e. how accurately the equation echoes any relationship between two sets of figures). Score of 1 is a perfect fit to the data, 0 shows no useful relationship.


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ignored (and so likely to incur an error of less than 3%). This issue is considered a minor risk.

iii. The limitations arising from the scope of data used to generate Equation 1 have been discussed above. Errors from machines with low consumption are eliminated by removing products with consumption less than 3 kWh (only one product was removed through this rule). Errors from products with high consumption are possible, along with the errors inherent in an imperfectly fitting equation.



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