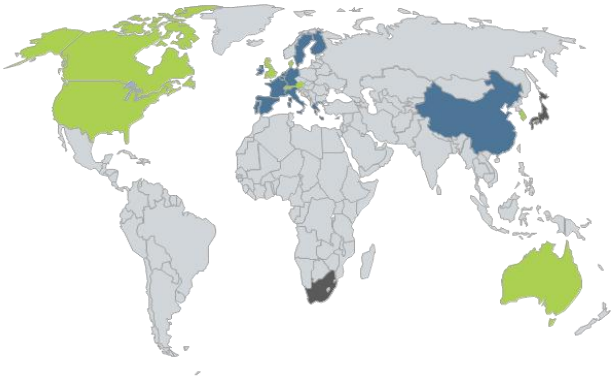
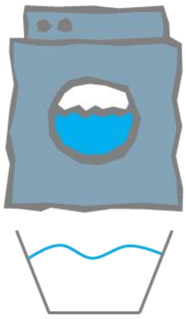
Technology: Washing machines (clothes washers)





Participating countries:
Australia, Austria, Canada, Denmark, Republic of Korea, Switzerland, UK, USA

Other funding countries:
France, Netherlands, Japan, South Africa, Sweden

Other regions covered:
China, EU

Benchmarking report for Washing Machines (clothes washers)

Issue Date: 28 April 2012 (*Danish data updated July 2012)*

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

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Summary for policy makers

This benchmarking has been undertaken as part of the IEA's Mapping and Benchmarking Annex of the Efficient End-Use Electrical Equipment (4E) Implementing Agreement.
The analysis has been undertaken to provide policy makers with comparisons of the performance of new **washing machines (clothes washers)** over time and is designed to provide policy makers with a broad analysis of:

- Key differences in product performance between countries;
- Major outcomes of policy interventions to date;
- Areas of concern for policy makers, including areas where policy intervention may be desirable in the future.

Due to differences in the test methodologies used in these countries/regions, adjustment or 'normalisation' of the original datasets is required to present consistent and comparable information to enable benchmarking of product performance between the different jurisdictions. However, when applied to washing machines, such an approach leads to some inherent issues of which readers should be aware. In particular there is a strong interrelationship in performance variables, i.e. the energy performance of washing machines is affected by a range of interdependent variables including washing temperature; washing cycle time; wash quality; spin effectiveness; rinse effectiveness; the type and size of the laundry load, and a number of other variables. While recognising that these key performance characteristics are all intrinsically linked, no public domain information has been identified that has allowed the Mapping and Benchmarking Annex to compare washing machines of differing performance across all these variable types. Therefore readers should be aware that:

- Normalisation has been based on the energy used for water heating only which has limitations both in approach and due to the optimisation of machines to local requirements. In particular the approach is highly sensitive to variations in wash test temperature and water consumption.
- Individual performance attributes of the washing machines (wash quality, spin effectiveness, etc) have not been normalised, nor have they been accounted for in the normalisation of energy consumption.
- The use of the washing machine by consumers may be significantly different from the conditions under test. The data and analysis on energy use and other performance attributes presented in this report are based on testing outcomes and are likely to be different from those experienced by the consumer.

For these reasons, the resulting comparison of washing machine performance between jurisdictions has significant levels of uncertainty. Additional limitations in the normalisation process have a particular impact on the data presented for Canada and the USA. Therefore, normalised Canadian and USA data results are less comparable than normalised results

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from other countries, although the *relative* positioning of results from Canada and the USA are highly likely to be comparable.

Due to these significant uncertainties, and the need for reliable evidence when drawing conclusions for use by policy makers, it has not been possible to draw definitive conclusions on the potential for improvement in product efficiencies between countries. However, the following information drawn from the analysis may be of value to policy makers:

- The combination of frequently revised MEPS and labelling has had a very strong impact in Canada and the USA (although the biggest market response seems to align primarily with the introduction/revision of MEPS). Ultimately Canadian and US unit energy consumptions are now (likely) to be broadly in line with most European countries despite being at significantly higher initial levels. Therefore it is reasonable to conclude that challenging *and regularly revised* MEPS are a highly effective method of reducing consumption.

- The impact of labelling within the EU countries, and the associated voluntary agreement with industry, has had a mixed effect. Across the EU as a whole and within Austria, there has been a significant market response. However, within the UK improvement has been minimal. Therefore policy makers should be aware of the potential improvements that *can* be achieved through the combined application of labelling and voluntary agreements. However, ongoing monitoring of the market should be undertaken to ensure policy impacts are occurring in all market segments and, where this is not the case, revisions to the agreement/policy should be considered.

- In the one country reporting which relies solely on labelling as its policy intervention (Australia), improvements have been seen in overall average unit energy consumption of washing machines, but the performance of these units still lags significantly behind all other participating countries[1].

- The implementation of policy to drive improvement in the energy performance of top loading washing machines, or to encourage consumer switching from top loader machines to their front loader competitors, would yield significant energy savings in those countries where top loader penetration is still high. However, policy makers should be aware that such action may adversely affect other performance variables, in particular wash cycle times.

- The rated load capacities of washing machines (i.e. the amount of laundry that a unit can hold in a single wash cycle) are increasing in almost all jurisdictions and there is no indication that these increases are reaching a plateau in any country. This ongoing increase in volume is at least partly responsible for increasing product efficiency (more so in recent years where the improvement in unit energy

[1] However, the significant use of cold water in washes by Australian consumers (which is not reflected in the test methodology) *may* negate the need for policy intervention to address this apparent difference.

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consumption is beginning to stagnate in some regions). Hence policy makers may wish to investigate whether the *actual* size of loads washed by consumers is increasing in line with increasing machine sizes. If actual load sizes are not increasing significantly, it is likely that further improvements in declared product efficiencies due to increasing product sizes may be disguising stagnation in *actual* energy consumption per unit of clean laundry. If this is the case, consideration should be given to limiting unit size and/or capping energy consumption directly (or a combination of both through amendments to algorithms that define minimum efficiency levels).

- The load capacities of top loading washing machines were traditionally greater than front loading units. However, this trend has reversed, with average front loader capacities now larger than average top loader capacities for all markets where data are available.

- Total water consumption per cycle has been reducing over a number of years but has recently reached a plateau in many countries (at significantly differing levels). Hence, it is *possible* that a point is approaching where reductions in water consumption can no longer be sustained without significant deterioration in wash performance and/or rinse effectiveness, or increased cycle time. Therefore, in countries where water and/or energy consumption/efficiency will continue to be a focus of policy intervention, policy makers should consider increasing vigilance regarding wash and rinse performance to ensure their policy intervention will not result in impaired unit performance to which consumer reaction may be negative. .

- Spin effectiveness is improving in all countries where it is measured. However, as manufacturers strive to reduce energy consumption, it is possible that spin effectiveness *may* be reduced. Therefore, policymakers may wish to keep a watching brief on spin efficiency to ensure consumers remain satisfied with spin performance, and to ensure that improvements in washing machine energy consumption through reduced spinning are not resulting in significantly greater increases in consumption in the post-wash drying of the laundry.

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Contents

Annexes

The information and analysis contained within this summary document is developed to inform policy makers. Whilst the information analysed was supplied by representatives of National Governments, a number of assumptions, simplifications and transformations have been made in order to present information that is easily understood by policy makers, and to enable comparisons with other countries. Therefore, information should only be used as guidance in general policy - it may not be sufficiently detailed or robust for use in setting specific performance requirements. Details of information sources and assumptions, simplifications and transformations are contained within the document or the related Mapping Documents.

1 Introduction

This benchmarking has been undertaken as part of the IEA's Mapping and Benchmarking Annex of the Efficient End-Use Electrical Equipment (4E) Implementing Agreement.

The analysis seeks to provide policy makers with comparisons of the performance of new and installed **washing machines (clothes washers)** over a period of years and is designed to provide policy makers with a broad analysis of:

- Key differences in product performance between countries;
- Major outcomes of policy interventions to date;
- Areas of potential concern, including areas where policy intervention may be desirable in the future.

This benchmarking addresses all washing machines *excluding*:

- Twin-tub units;
- Washer/dryers (single and two drum);
- Machines with capacity less than 1 kg or bigger than 13 kg[2].

Data was sought from all countries participating in the Annex and a number of additional countries/geographical areas. The countries/areas for which information was available and could be sourced were:

> **Australia, Austria, Canada, China, Denmark, the Republic of Korea, Switzerland, the UK, the USA. and a sample of countries that are representative of the EU.**

Information was sought for the period 1996 to 2009 relating to product energy efficiency, product energy consumption, water consumption, product capacity, etc. For individual countries and regions, information obtained was mapped in a consistent format and presented to show:

- The energy efficiency and energy consumption of new products sold within individual markets;
- The overall changes in new products for functional performance that affect energy consumption including load capacity, water consumption, wash quality, spin efficiency, rinse efficiency, etc;
- Policies that are thought to have influenced the performance of new products and stock;
- Changes in products within the stock (products in use in households) over the period;
- Cultural issues that may have influenced product selection within individual countries.

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[2] Please refer to the Mapping and Benchmarking Annex website to review the detailed product definition, data request and individual country mappings at: http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=3

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The comparisons of the reported product performance presented in the individual mappings form the basis of this analysis.

1.1 Important cautions for interpreting and using mapping and benchmarking information

1.1.1 Original data quality

Significant efforts have been made by all participating parties to obtain and process data from a range of sources and to ensure the integrity of the data supplied. However, inevitably there have been some difficulties sourcing information for all countries/regions, and indeed in sourcing all information from individual countries/regions even where this information exists. Therefore, the specific nature of each dataset is different. For example, some datasets are based on detailed information on individual models across a whole market; others are based on averages of aggregated data from the whole market, and some datasets are selections/samples which may be representative of the market as a whole or just a subset of the market (for example the best performing products).

Further, in some cases, data adjustment is required to make the material comparable between countries (for example, the conversion of North American unit capacities defined by the overall drum size to the equivalent load capacity in kilogrammes used elsewhere).

Thus, to provide readers with an indication of the relative reliability of a particular dataset within the context of the other data being presented, the Mapping and Benchmarking Annex has developed the 'Framework for Grading Mapping and Benchmarking Outputs'[3.] This framework enables the allocation of gradings based on a robust, indicative and illustrative scale. The original data received (including any manipulations necessary[4]) have been classified based on this framework with the associated gradings shown in Figure 1 (refer to Annex 3 for a summary of the justification for individual data classifications and significant associated cautions).

1.1.2 Benchmarking approach and related quality of outputs and cautions

To enable the comparison of product performance between countries, the Mapping and Benchmarking Annex compares products based on their performance when undergoing the standard test defined in the local methodology/regulations. Differences in the local test methodologies are then 'normalised' in an effort to make each original dataset supplied comparable with those from elsewhere.

However, when applied to washing machines, such an approach leads to some inherent issues of which readers should be aware. In particular there is a strong interrelationship in performance variables, i.e. the energy performance of washing machines is affected by a

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[3] This Framework is generally used across all Mapping and Benchmarking outputs (refer to Annex 2).
[4] All manipulations of individual data sets are detailed in the associated country/region mapping at http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=3

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range of interdependent variables including washing temperature; washing cycle time; wash quality; spin effectiveness; rinse effectiveness; the type size, material and number of garments that make up the load to be washed; the total size of load, and a number of other variables. Even where the same test method is used, there is a great deal of uncertainty over how these factors interrelate for an individual machine. This means the development of normalisation factors related to an individual variable (for example energy consumption) will have inherent shortcomings as they do not factor in the positive or negative impact on other variables. For example, units tested at a specific test temperature may provide a particularly level of washing performance which may vary at an alternative temperature, hence simply adjusting energy consumption based on the energy required to heat the water to an alternative wash temperature does not reflect the full impact on the overall machine performance.

Having recognised that key performance characteristics (energy consumption, load type and size, wash quality, etc.) are all intrinsically linked:

- No public domain information has been identified that has allowed the Mapping and Benchmarking Annex to compare washing machines of differing performance across all the performance variables;
- There is limited public domain information on the impact of the various testing methodologies on the reported overall performance of individual units, or indeed, to convert the individual performance characteristics where they are measured differently.

Within the context of the specific datasets received, these issues are further compounded by the provision by some countries of product level data which allows analysis of the interrelation of many variables for individual machines, and the provision of aggregated market data from elsewhere which makes such analysis impossible.

Therefore, analysis and reporting within this benchmarking is restricted to:

- Normalisation of energy consumption based on a correction for nominal **test/performance standard** water inlet temperatures and wash temperatures;
- Data that is 'as declared under local test methodologies' for all the individual performance characteristics of the washing machines other than energy. **No normalisation is undertaken to account for variations in the measurement of these variables between testing regimes, nor for the associated impact on energy consumption.**

Accurate comparisons are further challenged by the following issues:

- Washing machines are optimised to local conditions. Therefore, simple correction of water temperature is not thoroughly robust as units tested at a lower temperature (typically) require less water to achieve the same wash performance when operated

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at higher wash temperatures[5]. Hence normalisation using the original water quantity will not be wholly representative of the performance of all units.

- There is some empirical evidence[6] to suggest washing machines under test in some jurisdictions do not actually reach the test temperature specified in the test methodology and hence normalisation of energy consumption based only upon test temperatures may not be accurate.
- The difference in the requirements of individual testing methodologies and the 'normal use' of washing machines by consumers adds one further complication to the interpretation of benchmarked data, i.e., the actual energy consumption of the washing machines will vary significantly as consumers will often wash at temperatures very different to those specified in test standards. While this is relevant to all datasets, it is known to be of particular relevance to benchmarking data for Australia. Australian normalisation has been undertaken based on the nominal warm wash temperature defined in the local standard. However consumers are known to perform a large number of washes in cold water (at the temperature of water intake or similar), particularly in top loading washing machines. **Hence, comparative benchmarking of Australian data, particularly those data associated with top loading washing machines, should be treated with some caution[7].**
- Normalised Canadian and USA data results are less comparable than normalised results from other countries (although the *relative* positioning of results from Canada and the USA are highly likely to be comparable). This is partly due to a shortcoming of the normalisation methodology which is based on a unit energy consumption value for a specific set of operating conditions, where as the original average unit energy consumption declared in Canada and the USA is based over a range of cycle conditions (in particular the quantity and temperature of water used). This shortcoming in the normalisation methodology is compounded by a revision to the Canadian and USA required test method/energy reporting algorithm in 2004. This revision included changes to the balance of wash temperatures**, such that the hot and warm wash cycles were assigned lower weighting factors after 2004.** This revision, on average, will tend to result in higher energy consumption values being reported prior to 2004 in comparison with those after[8]. Further, the load (tub) capacities of washing machines in Canada and the USA are declared based on the physical internal dimensions of the machines which require conversion to kilogramme loads to be comparable with data reported from elsewhere. **Thus, benchmarked data from Canada and the USA is presented in separate sections. The results presented in these sections should be interpreted in the context of the**

[5] The cleaning performance of a washing machine is governed by a combination of detergent, temperature, quantity of water, the degree of agitation the laundry experiences and the cycle time. If all things remain equal and the water temperature is increased, less water will be required to achieve the same wash performance.
[6] Unpublished results from tests within the EU indicate that units rarely reach the specified nominal 60°C test temperature during washes, and the average temperature is significantly below the nominal test. This situation may or may not occur in other jurisdictions.
[7] Refer to Annex 3, in particular the section *Test Declarations, Actual Water Temperature and 'Normal Usage'* for details of the sensitivity of the normalisation approach and benchmarking outcomes to temperature variation.
[8] For more detailed information on the revision and associated impact, please refer to the USA mapping document at http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=3.

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limitations in comparability with washing machine performance from elsewhere as outlined above.

1.1.3 Important cautions

The above descriptions of the limitations of original data and the normalisation approach employed for the cross-country/region comparisons lead to the following summary cautions of which readers should be aware:

- All original data and the benchmarking results derived from them are not 100% comparable and have been graded to provide an indication of the quality/comparability.
- Normalisation has been based ***on the energy used for water heating only*** which has limitations as an approach as it is highly sensitive to variations in wash test temperature and water consumption, and does not account for optimisation of machines to local requirements.
- Individual performance attributes of the washing machines (wash quality, spin effectiveness, etc) have not been normalised, nor have they been accounted for in the normalisation of energy consumption.
- The use of the washing machine by consumers may be significantly different from the conditions under test. The data analysis on energy use and other performance attributes presented in this report are based on reported testing outcomes which are likely to be different from those experienced by the consumer.
- The original data from Canada and the USA is in a form that requires significant manipulation to be comparable with data supplied from elsewhere. The level of manipulation required is substantial and introduces uncertainty in the level of direct comparability with other countries, although the *relative* positioning of results from Canada and the USA is highly likely to be comparable. Therefore, benchmarked data from the Canada and the USA is presented alongside data from elsewhere, but in a separate section and should be interpreted in the context of the limitations in comparability.

For a fuller description of original data quality, the approach to normalisation of data to enable comparison benchmarking between countries, and the associated cautions, please refer to Annex 3. However, Figure 1 provides a summary of gradings of both original mapping data and the associated benchmarking outputs.

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Figure 1. Summary classification of original data and benchmarking outputs.

Country	Data classification and limitations
Australia	Sales weighted source data is Robust, product weighted source data is Indicative. Benchmarking outputs: Sales weighted information is Indicative, product weighted information is Illustrative. However, extreme caution should be used when comparing with other countries given the known consumer preference for cold wash (resulting in significantly lower energy consumption that that shown).
Austria	All source data is Indicative. Benchmarking outputs: All information is Illustrative.
Canada	All source data is Indicative. Benchmarking outputs: All information is Illustrative and, due to known limitations in the benchmarking approach, the degree of comparability with other countries is limited.
China	All source data is Illustrative. Benchmarking outputs: Due to the uncertain nature of the quality of this data source, information on China is excluded from the analysis.
Denmark	All source data is Indicative. Benchmarking outputs: All information is Illustrative.
Korea	All source data is Indicative. Benchmarking outputs: Data is Illustrative (front-loaders only). *Due to the lack of definition of a test temperature for top-loading units, these units have been excluded from the benchmarking analysis.*
Switzerland	Sales weighted source data is Indicative: Benchmarking outputs: Data is Illustrative
UK	Front-loader sales weighted source data is Robust, front-loader weighted source data is Indicative. Benchmarking outputs: Sales weighted information is Indicative, product weighted information is Illustrative. (Note: all full market data is based solely on front-loader data given the extremely limited nature of top-loader penetration in the market).
USA	Sales weighted source material is Indicative. Benchmarking outputs: All information is Illustrative and, due to known limitations in the benchmarking approach, the degree of comparability with other countries is limited.
EU	All source data is Indicative. Benchmarking outputs: All information is Illustrative.

Given the significant differences in measurement methodologies and reporting protocols, all non-energy variables, i.e. load, water consumption, drying effectiveness and wash quality, are presented as illustrative.

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2 Comparison of energy consumption and efficiency

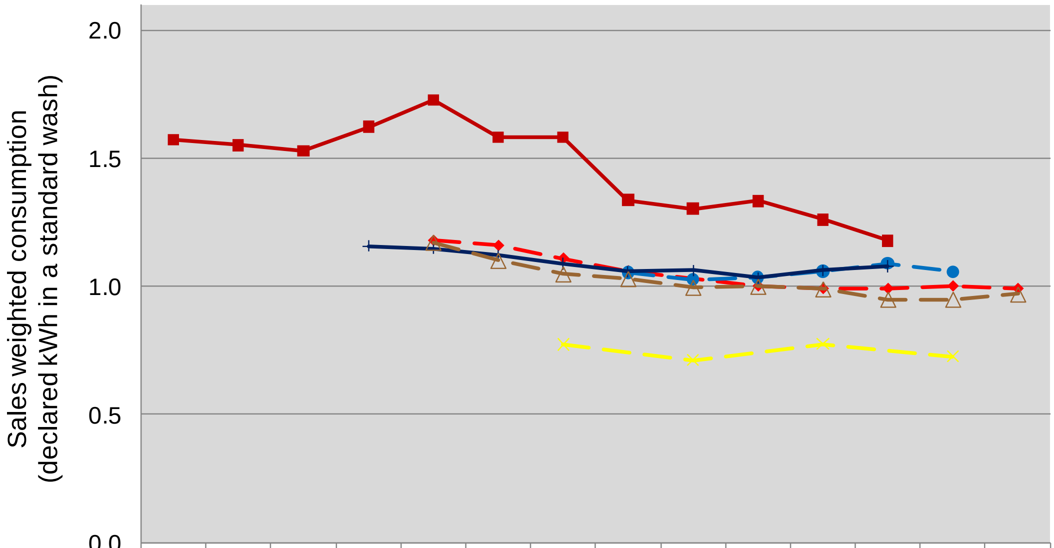
2.1 Observations (excluding Canada and the USA)

2.1.1 Unit energy consumption

With the exception of Switzerland and recently Denmark, all countries have reported a fall in the sales weighted (manufacturer declared) unit energy consumption (UEC) of new washing machines when tested under local test conditions over the reporting period (refer to Figure 2). In some cases, this fall has been substantial, with UEC in Australia falling by 26% over the 2001 to 2007 period[9], although from a relatively high starting point. The primary policy in force in Australia was mandatory labelling and product registration from 1998 onwards[10].

The fall in UEC within the EU countries as a whole appears to still be significant at 19% over the slightly longer 2000 to 2007 period, with this fall mirrored in the individual case of Austria (16%). However, falls in the UEC in UK washing machines were well below the EU average at 6%[11]. This is despite mandatory EU labelling across all EU countries from 1996, and two

Figure 2. Sales weighted energy consumption as declared under local test conditions (kWh).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia (40 degC)	1.57	1.55	1.53	1.62	1.73	1.58	1.58	1.34	1.30	1.33	1.26	1.18		
Austria (60 degC)					1.18	1.16	1.11	1.06	1.03	1.00	0.99	0.99	1.00	0.99
Denmark (60 degC)							0.77		0.71		0.78		0.73	
Switzerland (60 degC)								1.05	1.03	1.04	1.06	1.09	1.06	
United Kingdom (60 degC)				1.16	1.15	1.12	1.09	1.06	1.06	1.03	1.06	1.08		
EU (60 degC)					1.17	1.10	1.05	1.03	1.00	1.00	0.99	0.95	0.95	0.97

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

[9] Reported UEC in Australian prior to 2001 is based on a smaller proportion of the market than 2001 and later, hence the comparison of 2001 with later years. Refer to the Australian Mapping document for more details.
[10] The introduction of this requirement, and the associated stricter reporting regime, is thought to account for the sudden rise in average product UEC shown over the 1998 to 2000 period.
[11] The UK UEC in 2000 (1.15 kWh/cycle) was only slightly better than in the EU as a whole (1.17 kWh/cycle). By 2009, the UK UEC lagged most EU reporting countries by at least 10%.

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voluntary agreements between the EU and the washing machine producers covering the period 1996 to 2008[12]. Note that there is a sharp improvement in UEC in the EU as a whole and within Austria between 2000 and 2003 which *may* indicate that rapid improvements in product consumption occurred in EU countries prior to 2000. Such a conclusion is somewhat supported by the reductions in UEC experienced by Denmark over the 1996-2001 period. However, given the lack of available data, such a conclusion is rather speculative.

Interestingly, in Switzerland, where use of the EU label became mandatory in 2003 and MEPS (equivalent to the EU labelling A level) were introduced in 2010, the UEC has remained broadly fixed, starting at 1.05 kWh/cycle in 2003 and reaching 1.06 kWh/cycle in 2008 (in line with the UK).

However, these apparently significant differences in initial unit energy consumptions and subsequent reductions in consumption are *potentially* misleading because of:

- Variations in the required testing temperatures;
- Potential variation in the relative percentages of top and front-loader units in the different markets and the associated differences in performance;
- Potential variations in the size of load serviced by machines in individual markets.

The impact of each of these issues is examined below.

2.1.2 Normalised unit energy consumption

Figure 3 provides exactly the same unit energy consumption data as Figure 2 but this time normalised to account for the differences in energy required to heat water for the varying local test/regulatory requirements (see Annex 3 for details of the normalisation undertaken).

As can be seen, in almost all countries the normalisation process results in the UEC sharply reducing to between 40-50% of the initial unadjusted levels, the exception being Australia where UEC *rises* by approximately 10%. Hence the *relative* UECs have moved significantly, with the 2007 Australian UEC now almost 2.5 times higher than that the EU average compared with just 25% higher prior to normalisation.

However, overall the picture remains broadly similar with approximately equal improvements being experienced by countries before and after normalisation and average UEC for products in most countries bunching around the 0.5 kWh/cycle mark in 2007. The exceptions

[12] For the EU countries where data are available for 2008-09, reduction in UEC has all but stagnated (and in some cases increased). It is interesting to note that there is some anecdotal evidence that manufacturers supplying products to the EU have continued to improve the performance of some units. However, this improvement in performance would not have been visible to consumers due to the EU labelling regime in place (as a large majority of units on the market achieve the top 'A' rating and further product improvements would not be 'recognised' in the label). Therefore, the declarations of unit performance made by manufacturers may have been *under* reporting the actual unit performance with a view to rapidly taking advantage of future revisions to the labelling regime. However, such a conclusion is speculative as the evidence is based on unpublished test data on a small sample of models over the 2007 to 2009 period, and actual variations in consumption and efficiency are somewhat masked by changes to unit capacity (see section 2.14).

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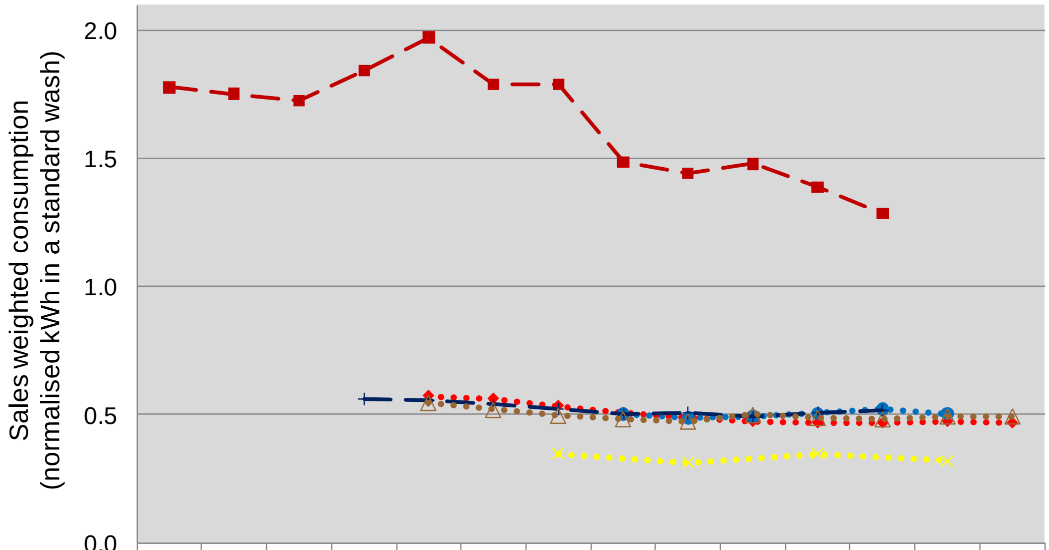
to this 0.5 kWh/cycle UEC are washing machines in Australia which are using on average more than twice as much energy per cycle (1.29 kWh/cycle in 2007).

Figure 3. Sales weighted normalised energy consumption (kWh).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia (40 degC)	1.78	1.75	1.73	1.84	1.97	1.79	1.79	1.48	1.44	1.48	1.39	1.29		
Austria (60 degC)					0.57	0.56	0.53	0.51	0.49	0.47	0.47	0.47	0.47	0.47
Denmark (60 degC)							0.35		0.31		0.35		0.32	
Switzerland (60 degC)								0.50	0.49	0.49	0.50	0.52	0.50	
United Kingdom (60 degC)				0.56	0.55	0.54	0.52	0.50	0.51	0.49	0.51	0.52		
EU (60 degC)					0.55	0.52	0.50	0.48	0.47	0.50	0.49	0.48	0.49	0.49

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

2.1.3 Comparative unit energy consumption based on orientation of the washing machine

There are significant historical and cultural differences between countries in the orientation of washing machines used. In general, Australia, Korea and North America consumers have traditionally favoured top-loading washing machines, and European consumers front-loading machines. However, more recently there is a migration in all markets towards front-loading machines, albeit at differing speeds. Therefore, while the preceding comparison gives an indication of the average UEC of units across the whole market in each country, there is value in comparing the performance of washing machines by orientation. Such an analysis gives a more realistic comparison of machines of a similar type and enables the identification of opportunities that may exist for improvements in each specific machine orientation. Figure 4. and Figure 4 give this normalised Unit Energy Consumption breakdown by the orientation of the washing machine for countries where this split in data was available.

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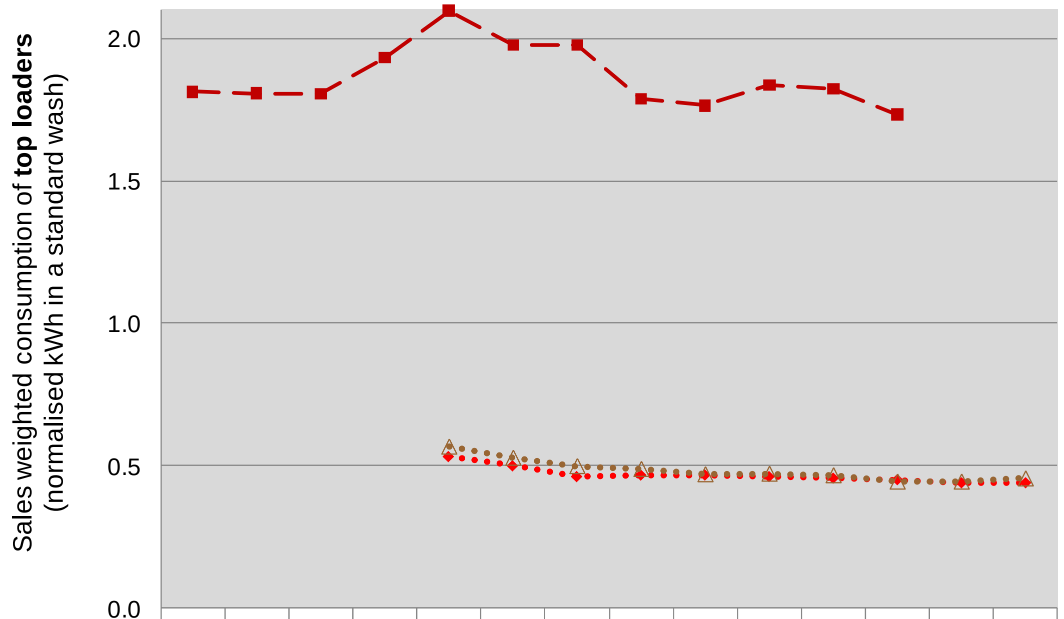
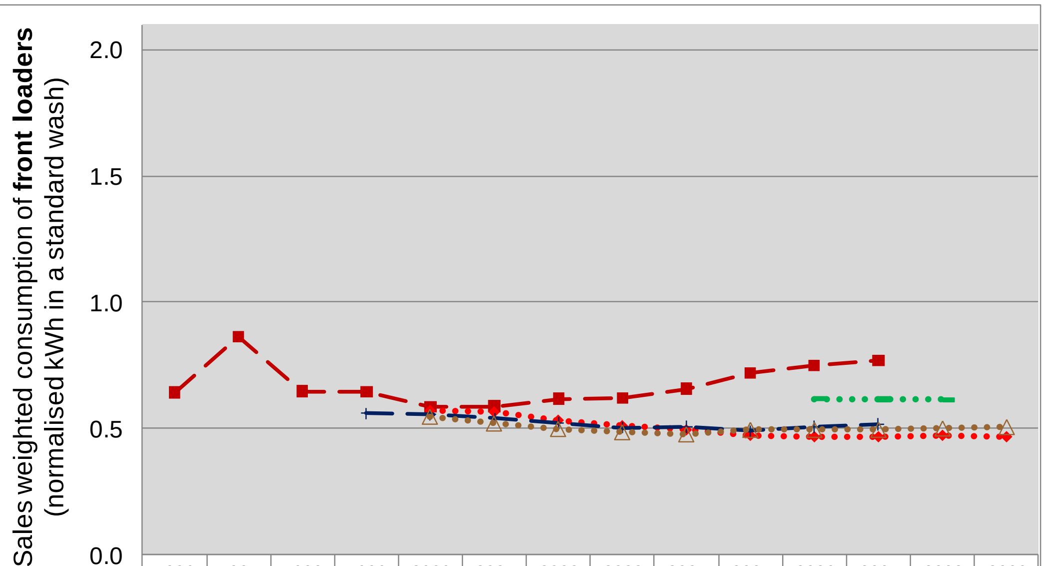
Figure 5. Sales weighted normalised energy consumption for top-loader machines (kWh).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia (20+ degC)	1.81	1.81	1.81	1.93	2.10	1.98	1.98	1.79	1.76	1.84	1.82	1.73		
Austria (60 degC)					0.53	0.50	0.46	0.47	0.47	0.46	0.46	0.45	0.44	0.44
EU (60 degC)					0.57	0.53	0.50	0.49	0.47	0.47	0.47	0.44	0.44	0.46

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

Figure 4. Sales weighted normalised energy consumption for front-loader machines (kWh).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia (40 degC)	0.64	0.86	0.65	0.65	0.59	0.59	0.62	0.62	0.66	0.72	0.75	0.77		
Austria (60 degC)					0.57	0.57	0.53	0.51	0.49	0.47	0.47	0.47	0.47	0.47
Republic Of Korea											0.62	0.61	0.61	
United Kingdom (60 degC)				0.56	0.55	0.54	0.52	0.50	0.51	0.49	0.51	0.52		
EU (60 degC)					0.55	0.52	0.50	0.49	0.48	0.49	0.49	0.49	0.50	0.51

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

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In the EU as a whole, top-loader UEC has improved by almost 23% compared with 11% for front-loaders. However, the reverse is true in Austria where front-loader UEC has improved by almost 18% while top-loaders have improved by 15%. In Australia, this situation is even more extreme, where top-loader energy consumption has *reduced* by 15%, but front-loader consumption has actually *increased* by 30% (although in Australia, despite these relative movements, front-loader washing machines still have UECs at half the level of top-loader units[13]).

These significant changes over the period have resulted in a current situation where:

- Average top-loader UECs ultimately become similar in Austria (0.45 kWh) and the EU as a whole (0.44 kWh). This leaves Australia as the very significant outlier with top loader UEC of 1.73 kWh, more than three times the EU levels;
- Average front-loader UECs have a much smaller variation in 2000 with almost all countries in the 0.55-0.59 kWh performance range. However, this spread widens by 2007 with Australia increasing to 0.77 kWh, the UK staying broadly flat at 0.52 kWh, and the EU and Austrian UECs falling to 0.51 kWh and 0.47 kWh respectively.

Thus, the picture to date is rather complex with few clear lessons. However, this mixed picture of variable UEC may become clearer when the size of the load is taken into account. By doing so, the energy consumption per unit of 'washing service' can be calculated.

2.1.4 Trends in rated load sizes

The rated size of the load defines the quantity of service that a particular washing machine can provide, i.e. the quantity of laundry that can be washed in a single cycle. The different average product weighted rated capacity split between front (single line) and top-loaders (double line) in each country is shown in Figure 6. As can be seen, almost all countries are experiencing annual growth in average product volumes[14]. Between 2000 and 2007, where information is available for the majority of countries, average front-loader rated load capacity has increased by almost 17%, while top-loader capacity has risen by an average of just 4%.

The lowest growth in top-loaders was experienced by Austria at 2.2%. Loads in Australian top-loading machines grew considerably, by 8.8%. However, growth in the capacity of front-loaders was significantly higher, with Australia and the UK experiencing 22% and 19% respective growth in average rated front-load capacities. Over the period the smallest growth in rated load of front-loader units was reported in Austria, and even here the increase was 11% over 7 years.

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[13] However, the apparent significant differences in top and front loader units in Australia should be treated with caution due to local cultural and test method issues. Refer to Annex 3 for more information.

[14] Note that data reported is product weighted load capacities. Insufficient data is available to report changes in rated load capacities on a sales weighted basis. However, from the limited data that is available, and from additional anecdotal reports, it is *likely* that sales weighted growth in product capacities is actually higher than product weighted growth in rated load capacities, i.e. among the products presented for sale, consumers are by preference choosing products with larger rated capacities.

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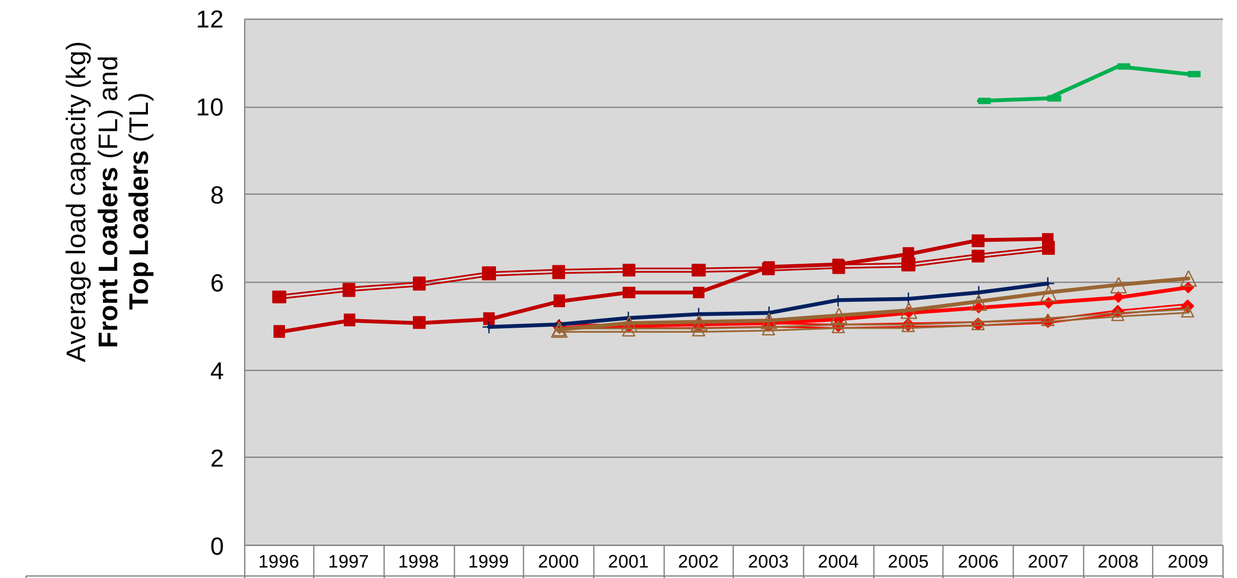
Figure 6. Average product weighted load capacities in kg for both front and top-loader washing machines.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia FL	4.87	5.14	5.07	5.17	5.57	5.77	5.76	6.34	6.41	6.65	6.94	6.98		
Australia TL	5.66	5.82	5.96	6.20	6.23	6.27	6.27	6.30	6.35	6.40	6.59	6.78		
Austria FL					4.95	5.00	5.04	5.07	5.14	5.31	5.42	5.53	5.66	5.88
Austria TL					4.99	5.00	5.00	5.01	5.00	5.02	5.04	5.10	5.32	5.45
Republic Of Korea FL											10.12	10.20	10.93	10.75
United Kingdom FL				4.97	5.02	5.19	5.27	5.30	5.58	5.62	5.76	5.98		
EU FL					4.93	5.05	5.08	5.13	5.24	5.36	5.55	5.75	5.94	6.09
EU TL					4.91	4.90	4.91	4.93	4.98	5.01	5.05	5.15	5.26	5.35

Of particular note is the surprisingly large capacity of domestic units in Korea. The rated load of front-loader machines averages over 10 kg in 2006, with continued rises since this date.

Again this picture of variations in capacity is somewhat complex. However, there are clearly two messages that policy makers can draw:

- The rated load sizes of units are increasing and there is no indication that these increases in capacity are reaching a plateau in any country. At some point the physical dimensions of units will create a maximum possible rated load[15], but it appears this point is yet to be reached in any market.
- The load capacities of top-loading washing machines were generally traditionally greater than front-loading units. However, this trend has reversed with average front-loader capacities now larger than average top-loader capacities for all markets where data is available.

Having established the average load sizes in each country/region, it is now possible to establish how efficiently units wash each kilogramme of load.

[15] The footprint of a unit is the dimensions of the base of the unit (or sometimes defined as the outermost width and depth dimensions of the product). Note that typical unit footprints vary slightly by region.

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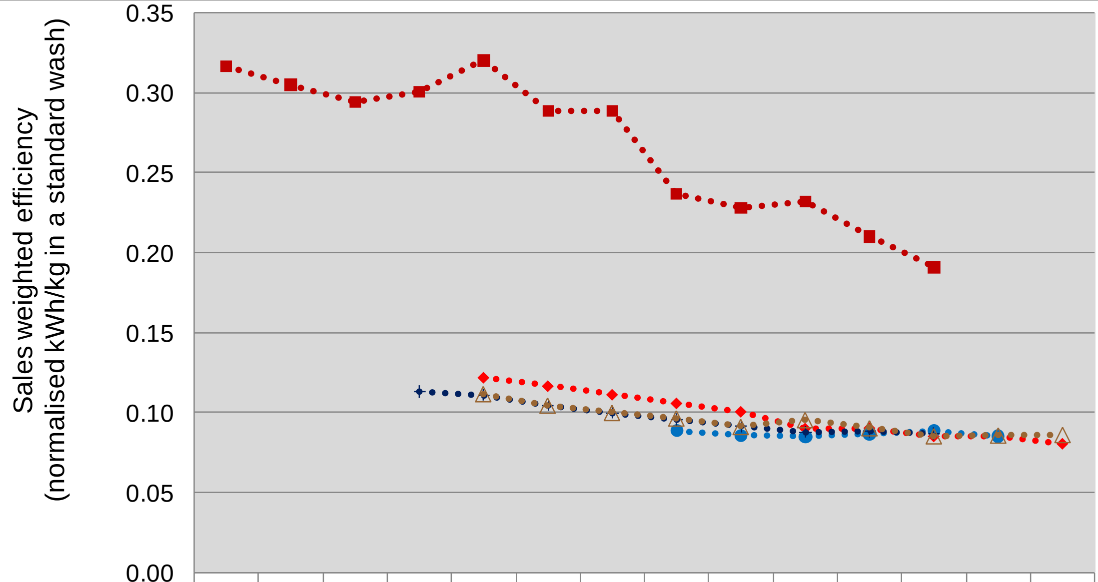
2.1.5 *Product efficiencies*

Perhaps the most useful comparison of product energy performance is to examine the energy used to wash each kilogramme of load, i.e. the amount of energy required to deliver one unit (kg) of clean laundry. This is the measure of washing machine efficiency as defined in the original Mapping and Benchmarking washing machine product definition.

Sales weighted normalised average energy efficiencies (kWh/kg) for *all* washing machines in each country are shown in Figure 7.

Figure 7. Sales weighted normalised average washing machine energy efficiency (kWh/kg) for all products.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia (40 degC)	0.32	0.30	0.29	0.30	0.32	0.29	0.29	0.24	0.23	0.23	0.21	0.19		
Austria (60 degC)					0.12	0.12	0.11	0.11	0.10	0.09	0.09	0.08	0.09	0.08
Switzerland (60 degC)								0.09	0.09	0.08	0.09	0.09	0.09	
United Kingdom (60 degC)				0.11	0.11	0.10	0.10	0.10	0.09	0.09	0.09	0.09		
EU (60 degC)					0.11	0.10	0.10	0.10	0.09	0.10	0.09	0.09	0.09	0.09

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

Initially looking at the whole market over the 2000 to2007 period, there has been a noticeable 18% improvement in efficiency of European washing machines (and in individual EU countries, 18% in the UK and a significant 33% in Austria). This reflects the combined action of falls in UEC and increase in volumes. This has resulted in the average unit energy efficiencies in the EU (and Switzerland) converging to between 80 and 90 Wh/kg. Again the significant outlier is Australia where, despite an average whole market increase in efficiency of 40%, the resulting efficiency level of 190 Wh/kg is still more than double the level of any other country. Obviously this lower level of efficiency in Australia reflects their significantly higher UEC which is only slightly offset by load capacities marginally larger than those in the EU countries.

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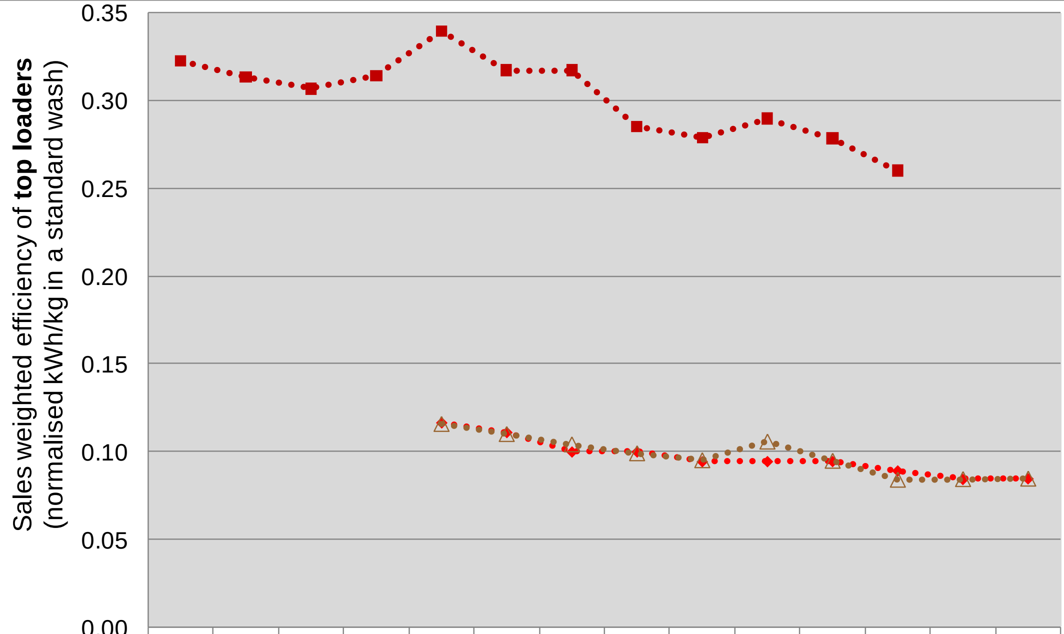
Where information was available, efficiencies were broken into top and front-loader market segments (Figure 8 and Figure 9 respectively).

In the top-loader segment a similar picture emerges to that in the full market, i.e. Austria and the EU as a whole have efficiency levels of around 80 Wh/kg, with Australia again being a significant outlier at 2.5 times these efficiencies. However, in all three cases, efficiency has improved by 23-25%.

Looking at front-loader units in isolation, improvements in efficiency are *similar* to those in top loader units (EU 18%, UK 18% and Austria 33%), but there are significant deviations in product performance across nations. While the European countries again converge on the 80 and 90 Wh/kg efficiency range, Australia still lags behind other countries at 110 Wh/kg (albeit this level is more than twice as efficient as Australian top-loaders). Korea performs extremely well in comparison with the European countries, with unit efficiencies of 60 Wh/kg (although this is primarily due to the very large unit capacities which are unlikely to be replicated elsewhere).

Figure 8. Sales weighted normalised average top-loader washing machine energy efficiency (kWh/kg).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia (20+ degC)	0.32	0.31	0.31	0.31	0.34	0.32	0.32	0.29	0.28	0.29	0.28	0.26		
Austria (60 degC)					0.12	0.11	0.10	0.10	0.09	0.09	0.09	0.09	0.08	0.08
EU (60 degC)					0.12	0.11	0.10	0.10	0.09	0.11	0.09	0.08	0.08	0.08

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

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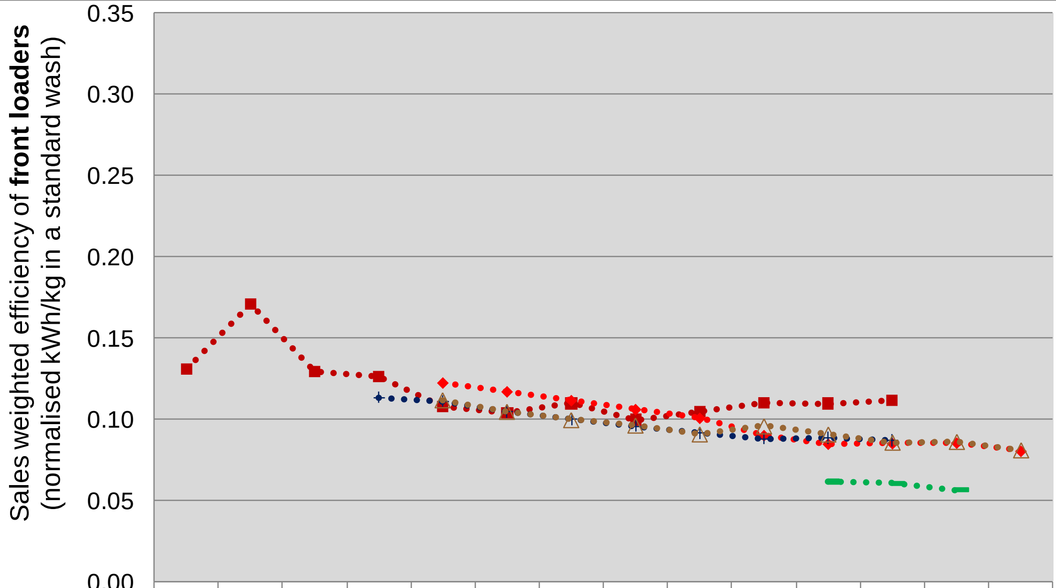
Figure 9. Sales weighted normalised average front-loader washing machine energy efficiency (kWh/kg).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia (40 degC)	0.13	0.17	0.13	0.13	0.11	0.10	0.11	0.10	0.10	0.11	0.11	0.11		
Austria (60 degC)					0.12	0.12	0.11	0.11	0.10	0.09	0.08	0.08	0.09	0.08
Republic Of Korea											0.06	0.06	0.06	
United Kingdom (60 degC)				0.11	0.11	0.10	0.10	0.10	0.09	0.09	0.09	0.09		
EU (60 degC)					0.11	0.10	0.10	0.10	0.09	0.10	0.09	0.09	0.09	0.08

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

2.1.6 Summary potential improvements in the energy performance of units

Based on the evidence available, Australia has significant potential to adopt policies that may drive the energy performance of washing machines to align more closely with models elsewhere. This is particularly the case with top-loading units, but increasingly front-loading models are diverging from equivalents elsewhere. However, such action may not actually be necessary given the cultural preference for cold washes in Australia which will result in actual consumption by the user being significantly below the test values.

Elsewhere there is insufficient evidence to draw reasonable conclusions on the potential for improvement in product efficiencies given the inherent inaccuracies of the normalisation approach. However, the evidence does allow the following observations:

1) In almost all markets UEC is beginning to plateau or increase, with recent improvements in efficiencies primarily related to increasing volumes of the machines[16]. Therefore, it may be appropriate for policy makers to investigate whether *actual load sizes used by consumers* are increasing. If actual load sizes are increasing in line with the increase in load capacities of units, then clearly the energy consumption per unit of clean laundry is decreasing as desired. However, if

[16] Although this *may* not be true for the EU. Refer to Footnote 12.

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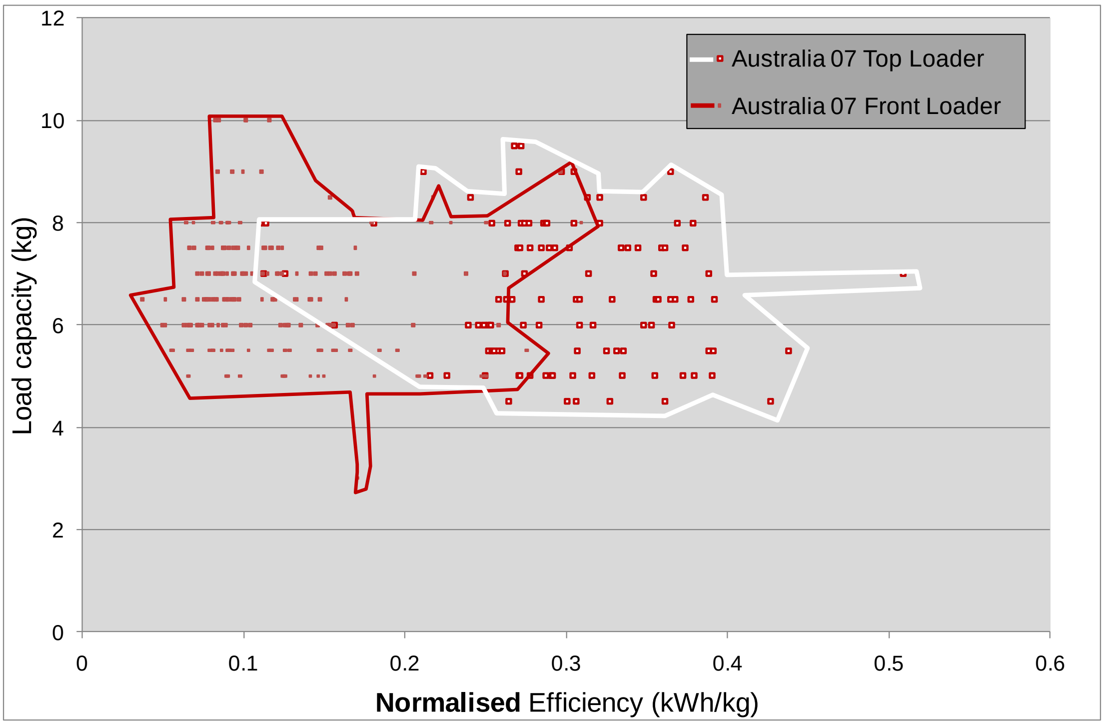
consumers are selecting larger machines *but not increasing actual load sizes*, then it is likely that further improvements in declared product efficiencies may be disguising stagnation in *actual* energy consumption per unit of clean laundry. If this is the case, consideration should be given to limiting unit size and/or capping energy consumption directly (or a combination of both through amendments to algorithms that define minimum efficiency levels).

2) In all markets front-loading washing machines now have lower UECs, higher capacities and better efficiencies than their top-loading competitors. Therefore the implementation of policy to drive improvement in top-loader energy consumption, or to encourage consumer switching to front-loader units, would yield significant energy savings[17] in those countries where top-loader penetration is still high. Such a conclusion is supported by looking at the distribution of normalised efficiencies of front and top-loader models in each rated load range in a single year (2007), in a single market (Australian) (Figure 10). By looking at the single market, unit efficiencies should be directly comparable for any given rated load capacity. As can be seen, the efficiencies of front-loading machines (bounded by the red line) are generally significantly better than top-loader washing machines of the same rated load capacities (bounded by the white line).

Figure 10. Comparative normalised efficiencies of front- (FL) and top- loader (TL) models in each rated load range for washing machines in the Australian market.



[17] Although it is recognised that other performance variables, in particular wash cycle times, *may* be adversely affected by such intervention.

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2.2 Observations (including the USA and Canada)

Unit energy consumption information declared in Canada and the USA is based on test information drawn from a range of cycle conditions (in particular the quantity and temperature of water used). Due to a shortcoming of the normalisation methodology (which is based on a single unit energy consumption value for a specific set of operating conditions) normalised Canadian and USA data results are less comparable than normalised results from other countries, although the *relative* positioning of results from Canada and the USA are highly likely to be comparable. This shortcoming in the normalisation methodology is compounded by a revision to the Canadian and USA required test method/energy reporting algorithm in 2004. This revision included changes to the balance of wash temperatures**, such that the hot and warm wash cycles were assigned lower weighting factors after 2004.** This revision, on average, will tend to result in higher energy consumption values being reported prior to 2004 in comparison with those after[18]. Further, the load (tub) capacities of washing machines in Canada and the USA are declared based on the physical internal dimensions of the machines which have been converted to kilogramme loads to be comparable with data reported from elsewhere. **Thus, the benchmarked data for Canada and the USA presented in this section should be interpreted in the context of the limitations in comparability with washing machine performance from elsewhere as outlined above.**

2.2.1 Unit energy consumption

As with almost all other countries, both Canada and the USA have reported a fall in the sales weighted manufacturer declared UEC of new washing machines when tested under local test conditions (Figure 12). This general picture is reinforced when UEC data is normalised to account for the differences in energy required to heat water for the varying local test/regulatory requirements, bearing in mind the limitations of the normalisation process for Canadian and US data (Figure 12.).

However, in Canada and the USA, this reduction in UEC has been more substantial than elsewhere, with normalised UECs falling by 71% in Canada, and 67% in the USA, over the period 2000 to 2007. Nevertheless, this must be viewed in the context that in 2000, Canadian and US normalised UECs were over twice that of any reporting country, with the obvious exception of Australia. By 2007 the UECs in Canada and the USA were 0.35 kWh and 0.4 kWh respectively. These UECs make the Canadian and USA levels marginally the best of all reporting countries. However, given the limitations of the normalisation process, it is *likely* that the Canadian and USA washing machines are actually comparable with the broad grouping of units elsewhere at around 0.5 kWh.

[18] For more detailed information on the revision and associated impact, please refer to the USA mapping document at http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=3.

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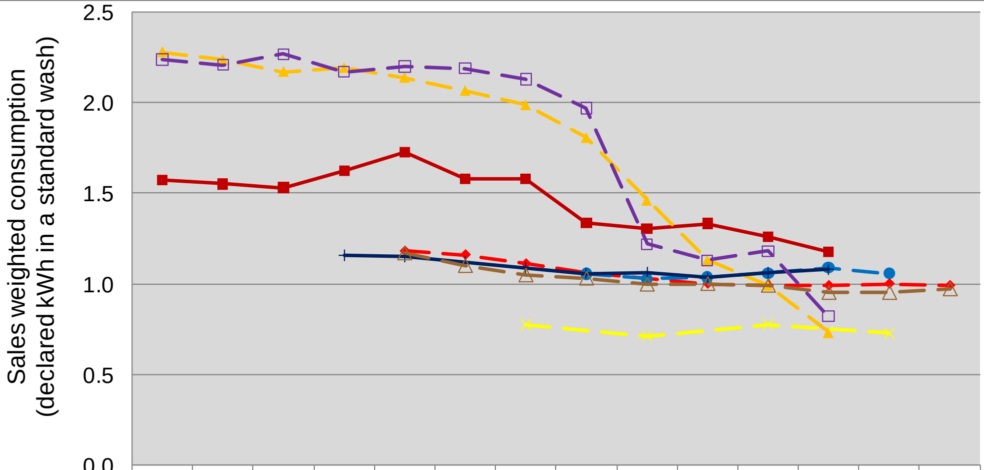
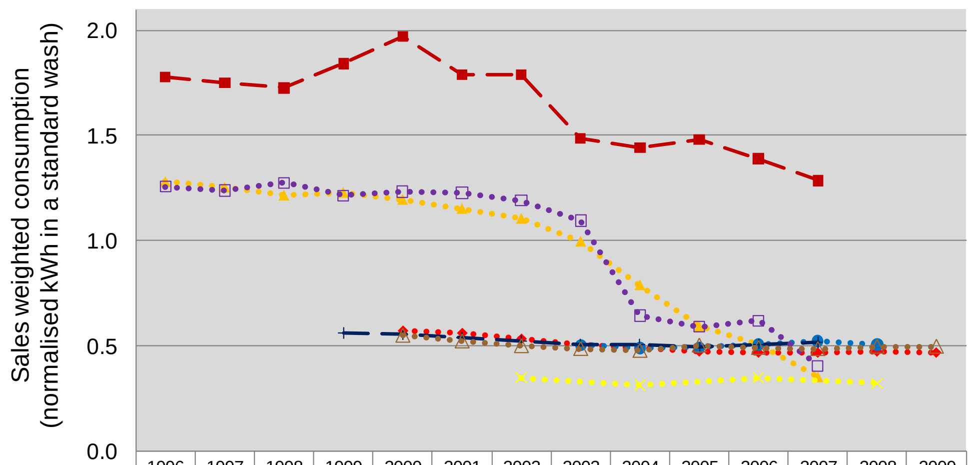
Figure 12. Sales weighted energy consumption as declared under local test conditions (kWh).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia (40 degC)	1.57	1.55	1.53	1.62	1.73	1.58	1.58	1.34	1.30	1.33	1.26	1.18		
Austria (60 degC)					1.18	1.16	1.11	1.06	1.03	1.00	0.99	0.99	1.00	0.99
Canada CAM (57.2 degC)	2.28	2.24	2.17	2.19	2.14	2.07	1.99	1.81	1.46	1.13	0.99	0.73		
Denmark (60 degC)							0.77		0.71		0.78		0.73	
Switzerland (60 degC)								1.05	1.03	1.04	1.06	1.09	1.06	
United Kingdom (60 degC)				1.16	1.15	1.12	1.09	1.06	1.06	1.03	1.06	1.08		
USA AHAM (57.2 degC)	2.24	2.21	2.27	2.17	2.20	2.19	2.13	1.97	1.22	1.13	1.18	0.82		
EU (60 degC)					1.17	1.10	1.05	1.03	1.00	1.00	0.99	0.95	0.95	0.97

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

Figure 11. Sales weighted normalised energy consumption (kWh).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia (40 degC)	1.78	1.75	1.73	1.84	1.97	1.79	1.79	1.48	1.44	1.48	1.39	1.29		
Austria (60 degC)					0.57	0.56	0.53	0.51	0.49	0.47	0.47	0.47	0.47	0.47
Canada CAM (57.2 degC)	1.28	1.25	1.21	1.23	1.20	1.15	1.10	1.00	0.79	0.59	0.51	0.35		
Denmark (60 degC)							0.35		0.31		0.35		0.32	
Switzerland (60 degC)								0.50	0.49	0.49	0.50	0.52	0.50	
United Kingdom (60 degC)				0.56	0.55	0.54	0.52	0.50	0.51	0.49	0.51	0.52		
USA AHAM (57.2 degC)	1.26	1.24	1.27	1.21	1.23	1.23	1.19	1.09	0.64	0.59	0.62	0.40		
EU (60 degC)					0.55	0.52	0.50	0.48	0.47	0.50	0.49	0.48	0.49	0.49

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

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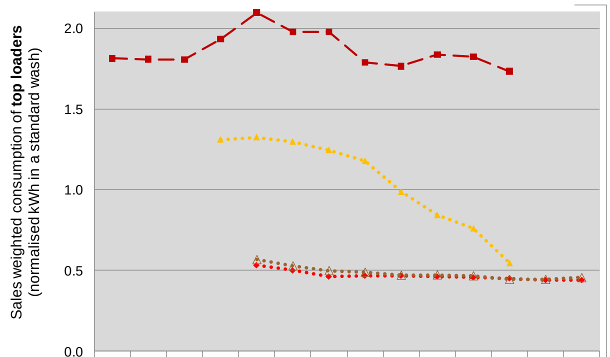
The majority of the fall in UEC in Canada and the USA coincides with the announcement and implementation of revised mandatory Minimum Energy Performance Standards (MEPS) in both countries in 2004 (and a revision in the labelling requirement in the US), and the further revisions of these MEPS in 2007[19] (USA) and 2008 (Canada)[20]. However, it should be noted that the 2004 MEPS revision coincided with a revision to the test method/energy reporting algorithm which will tend to result in higher UEC values being reported prior to 2004 in comparison with those after. Therefore, the actual degree of product improvement resulting from the 2004 MEPS may be less than it appears, although still remaining substantial.

2.2.2 Comparative unit energy consumption based on orientation of the washing machine

No data was available on the split between UEC for top and front-loading washing machines in the USA, but this data is available for Canada and is presented alongside similar data for other reporting countries in Figure 13. and Figure 13

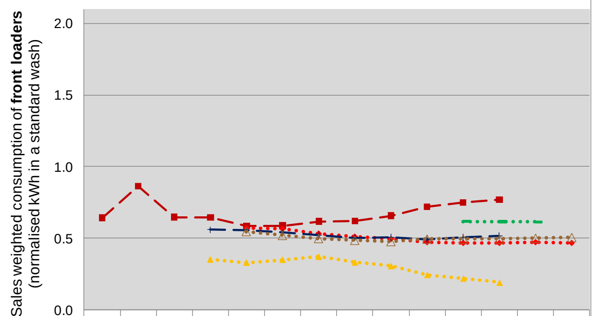
Figure 14. Sales weighted normalised energy consumption for Top Loader Machines (kWh).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia (20+ degC)	1.81	1.81	1.81	1.93	2.10	1.98	1.98	1.79	1.76	1.84	1.82	1.73		
Austria (60 degC)					0.53	0.50	0.46	0.47	0.47	0.46	0.46	0.45	0.44	0.44
Canada (57.2 degC)				1.31	1.32	1.30	1.25	1.18	0.99	0.84	0.76	0.55		
EU (60 degC)					0.57	0.53	0.50	0.49	0.47	0.47	0.47	0.44	0.44	0.46

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

Figure 13. Sales weighted normalised energy consumption for Front Loader Machines (kWh).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia (40 degC)	0.64	0.86	0.65	0.65	0.59	0.59	0.62	0.62	0.66	0.72	0.75	0.77		
Austria (60 degC)					0.57	0.57	0.53	0.51	0.49	0.47	0.47	0.47	0.47	0.47
Canada (57.2 degC)				0.35	0.33	0.35	0.37	0.33	0.31	0.25	0.22	0.19		
Republic Of Korea											0.62	0.61	0.61	
United Kingdom (60 degC)				0.56	0.55	0.54	0.52	0.50	0.51	0.49	0.51	0.52		
EU (60 degC)					0.55	0.52	0.50	0.49	0.48	0.49	0.49	0.49	0.50	0.51

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

Although the Figures and associated analysis should be considered in the context of the limitations of comparability, presentation of the Canadian data does provide some interesting insights:

1) In percentage terms, over the 2000 to 2007 period, the improvement in the UEC of Canadian top-loader machines (58%) is significantly higher than the improvement in front-loader machines (42%). However, despite this relative improvement, top-loader machines still use more than twice the energy of their front-loading equivalents.
2) The significant improvements in Canadian top-loader UECs have only recently brought them broadly into line with the 0.5 kWh consumptions of equivalent top-loader machines in Europe.

[19] Canada also revised its standard in 2008 to include commercial clothes washers. However, this revision did not impact the domestic washing machine test method or MEPS level.
[20] Refer to Annex 4 for summary details of primary policy actions and associated timescales.

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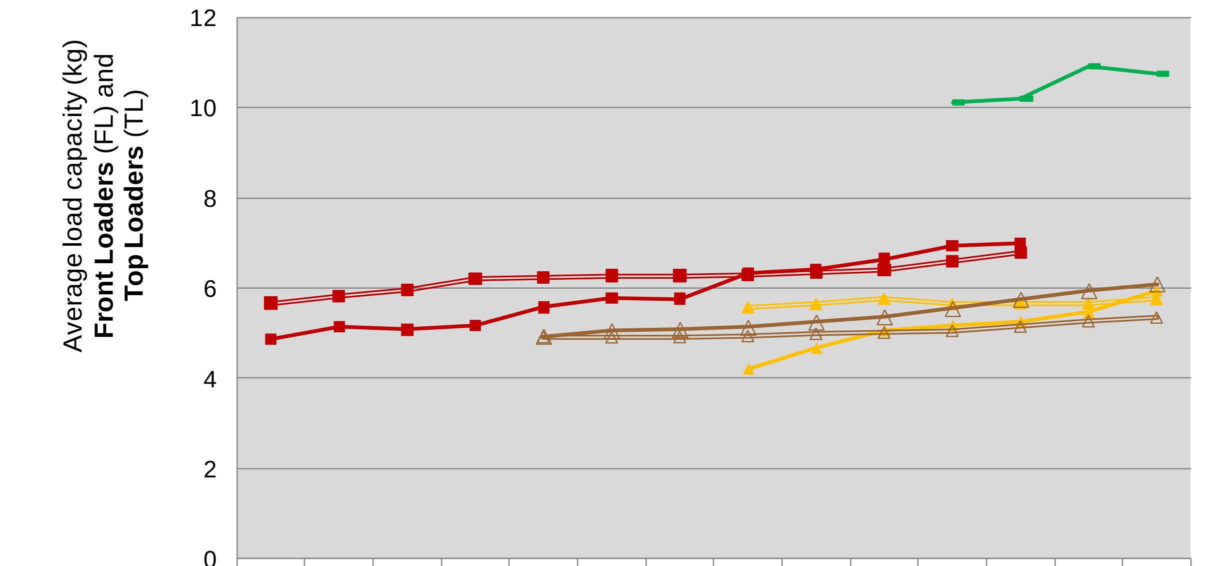
3) Despite the improvements in both front and top-loader performance, individually neither account for the 71% improvement in the *overall* UEC of new washing machines in Canada over the 2000 to 2007 period. Much of this overall market improvement is the result of a market switch from the higher consuming top-loaders, to the lower consuming front-loaders – the market share of front-loaders in 2001 was 16%, but this had risen to 57% by 2008.

2.2.3 Trends in rated load sizes and product efficiencies

Contrary to belief among many consumers, as Figure 15 illustrates, Canadian washing machines do not have markedly larger capacity than European models (despite a slightly larger footprint) and are significantly smaller than comparable Australian units. In fact, given the uncertainty in the approach to normalisation of load size, there is a possibility that the sizes shown for Canadian washing machines is somewhat exaggerated and their load capacities are smaller than European models[21]. However, as elsewhere, the trend is for increasing load capacities, particularly in front-loading units[22]. Over the 2003 to 2009 period,

Figure 15. Average product weighted load capacities in kg for both front and top-loader washing machines.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia FL	4.87	5.14	5.07	5.17	5.57	5.77	5.76	6.34	6.41	6.65	6.94	6.98		
Australia TL	5.66	5.82	5.96	6.20	6.23	6.27	6.27	6.30	6.35	6.40	6.59	6.78		
Canada FL								4.21	4.67	5.06	5.18	5.26	5.46	5.95
Canada TL								5.57	5.64	5.76	5.64	5.66	5.66	5.76
Republic Of Korea FL											10.12	10.20	10.93	10.75
EU FL					4.93	5.05	5.08	5.13	5.24	5.36	5.55	5.75	5.94	6.09
EU TL					4.91	4.90	4.91	4.93	4.98	5.01	5.05	5.15	5.26	5.35

[21] Although it should be noted that Canadian capacities are based on the physical dimensions of the unit whereas European capacities are based on manufacturer declared values which are used to define the load under test – so comparison is not direct.
[22] Note that data reported is product weighted load capacities. Insufficient data is available to report changes in rated load capacities on a sales weighted basis. However, from the limited data that is available, and from additional anecdotal reports, it is *likely* that sales weighted growth in product capacities is actually higher than product weighted growth in rated load capacities, i.e. among the products presented for sale, consumers are by preference choosing products with larger rated capacities.

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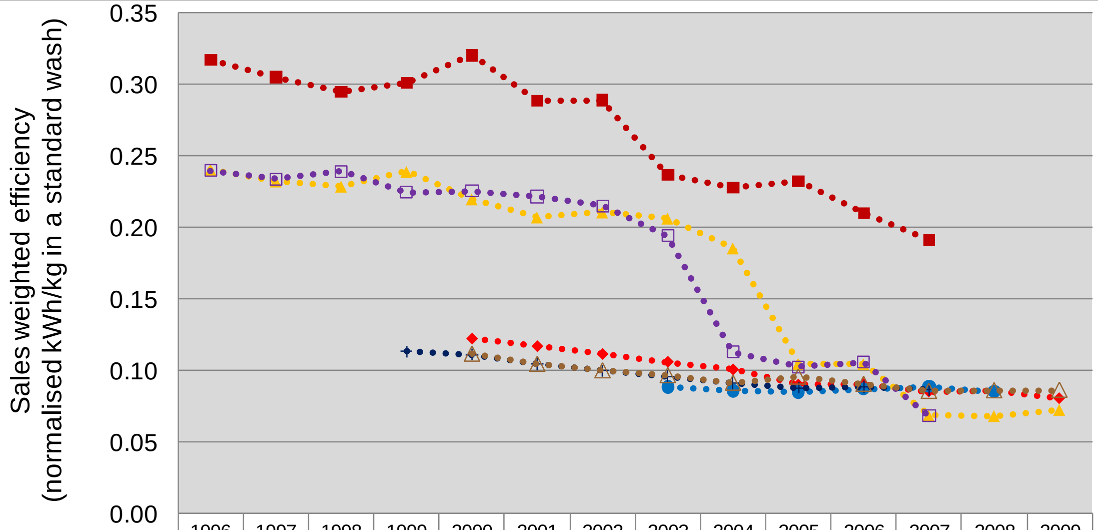
the average load capacity of front-loading units has increased from 4.2 kg to 6 kg. Front-loading units now have average capacities significantly larger than the higher energy consuming top-loading machines.

As noted previously, perhaps the most useful comparison of product energy performance is to compare the energy used to wash each kilogramme of load, i.e. the amount of energy required to deliver one unit (kg) of clean laundry. Noting again that caution should be applied when comparing the Canadian and USA results with those from elsewhere, Figures illustrating comparisons of whole market product efficiency (Figure 16), and comparisons for Canadian top-loader (Figure 17.) and front-loader (Figure 17) units are included for completeness.

Figure 16. Sales weighted normalised average washing machine energy efficiency (kWh/kg) for all products.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia (40 degC)	0.32	0.30	0.29	0.30	0.32	0.29	0.29	0.24	0.23	0.23	0.21	0.19		
Austria (60 degC)					0.12	0.12	0.11	0.11	0.10	0.09	0.09	0.08	0.09	0.08
Canada CAM (57.2 degC)*	0.24	0.23	0.23	0.24	0.22	0.21	0.21	0.21	0.19	0.10	0.10	0.07	0.07	0.07
Switzerland (60 degC)								0.09	0.09	0.08	0.09	0.09	0.09	
United Kingdom (60 degC)				0.11	0.11	0.10	0.10	0.10	0.09	0.09	0.09	0.09		
USA AHAM (57.2 degC)	0.24	0.23	0.24	0.22	0.23	0.22	0.21	0.19	0.11	0.10	0.11	0.07		
EU (60 degC)					0.11	0.10	0.10	0.10	0.09	0.10	0.09	0.09	0.09	0.09

Solid line = robust data Dashed line = indicative data Dotted line = illustrative data
* = product weighted

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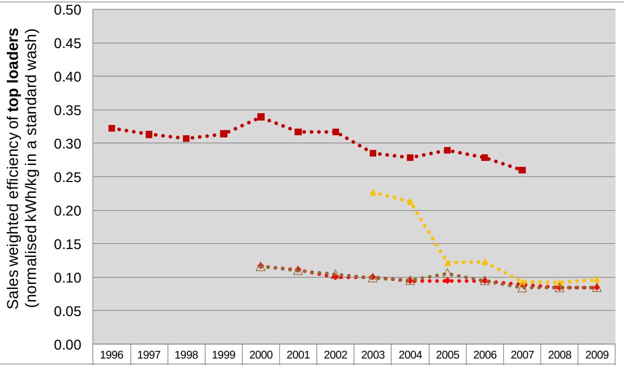
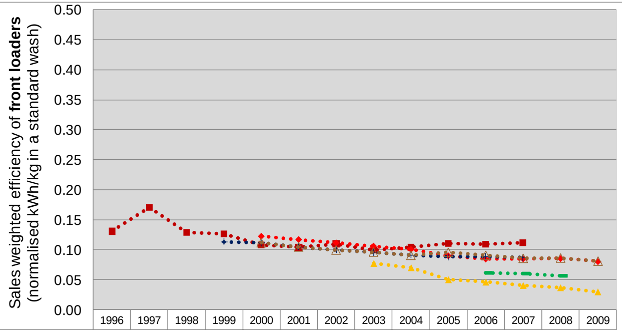
Figure 18. Sales weighted normalised average top-loader washing machine energy efficiency (kWh/kg).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia (20+ degC)	0.32	0.31	0.31	0.31	0.34	0.32	0.32	0.29	0.28	0.29	0.28	0.26		
Austria (60 degC)					0.12	0.11	0.10	0.10	0.09	0.09	0.09	0.09	0.08	0.08
Canada (57.2 degC)*								0.23	0.21	0.12	0.12	0.09	0.09	0.10
EU (60 degC)					0.12	0.11	0.10	0.10	0.09	0.11	0.09	0.08	0.08	0.08

Solid line = robust data   Dashed line = indicative data   Dotted line = illustrative data
* = product weighted

Figure 17. Sales weighted normalised average front-loader washing machine energy efficiency. (kWh/kg)



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia (40 degC)	0.13	0.17	0.13	0.13	0.11	0.10	0.11	0.10	0.10	0.11	0.11	0.11		
Austria (60 degC)					0.12	0.12	0.11	0.11	0.10	0.09	0.08	0.08	0.09	0.08
Canada (57.2 degC)*								0.08	0.07	0.05	0.05	0.04	0.04	0.03
Republic Of Korea											0.06	0.06	0.06	
United Kingdom (60 degC)				0.11	0.11	0.10	0.10	0.10	0.09	0.09	0.09	0.09		
EU (60 degC)					0.11	0.10	0.10	0.10	0.09	0.10	0.09	0.09	0.09	0.08

Solid line = robust data   Dashed line = indicative data   Dotted line = illustrative data
* = product weighted

2.3 Key issues for policy makers

Based on the evidence available, policy makers may wish to note the following:

- The combination of MEPS and labelling has had a very strong impact in Canada and the USA (although the biggest market response seems to align primarily with the introduction/revision of MEPS and the associated labelling revisions). Ultimately Canadian and US unit energy consumptions are now (likely) to be broadly in line with most European countries despite previously being at significantly higher initial levels. Therefore, it is reasonable to conclude that challenging *and regularly revised* MEPS are a highly effective method of reducing consumption.
- The impact of labelling within the EU countries, and the associated voluntary agreement with industry, has had a mixed effect. Across the EU as a whole and within Austria, there has been a significant market response. However, within the UK improvement has been minimal[23,24]. Therefore policy makers should be aware of the potential improvements that *can* be achieved through the combined application of labelling and voluntary agreements. However, ongoing monitoring of the market should be undertaken to ensure policy impacts are occurring in all market segments and, where this is not the case, revisions to the agreement/policy should be considered.

[23] Unfortunately there is insufficient information available at this time to account for this difference in consumer purchasing patterns (eg whether the difference is caused by pricing strategies, consumer information/preference, model availability, etc).

[24] Note that the improvements across of the EU have reduced in the most recently reported years. There is some anecdotal evidence that this is due to a lack of a revision of the labelling categories. As a large proportion of units have reached the highest 'A' level, there is no visible sign to the consumer that a product has improved past this level. Thus, manufacturers have no incentive to improve products, or if they do, no incentive to report this improvement until the labelling categorisation system is revised (there is some limited test data to support the latter thesis).

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- In the one country reporting which relies solely on labelling as its policy intervention (Australia), improvements have been seen in overall average unit energy consumption of washing machines, but the performance of these units still lags significantly behind all other participating countries (Australian unit energy consumption is more than twice that of the country with the next highest unit consumption, and the consumption of Australian front-loading units is actually rising, which is at odds with all other countries). However, the significant use of cold water in washes by Australian consumers (which is not reflected in the test methodology) may negate the need for policy intervention to address this apparent difference.
- The implementation of policy to drive improvement in the energy performance of top-loading washing machines, or to encourage consumer switching from top-loader machines to their front-loader competitors, would yield significant energy savings in those countries where top-loader penetration is still high. However, policy makers should be aware that such action may adversely affect other performance variables, in particular wash cycle times (see the following section).
- The rated load sizes of washing machines are increasing in almost all jurisdictions and there is no indication that these increases are reaching a plateau in any country. This ongoing increase in rated capacity is at least partly responsible for increasing product efficiency (more so in recent years where the improvement in unit energy consumption is beginning to stagnate in some regions). Hence policy makers may wish to investigate whether the *actual* size of loads washed by consumers is increasing in line with increasing machine sizes. If actual load sizes are not increasing significantly, it is likely that further improvements in declared product efficiencies due to increasing product sizes may be disguising stagnation in *actual* energy consumption per unit of clean laundry. If this is the case, consideration should be given to limiting unit size and/or capping energy consumption directly (or a combination of both through amendments to algorithms that define minimum efficiency levels).
- The load capacities of top-loading washing machines were traditionally greater than front-loading units. However, this trend has reversed, with average front-loader capacities now larger than average top-loader capacities for all markets where data is available.

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3 Non energy performance variables

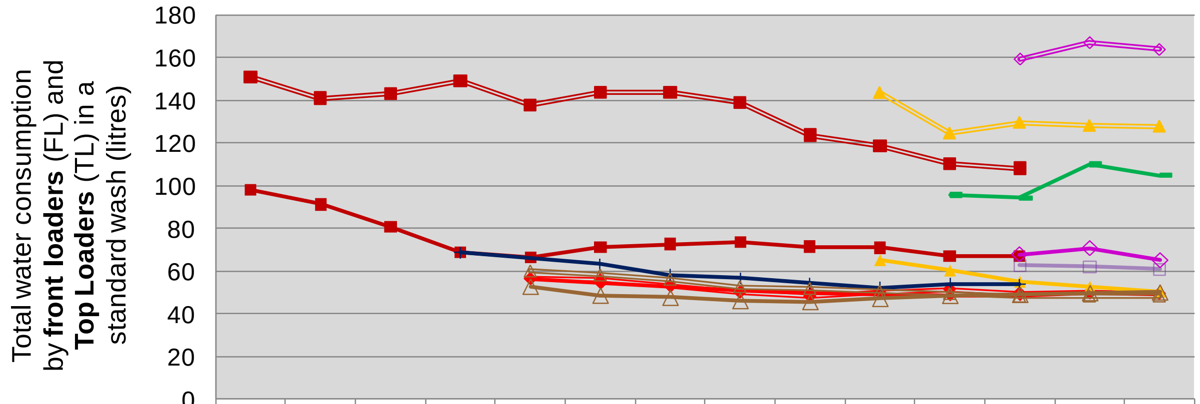
3.1 Observations

3.1.1 Water consumption

The water consumption of individual washing machines is labelled in almost all countries in conjunction with the energy consumption/efficiency label; or as a stand-alone water efficiency label in Australia (the exception being Canada).

Water consumption has been falling in almost all countries over an extended period, although recently such consumption has begun to plateau (albeit at significantly differing levels) with slight recent increases being experienced in some countries (see Figure 19).

Figure 19. Total water consumption of front and top-loading washing machines in a standard wash using local test methodologies (litres).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia FL	98	91	81	69	67	71	73	74	71	71	67	67		
Australia TL	151	141	143	149	138	144	144	139	124	119	110	108		
Austria FL					56	54	53	51	50	49	49	49	50	50
Austria TL					57	56	53	50	48	50	52	50	50	49
Canada FL										65	60	55	53	51
Canada TL										144	125	130	128	128
Republic Of Korea FL											96	94	110	105
United Kingdom FL				69		63	58	57	54	52	54	54		
USA Energy Star FL												63	62	61
China FL												68	71	65
China TL												159	167	164
EU FL					53	49	48	46	46	47	49	49	50	50
EU TL					60	58	56	53	52	50	49	48	48	48

However, water efficiency (defined as water consumption in litres per kg of laundry) has continued to reduce in all countries for all years as would be expected given the increasing load sizes (Figure 20). It is to be expected that water consumption would reduce in a proportion directly linked to energy consumption (when non cold washes are used). Reported average water efficiency reductions do indeed almost exactly match reductions in average unit energy efficiency in each market. However, there will come a point where further reductions in water consumption can no longer be sustained without significant

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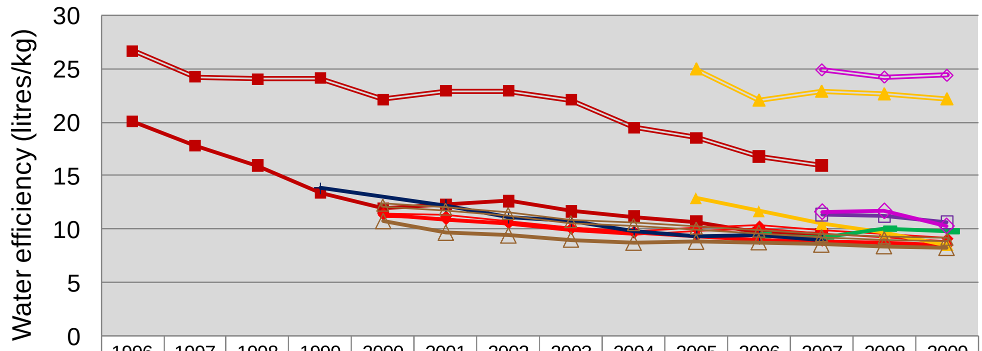
deterioration in wash performance and/or rinse effectiveness; or without increased cycle time. It is *possible* that such a point is approaching as water consumption and water efficiency are both beginning to plateau. Therefore, in countries where water and/or energy consumption/efficiency will continue to be a focus of policy intervention, policy makers should consider increasing vigilance of wash and rinse performance to ensure their policy intervention will not result in impaired unit performance to which consumer reaction may be negative.

Figure 20. Water efficiency of front and top-loading washing machines in a standard wash using local test methodologies (litres).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia FL (40 degC)	20.1	17.8	15.9	13.3	12.0	12.3	12.6	11.7	11.2	10.7	9.6	9.6		
Australia TL (40 degC)	26.6	24.2	24.0	24.1	22.1	22.9	22.9	22.1	19.5	18.5	16.8	16.0		
Austria FL (60 degC)					11.4	10.9	10.5	10.0	9.7	9.3	9.0	8.8	8.8	8.4
Austria TL (60 degC)					11.3	11.2	10.6	10.0	9.6	10.0	10.2	9.7	9.4	9.1
Canada FL (57.2 degC)										12.9	11.7	10.5	9.7	8.5
Canada TL (57.2 degC)										25.0	22.1	22.9	22.7	22.2
Republic of Korea FL (37 degC)											9.5	9.2	10.1	9.8
UK FL (60 degC)				13.8		12.2	11.1	10.7	9.8	9.3	9.4	9.0		
USA Energy Star FL (57.2 degC)												11.3	11.2	10.6
China FL (unknown)												11.6	11.7	10.3
China TL (unknown)												24.9	24.2	24.4
EU FL (60 degC)					10.7	9.7	9.4	9.0	8.7	8.8	8.8	8.5	8.4	8.3
EU TL (60 degC)					12.2	11.9	11.4	10.7	10.4	10.1	9.8	9.4	9.2	9.0

ALL DATA IS ILLUSTRATIVE

3.1.2 Wash quality

Given the observation on water consumption and potential impact on wash quality, evidence to date suggests that so far the reductions in water consumption have had no adverse impact on wash quality, at least in those countries where wash quality is measured. While absolute wash quality is not comparable, Figure 21 illustrates the relative changes in wash performance in each market relative to the first year of data availability in that market – all of which are positive.

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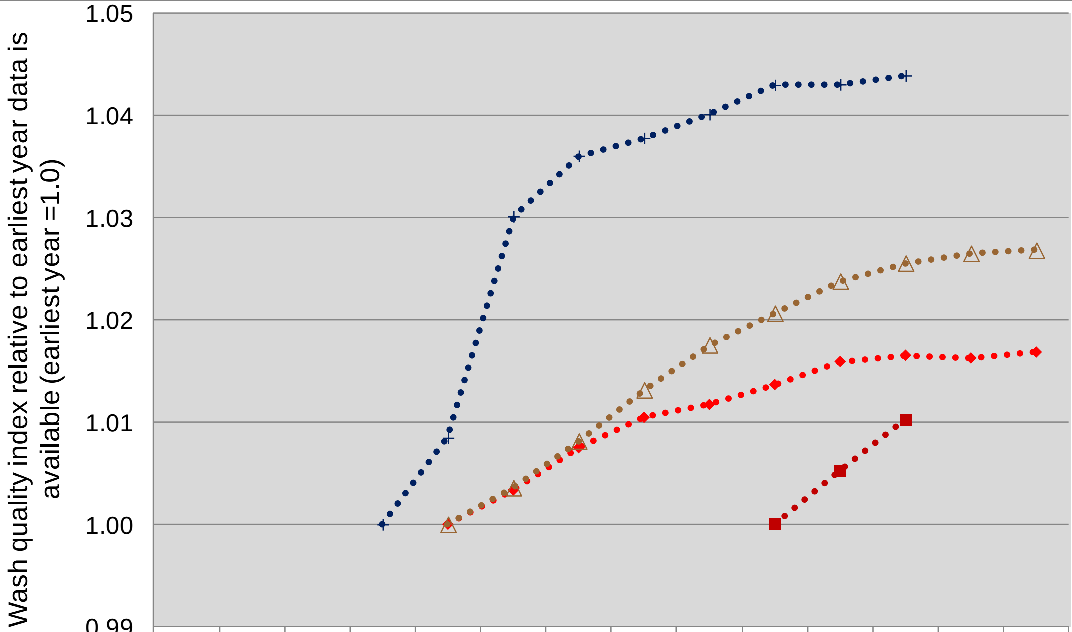
Figure 21. Wash quality relative to performance in the first year data is available.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia										1.00	1.01	1.01		
Austria					1.00	1.00	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.02
United Kingdom				1.00	1.01	1.03	1.04	1.04	1.04	1.04	1.04	1.04		
EU					1.00	1.00	1.01	1.01	1.02	1.02	1.02	1.03	1.03	1.03

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

3.1.3 Spin effectiveness

Spin effectiveness is a measure of how much residual moisture is left in clothes at the end of the washing cycle. Such a measurement is of particular importance in those countries where the use of laundry dryers is significant, as any additional moisture left in the laundry will result in increases in drying energy.

Again local test measurements are non-comparable, but Figure 22 illustrates the changes in spin effectiveness in each market relative to the first year of data availability in that market. In line with the improvements in wash quality, all reporting countries have shown an improvement in spin effectiveness (reduction in residual moisture content). However, as other options to reduce the energy consumption of units appear to be reducing (as evidenced by unit energy consumption appearing to reach a plateau), there *may* be a tendency for manufacturers to sacrifice spin performance in order to reduce overall unit consumption. Therefore, policy makers may wish to keep a watching brief on spin efficiency to ensure consumers remain satisfied with spin performance, and to ensure that improvements in washing machine energy consumption through reduced spinning are not resulting in significantly greater increases in consumption in the post-wash drying of the laundry.

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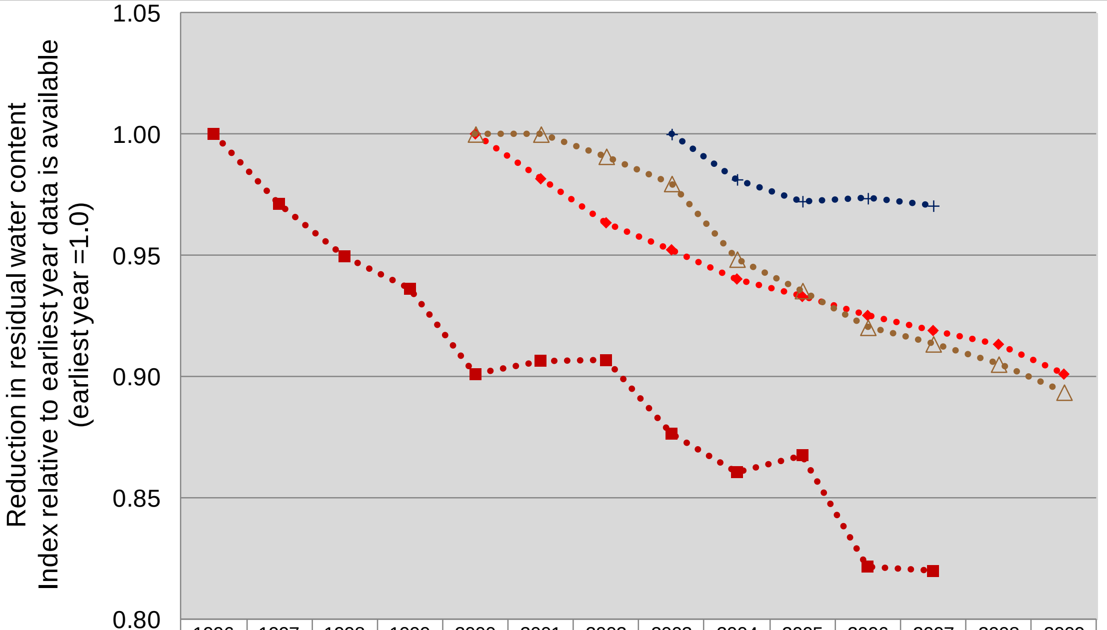
Figure 22. Spin effectiveness relative to performance in the first year data is available.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	1.00	0.97	0.95	0.94	0.90	0.91	0.91	0.88	0.86	0.87	0.82	0.82		
Austria					1.00	0.98	0.96	0.95	0.94	0.93	0.93	0.92	0.91	0.90
United Kingdom								1.00	0.98	0.97	0.97	0.97		
EU					1.00	1.00	0.99	0.98	0.95	0.94	0.92	0.91	0.91	0.89

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

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Annex 1 Terminology used

The following lists some of the terminology used within this benchmarking document. It does not attempt to provide a full listing of all terminology, but rather to provide a summary of terminology most frequently used and/or terminology used in a context with a meaning that is less well known or different to its more common usage.

Front-loading washing machines	*Washing machines where the load is inserted through a door in the front of the machine (often referred to as horizontal axis washing machines)*
Load	*The size and type of laundry being washed by the machine as defined in local test conditions*
Product weighted data	*Data that has been weighted in line with the number of individual products reportedly available to the consumer*
Rated load	*The maximum size of load that can be washed by the machine as declared by the manufacturer (note that the benchmarking uses kilogrammes to define load although Canada and the USA define the capacity of the drum – refer to Annex 3 for details of the conversion used)*
Rinse effectiveness	*A measure of how effectively detergent has been extracted from the load at the end of the washing cycle (values quoted use local test declaration unit)*
Sales weighted	*Data that has been weighted in line with the number of total sales of individual products*
Spin effectiveness	*A measure of how much water has been extracted from the load at the end of the washing cycle (values quoted use local test declaration unit)*
Top-loading washing machines	*Washing machines where the load is inserted through a door on the top of the machine (often referred to as vertical axis washing machines)*
Unit Energy Consumption (UEC)	*The energy consumption of the washing machine under local test conditions (or following normalisation) in kWh*
Unit energy efficiency	*The energy consumption per kilogramme of laundry washed under local test conditions (or following normalisation) in kWh/kg*
Washing cycle time	*The average period of time to complete the test cycle as declared by the manufacturer*
Wash quality	*A measure of how effectively the washing machine has cleansed the 'dirt' from the load at the end of the washing cycle (values quoted use local test declaration unit)*

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Washing temperature	*The nominal temperature of the water as defined in local test conditions*
Water consumption	*The total water consumption (both hot and cold) of the washing machine under local test conditions (or following normalisation) in litres*
Water efficiency	*The water consumption per kilogramme of laundry washed under local test conditions in litres/kg*

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Annex 2 Framework for grading mapping and benchmarking outputs

In order for the Mapping and Benchmarking Annex to provide transparency regarding the degree of 'reliability' that can be attributed to the results produced by the Annex, a framework has been developed that allows the *grading* of benchmarking outputs. This grading is based on a three part 'scale' of robust, indicative and illustrative. This grading is applied to both the initial data input and any manipulations that are required to present the data in a consistent form in the country mappings, and to the subsequent manipulations of that data in order to make it comparable with datasets from other countries/regions during the benchmarking process. While expert opinion is used to formulate the specific grading allocated to individual datasets or outputs, this expert opinion is formed with the following framework.

Grading of data/mapping outputs

Robust – where typically:

- The data are largely representative of the full market and
- The data include at least a significant element of individual product data and
- The data are from known and reliable sources and
- Test methodologies are known and reliable and
- Any data manipulations are based on solid evidence and should not unduly distort results.

Conclusions from such datasets are as reliable as reasonably possible within boundaries of the Annex operation.

Indicative – where typically:

- Datasets may not be fully representative of the markets (but do account for a majority, ideally a known and understood majority) and/or
- Any data manipulation used includes some assumptions or unavoidable approximations that could unintentionally reduce accuracy.

Accuracy is, however, judged such that meaningful but qualified conclusions could be drawn.

Illustrative – where typically:

- One or more significant parts of a dataset is known to represent less than a majority of the full market or
- Test methodologies used to derive data are not known or
- Test methodologies used to derive data are known but could lead to significant differences in outcome or
- Data manipulations for the analysis contain an element of speculation or significant assumption or
- Conflicting and equally valid evidence is available.

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Rather than being rejected completely, perhaps because the flaws in the data are at least consistent, such data could provide some insight into the market situation and so are worth reporting, but results must be treated with caution.

Grading of comparison between country outputs (benchmarking)

Robust – where typically:

- The data sources being compared are each largely 'robust' and
- No data manipulations for benchmarking were necessary; or if manipulations were used they were based upon solid evidence and should not distort results.

Conclusions from comparisons within and between such datasets are as reliable as reasonably possible within boundaries outlined above.

***Indicative* –** where typically:

- Datasets being compared are themselves only 'indicative' and/or
- Any data manipulation used for benchmarking includes some assumptions or unavoidable approximations that could unintentionally reduce accuracy and/or
- For any other reason(s) subsets of the data may not be strictly comparable which leads to some distortion.

However, accuracy is such that meaningful but qualified conclusions could be drawn.

Illustrative – where typically:

- One or more significant parts of the datasets are themselves 'illustrative' and/or
- Data manipulations for the benchmarking process contain an element of speculation or significant assumption.

Rather than being rejected completely, perhaps because the flaws in the data are at least consistent, such data could provide insight into the market situation and so are worth reporting, but results must be treated with caution.

The information and analysis contained within this summary document is developed to inform policy makers. Whilst the information analysed was supplied by representatives of National Governments, a number of assumptions, simplifications and transformations have been made in order to present information that is easily understood by policy makers, and to enable comparisons with other countries. Therefore, information should only be used as guidance in general policy - it may not be sufficiently detailed or robust for use in setting specific performance requirements. Details of information sources and assumptions, simplifications and transformations are contained within the document or the related Mapping Documents.

Annex 3 Categorisation of original datasets, approach to normalisation and associated cautions

Original data quality

Significant efforts have been made by all participating parties to obtain and process data from a range of sources and to ensure the integrity of the data supplied. However, inevitably there have been some difficulties sourcing information for all countries/regions, and indeed in sourcing all information from individual countries/regions even where this information exists. Therefore, the specific nature of each dataset is different. For example, some datasets are based on detailed information on individual models across a whole market; others are based on averages of aggregated data from the whole market, and some data sets are selections/samples which may be representative of the market as a whole or just a subset of the market (for example the best performing products).

Further, in some cases, data manipulation is required to make the material comparable between countries (for example, the conversion of North American unit capacities defined by the overall drum size in gallons or litres to the equivalent load capacity in kilogrammes used elsewhere[25]).

Thus, to provide readers with an indication of the relative reliability of a particular dataset within the context of the other data being presented, the Mapping and Benchmarking Annex has developed the *Framework for Grading Mapping and Benchmarking Outputs*[26]*.* This framework enables the allocation of gradings based on a robust, indicative and illustrative scale. The original data received (including any manipulations necessary[27]) have been classified based on this framework, with the associated gradings shown in Figure 24.

Benchmarking information

To enable the comparison or benchmarking of product performance between countries, the Mapping and Benchmarking Annex compares products based on their performance when undergoing the standard test defined in the local test methodology. Differences in the local test methodologies are then 'normalised' in an effort to make original data supplied from each region comparable with data from elsewhere.

However, such an approach leads to some inherent issues of which readers should be aware:

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[25] Data on the capacity of Canadian washing machines was supplied as a drum volume. To convert this to a load in kg, the maximum capacities in table 3 (CSA/C360-03 standard) were used to create an equation from which an equivalent load in kg could be calculated for any given declared capacity. The resulting formula used was Load (kg) = 0.0659 Container volume (L) – 0.0137. No capacity data was available on machines from the USA.
[26] This Framework is generally used across all Mapping and Benchmarking outputs (refer to Annex 2).
[27] All manipulations of individual datasets are detailed in the associated country/region mapping at http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=3

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- Normalisation/conversion factors are not 100% accurate. This is a particular issue for washing machines where a number of variables (water consumption and temperature, wash quality, drying performance, etc) are interdependent and affect overall energy consumption and unit efficiencies.
- Test methodologies (in particular wash temperatures) may not reflect actual consumer usage patterns and/or units may not comply fully with the stated requirements of the test.

These issues are investigated below and specific areas of importance highlighted to the reader.

The context of normalisation of data

Interrelationship of performance variables

The energy performance of washing machines is interdependent on a range of other variables including:

- **Washing temperature,** typically the higher the washing temperature, the cleaner the load (although this variation is more complex now given the advent of enzyme washing powders);
- **Washing cycle time,** typically the longer the wash time, the cleaner the wash for a given quantity of water/energy;
- **Wash quality,** typically the higher the wash quality, the more energy (through some combination of increased water temperature, increased agitation of the load and an extended wash time) is required to deliver the improved performance;
- **Spin effectiveness,** typically the drier the clothes following the spin cycle, the more energy has been expended to extract the water;
- **Rinse effectiveness,** typically units that deliver better rinse performance (the removal of detergent and softener residue) consume more water or have longer wash cycles;
- **Type of load,** dense cotton material has a different wash and spin requirement to the more gentle action required for woollens;
- **Size of load,** with a given washing container size, typically the greater the size of the washing load the lower the washing performance as the degree of agitation is reduced;
- **Other variables** including the water hardness, specific detergent used, etc all impact on the performance of one or more of the variables outlined above

Even where the same test method is used, there is a great deal of uncertainty over how each of these factors interrelate for an individual machine. This means the development of normalisation factors related to an individual variable (for example energy consumption) will have inherent shortcomings as it does not factor in the associated positive or negative impact of other performance variables. For example, a unit that uses slightly more energy than a competing unit *may* have overall better performance in terms of wash quality, dryness of the wash at cycle completion, use of water and other resources such as detergent, etc.

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Hence the unit that uses slightly more energy *may* be considered to be the more resource efficient for a given level of performance.

Within the context of the specific datasets received, these issues are further compounded by the provision by some countries of product level data which allow analysis of the interrelation of many variables for individual machines, and the supply of aggregated market data from elsewhere which makes such analysis impossible.

Differences in local test methodologies and regulatory requirements

Having established that even where testing requirements are identical, variables are interrelated, it is evident the development of conversion factors based on a single variable is challenging. This is further complicated by the difference in:

- Testing methodologies between countries/regions and the associated mandatory conditions of the test (type of load, water temperature, detergent, etc);
- Regulations between countries/regions that define minimum performance standards for one or more of the variables; the requirement to report/declare the performance related to one or more of the variables; or no requirement to measure or report anything other than unit energy performance.

To provide a simplified example, local requirements in country A may specify a test wash temperature of 40°C with no requirements to report wash performance or spin effectiveness. The requirements in country B may be to test at 60°C, and the units have a requirement to achieve (or report on the label) a level of wash performance and spin effectiveness. Clearly the difference in wash temperature will affect the amount of energy consumed by a machine. However, even if there is a correction/normalisation made for the differences in energy required to heat the water, overall consumption of energy for a machine in country B *may* be higher than that in country A in order to meet the minimum specified performance level or to present premium performance characteristics to the consumer via the label information (something that is not required in country A and therefore suppliers have no incentive to provide).

A *summary* of the differing wash test requirements, mandatory performance requirements and labelling declarations is given below[28]:

- **Australia** defines a minimum wash performance and rinse effectiveness (for warm wash) with energy and water consumption as labelled variables. The warm wash temperature test has water inlet temperature of 20°C and a 40°C wash. Australian normalisation has been undertaken based on the nominal warm wash temperature defined in the local standard. However consumers are known to perform a large number of washes in cold water (at the temperature of water intake or similar). **Hence, comparative benchmarking of Australian data, particularly that data**

[28] For more details on local test requirements, mandatory performance requirements and labelling declarations, please refer to individual country/region mappings provided at http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=3

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associated with top-loading washing machines, should be treated with extreme caution[29].

- **China** requires the declaration and labelling of energy consumption only. Nominal test temperatures are water inlet temperature of 20°C and a 40°C wash. However, the labelling requirements are based on the specific functionality of the machine which is not recorded in the aggregated market data provided. Therefore, data provided indicates that average washing machines consume less energy than that required simply to heat water through the temperature change required for testing. As it has been impossible to obtain a dataset that accounts for the differences in functionality, Chinese data has been excluded from the Benchmarking Analysis.

- **EU countries** have had, until recently, 'voluntary' minimum energy performance requirements and mandatory labelling of energy, wash quality, spin effectiveness and noise (current regulatory revisions involve the removal of wash quality as a labelled item), but other variables are not regulated or reported to the consumer. The wash temperature test is 60°C with a cold water inlet of 15°C (recent revisions change wash temperatures to a weighted average of wash temperatures but these revisions occur after the last date of data analysed).

- **Switzerland** has identical labelling requirements to the EU from 2003 onward, with the additional requirement for mandatory energy performance levels from 2010 onward (equivalent to 'A' on the EU energy label).

- **The Republic of Korea** has mandatory energy performance requirements and labelling of wash quality, rinse effectiveness and spin effectiveness. Different testing methodologies are used for front-loader units (similar to the EU but with water inlet temperature of 15°C and a 40°C wash) and top-loader units (water inlet temperature and wash of 15°C).

- **US/Canada** have mandatory energy and water consumption requirements (water currently only in the USA) but other variables are not regulated and have no labelling requirement.

  Wash temperature and water inlet temperatures are nominally 57.2°C and 15.6°C respectively. However, declared energy and water consumption is based on the average machine consumption over a range of cycle conditions (in particular the quantity and temperature of water used). A shortcoming of the normalisation methodology used is that it is based on a unit energy consumption value for a specific set of operating conditions. As the normalisation of data from Canada and the USA is based on this average unit consumption at the nominal operating temperatures rather than a value at a specific operating condition, the resulting normalised data will be less comparable than normalised results from other

[29] Refer to Annex 3, in particular the section *Test Declarations, Actual Water Temperature and 'Normal Usage'* for details of the sensitivity of the normalisation approach and benchmarking outcomes to temperature variation.

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countries, although the *relative* positioning of results from Canada and the USA are highly likely to be comparable.

Further, in 2004 the Canadian and USA test method/energy reporting algorithm was revised. This revision included changes to the balance of wash temperatures**, such that the hot and warm wash cycles were assigned lower weighting factors after 2004.** This revision, on average, will tend to result in higher energy consumption values being reported prior to 2004 in comparison with those after[30].

Additionally, the load (tub) capacities of washing machines in Canada[31] are declared based on the physical internal dimensions of the machines. These have been converted to a nominal kilogramme load equivalent to those elsewhere based on a standardised conversion of tub capacity to kilogrammes provided in the national standards. Such load conversion may not be accurate for all machines.

Thus, benchmarked data from Canada and the USA is presented in separate sections. The results presented in these sections should be interpreted in the context of the limitations in comparability with washing machine performance from elsewhere as outlined above.

Approach to normalisation

While recognising that key performance characteristics (energy consumption, load type and size, wash quality, etc.) are all intrinsically linked:

- No public domain information has been identified that has allowed the Mapping and Benchmarking Annex to compare washing machines of differing performance across all the performance variables;
- There is limited public domain information on the impact of the various testing methodologies on the reported overall performance of individual units, or indeed, to convert the individual performance characteristics where they are measured differently (for example the spin effectiveness using the European test method and load compared with test methods and loads elsewhere);
- Original data available to the Annex has varying levels of detail ranging from product level information on almost all performance variables, to aggregated market averages of energy performance only.

Therefore, the benchmarking analysis and reporting is restricted to:

- Normalisation of energy consumption based on a correction for nominal test/performance standard water inlet temperatures and wash temperatures (see below);

[30] Appendix J1 introduced the drying energy into the MEF metric, the post-2004 energy consumption values used for this report do not incorporate drying energy (i.e., they represent only machine electrical + hot water energy).
[31] A similar conversion would have been required for washing machines in the USA. However, load capacity data from the USA was not available.

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- Data that is 'as declared under local test methodologies' for all the individual performance characteristics of the washing machines other than energy, i.e. no normalisation was undertaken to account for variations in the measurement of these variables between testing regimes, nor for the associated impact on energy consumption.

Methodology for normalisation of energy consumption based on local test methodologies

Energy consumed by washing machines can be broken down broadly into two elements:

- **Mechanical energy** primarily used to pump water in and out of the washing machine and to provide the agitation of the wash through drum rotation, impeller action or other means, plus the energy used in any spinning to remove water from the laundry at various points in the cycle;
- **Water heating energy** which is the energy required to raise the water from inlet temperature to the specified wash temperature.

None of the data reported to the Annex separate the energy used in these two elements, nor is such reporting required in any of the local regulations reviewed. However, during the development of the process for normalisation of unit energy consumption, the Australian Government provided access to significant quantities of testing information that indicated the mechanical energy used by a washing machine was typically in the range 140-180 W cycle, i.e. typically between 10% and 20% of total washing machine consumption. Consequently, even a significant reduction (for example 20%) in this mechanical energy consumption would lead to relatively minor changes in the overall energy consumption of the washing machine. Therefore, the Annex participants agreed to focus attention on normalising for variations in nominal test temperatures between countries (hence focusing attention on water heating energy) by assuming a nominally fixed mechanical energy consumption of 150 Wh/cycle for all washing machines.

Using this approach, even where the total amount of water heated in the cycle is unknown (e.g. many units use an undeclared combination of hot and cold water during the washing and rinsing cycles), the total energy consumed in water heating can be deduced by:

Water heating energy = Total declared energy consumption – 150 Wh

Normalisation can then be achieved through:

Normalised energy consumption = Water heating energy consumption x (test methodology wash-inlet temperature)/(nominal wash-inlet temperature)

where nominal temperatures are:
Inlet temperature = 15°C
Wash temperature = 40°C
(see Differences in local test methodologies and regulations *above for local test temperature).*

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The following example illustrates the normalisation process:

Declared energy consumption of washing machine = 1 kWh/cycle

By assuming mechanical energy consumption of 150 Wh/cycle

'Water heating energy' = 1000 Wh – 150 Wh = 850 Wh

Now assuming:
Test method water inlet temperature = 20°C
Test method water wash temperature = 60°C

Then
Normalised water heating energy = 850 x (40-15)/(60-20) = 850 x 0.625
∴ Normalised water heating energy = 850 Wh x 0.625 = 531.25 Wh

And
Total normalised energy consumption of washing machine = 531.25 Wh + 150 Wh
∴ Total normalised energy consumption of washing machine = 681.25 Wh

Clearly this approach has flaws of which readers should be aware when reviewing inter-country comparisons. In particular:

- Washing machines are optimised to local conditions. Therefore, simple correction of water temperature is not thoroughly robust as units tested at a lower temperature (typically) require less water to achieve the same wash performance when operated at higher wash temperatures. Hence normalisation using the original water quantity is somewhat misleading.
- The normalisation of Canadian and US data is based on the average machine consumption over a range of cycle conditions (in particular the quantity of water used). **Thus, benchmarked data from Canada and the USA is presented in separate sections and should be interpreted in the context of the limitations in comparability with washing machine performance from elsewhere as outlined above.**

Test declarations, actual water temperature and 'normal usage'

The difference in the requirements of individual testing methodologies and the 'normal use' of washing machines by consumers adds one further complication to the interpretation of benchmarked data. To provide an illustration, Figure 23 compares the normalised unit energy consumption results for Australia using Australian nominal test temperatures (40°C); the equivalent normalised results for the EU as a whole using EU nominal test temperatures (60°C); and the same EU data using a nominal wash temperature of 43°C (which is both closer to the average wash temperature used by consumers, and *also* closer to the actual

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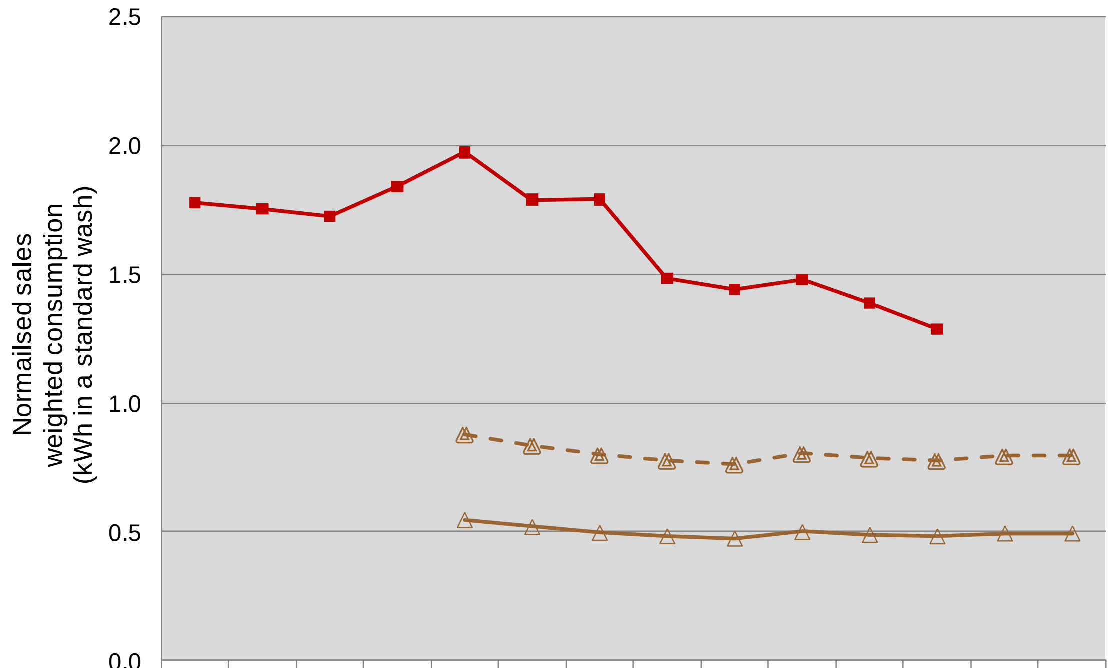
average hot water temperature achieved by a small number of units undergoing the compliance testing in the UK).

As can be seen, the comparative difference in performance between EU and Australian washing machines falls sharply when the 43°C nominal temperature is used for EU machines. This demonstrates the sensitivity of this normalisation approach to nominal test temperatures. This is known to be of particular relevance to benchmarking data for Australia where normalisation has been performed to the nominal warm wash test temperature, however consumers are known to perform a large number of washes in cold water (at the temperature of water intake or similar). **Hence, comparative benchmarking of Australian data, particularly that data associated with top-loading washing machines, should be treated with caution.**

Figure 23. Comparison of impact of varying test temperatures vs consumer usage on normalisation results.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia (40 degC)	1.778	1.752	1.726	1.842	1.973	1.789	1.790	1.484	1.442	1.479	1.389	1.285		
EU (60 degC)					0.55	0.52	0.50	0.48	0.47	0.50	0.49	0.48	0.49	0.49
EU (43 degC)					0.88	0.84	0.80	0.78	0.76	0.80	0.79	0.78	0.79	0.79

Important cautions

The above descriptions of the limitations of original data and the normalisation approach to benchmarking lead to the following summary cautions of which readers should be aware:

- All original data and the benchmarking results derived from them are not 100% comparable and have been graded to provide an indication of the quality/comparability.

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- Normalisation has been based on the energy used for water heating only which has limitations both in approach (and its particular sensitivity to variations in test temperature and water consumption) and due to the optimisation of machines to local requirements.
- Individual performance attributes (wash quality, spin effectiveness, etc) of the washing machines have not been normalised nor accounted for in the normalisation of energy consumption.
- The use of the washing machine by consumers may be significantly different from the conditions under test. The data and analysis on energy consumption and other performance attributes presented in this report are based on reported testing outcomes and are likely to be different from those experienced by the consumer.

Summary grading of mapping and benchmarking data

Based on the information on original data quality, the approach to normalisation of data for benchmarking across countries and the associated cautions, a summary of gradings of both mapping and benchmarking data and the associated summary rationale for each are provided in Figure 24.

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Figure 24. Summary classification of original data and benchmarking outputs.

Country	Data classification and limitations
Australia	**Sales weighted source data is Robust, Product weighted source data is Indicative.** High quality dataset consisting of product level data based on mandatory national registration system, sales weighted data more accurately represent actual products sold. **Benchmarking outputs: Sales weighted information is Indicative, product weighted information is Illustrative.** ***However, caution should be used when comparing with other countries given the known consumer preference for cold wash (and hence significantly lower energy consumption than that shown when normalisation is based on nominal test temperatures.***
Austria	**All source data is Indicative.** Product and sales weighted source material based on aggregated market data (although original source is product based with an estimated 90% coverage of the market). **Benchmarking outputs: All information is Illustrative.**
Canada	**All source data is Indicative.** Product weighted data based on high quality product level information. Sales weighted data supplied as market averages with derivation of sales weighting unknown but believed to be reliable. However, material based on Canadian standard measurement methodologies (e.g. unit capacity based on drum capacity) which require conversions to equivalent comparable measurements using established conversion methodologies, but which may not be accurate at the individual product level. Unit Energy Consumption data prior to 2004 *is not* 100% comparable with earlier data. In 2004 the Canadian and USA required test method/energy reporting algorithm was revised. This revision included changes to the balance of wash temperatures**, such that the hot and warm wash cycles were assigned lower weighting factors after 2004.** This revision, on average, will tend to result in higher energy consumption values being reported prior to 2004 in comparison with those after. It is also possible that manufacturers, anticipating the changes to the test procedure which provided more credit to colder wash settings, incorporated additional, cooler-temperature settings which would get averaged in to lower the rated energy use with no physical changes to the machine. Drying energy was also included within the test which may have resulted in manufacturers increasing spin speeds to give a net improvement in reported efficiency, although the additional drying energy is not included in the data reported within this report.[32] **Benchmarking outputs: All information is Illustrative and comparisons with other countries should be undertaken within the context of the cautions outlined above.**

[32] For more detailed information on the revision and associated impact, please refer to the USA mapping document at http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=3.

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Country	Data classification and limitations
China	**All source data is Illustrative.** Original source data supplied from the mandatory national registration system in the form of averages. However, the protocol for expired products being removed from this database is unknown (hence data may include products no longer available) and test procedure does not provide a mandatory temperature requirement. **Benchmarking outputs:** ***Due to the uncertain nature of the quality of this data source, information on China is excluded from the analysis.***
Denmark	**All source data is Indicative.** Data believed to provide comprehensive picture of both models available and sales. However, data presented based on each EU labelling category with specific model based energy consumptions unknown and assumed to be mid-point of labelling category (which is *likely* to result in slightly better energy performance than the true market average). **Benchmarking outputs: All information is illustrative.**
Korea	**All source data is Indicative.** Data based on compulsory product registration system (for top-loaders from 2001 and front-loaders from 2007). However, significant assumptions were necessary for the date products ceased to be on the market. **Benchmarking outputs: Data is Illustrative (front-loaders only). Due to the lack of definition of a test temperature for top-loading units, these units have been excluded from the benchmarking analysis.**
Switzerland	**Sales weighted source data is Indicative.** Only combined sales weighted data (i.e. both top and front-loader) available and supplied as market averages. However, the original dataset from which averages are defined is believed to be representative of the market as a whole. **Benchmarking outputs: Data is Illustrative (and is not sub-divided into top and front-loading units)**
UK	**Front-loader sales weighted source data is Robust, front loader product weighted source data is Indicative.** Data supplied on a model level basis and both product and sales weighted data believed to be representative of the market. However, some issues with data reliability for the years 1999 to 2001. Note the UK market is very strongly dominated by front-loading units with information on top-loading machines very limited (in some years only 2 models are known to be available). Therefore, to ensure no distortion of data analysis, benchmarking is limited to front-loading machines only with this also believed to be representative of the market as a whole. **Benchmarking outputs: Sales weighted information is Indicative, product weighted information is Illustrative.**

The information and analysis contained within this summary document is developed to inform policy makers. Whilst the information analysed was supplied by representatives of National Governments, a number of assumptions, simplifications and transformations have been made in order to present information that is easily understood by policy makers, and to enable comparisons with other countries. Therefore, information should only be used as guidance in general policy - it may not be sufficiently detailed or robust for use in setting specific performance requirements. Details of information sources and assumptions, simplifications and transformations are contained within the document or the related Mapping Documents.

Country	Data classification and limitations
USA	**Sales weighted source material is Indicative.** Sales weighted data sourced from an industry body in aggregated form and considered to be representative of the market. However, material based on USA standard measurement methodologies (e.g. unit capacity based on drum capacity in gallons) which require conversions to equivalent comparable measurements using established conversion methodologies, but given data based on market averages rather than product level, conversions may not be completely accurate. Unit Energy Consumption data prior to 2004 *is not* 100% comparable with earlier data. In 2004 the Canadian and USA required test method/energy reporting algorithm was revised. This revision included changes to the balance of wash temperatures**, such that the hot and warm wash cycles were assigned lower weighting factors after 2004.** This revision, on average, will tend to result in higher energy consumption values being reported prior to 2004 in comparison with those after. It is also possible that manufacturers, anticipating the changes to the test procedure which provided more credit to colder wash settings, incorporated additional, cooler-temperature settings which would get averaged in to lower the rated energy use with no physical changes to the machine. Drying energy was also included within the test which may have resulted in manufacturers increasing spin speeds to give a net improvement in reported efficiency, although the additional drying energy is not included in the data reported within this report[33]. Product weighted data is based on ENERGY STAR and is robust *but* represents only most efficient proportion of the market. **Benchmarking outputs: All information is Illustrative and comparisons with other countries should be undertaken within the context of the cautions outlined above.**
EU	**All source data is Indicative.** Data supplied on an aggregated market level. However, original data source is at model level and is believed to be representative of the whole market. **Benchmarking outputs: All information is Illustrative.**

Given the significant differences in measurement methodologies and reporting protocols, all non-energy variables, i.e. load, water consumption, drying effectiveness and wash quality, are presented as Illustrative.

[33] For more detailed information on the revision and associated impact, please refer to the USA mapping document at http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=3.

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Annex 4 Policy summary table

The following table summarises the timetable for key mandatory and voluntary labelling requirements, minimum energy performance standards (MEPs) and major voluntary industry actions in each of the countries/regions featured in the analysis.

	Australia	Canada	EU Countries	Korea	Switzerland	USA	China
Pre-1990		Mandatory labelling introduced in 1978					MEPs introduced in 1989
1990							
1991							
1992							
1993							
1994						MEPs introduced	
1995		MEPS introduced					
1996			Mandatory A-G Label for efficiency (and wash and spin performance). Industry Voluntary Agreement to remove E F and G rated by 1999, and D rated by 2003.				
1997						Introduction of voluntary ENERGY STAR labelling	
1998	Introduction of Mandatory Labelling of Energy Consumption (6 Star Rating System) including minimum wash and spin performance. Requirement to register product				Mandatory labelling introduced		

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	Australia	Canada	EU Countries	Korea	Switzerland	USA	China
1999			Introduction of Voluntary Eco-Label				
2000							Voluntary certification labelling introduced
2001		ENERGY STAR introduced		Mandatory labelling. Product registration and MEPS for vertical axis machines (1-5 scale)			
2002			New A+ labelling category adopted informally by industry. New Industry Voluntary Agreement to improve 'fleet average efficiency' by 2008 (to 02 kWh/kg)		Announcement of the adoption of EU A-G labelling		
2003					Mandatory use of EU A-G labelling		
2004		Revised MEPs (with associated revision to test standard and required mix of load/temperature tests) ENERGY STAR requirements revised				MEPs revised (with associated revision to test standard and required mix of load/temperature tests) ENERGY STAR requirements revised	
2005							MEPs and certification level revised
2006	Inclusion of mandatory rinse performance			Mandatory labelling, product registration and MEPS for horizontal axis machines (1-5 scale)			

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	Australia	Canada	EU Countries	Korea	Switzerland	USA	China
2007	Inclusion of standby power in derivation of label rating. Additional Water Label introduced (also 6 Star rating system)	ENERGY STAR requirements revised (including the addition of a water requirement) MEPS revised to harmonise with the US (no water efficiency requirement in Canada)		Introduction of Maximum Stand-by Power (off mode) requirement. Revised vertical axis MEPS		MEPs and Water Standard revised Revised ENERGY STAR product efficiency and water requirements	Mandatory labelling (1-5 scale) and product registration
2008		Addition of commercial clothes washers to the regulations					
2009		ENERGY STAR requirements revised		Revised MEPS for horizontal axis machines		ENERGY STAR requirements revised	
2010							
Post 2010		New ENERGY STAR minimum energy and water efficiency requirement effective Jan 20, 2012 Anticipated new MEPS standard in 2011 effective 2015 and 2018	Revised Energy Label (A+++ to D) MEPS revised : 1 December 2011 minimum requirements for washing efficiency (class A), energy efficiency (class A) and water consumption (according to formula). MEPS second revision: 1 December 2013		Revised Energy Label (A+++ to D) with required minimum A wash quality - effective December 2011	New ENERGY STAR product efficiency and water requirements (2011) Anticipated new MEPS standard in 2011 effective 2015 and 2018	

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