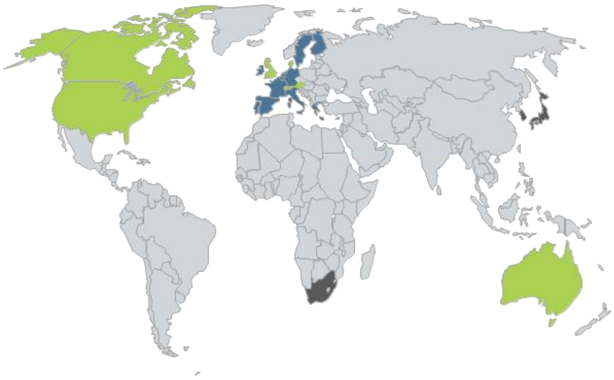
Technology: Residential Laundry Dryers



Participating countries:
Australia, Austria, Canada, Denmark, Switzerland, UK, and USA.

Other regions covered:
EU (CECED), France, Spain.

Other funding countries:
France, Japan, Netherlands, Republic of Korea, South Africa.

Energy efficiency benchmarking report on residential laundry dryers

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Benchmarking Energy Efficiency of New Laundry Dryers

1 Summary for policy makers

This study analyses the energy efficiency of residential laundry dryers with capacities between 4 kg and 10 kg of dry textiles and also looks at national/regional policies that influence efficiency. The study only covers electrically heated dryers in which textile material is dried by tumbling in a rotating drum through which heated air is passed. Dryers heated by burning gas, drying cabinets and washer dryers are excluded from the analysis. For the detailed product definition see http://mappingandbenchmarking.iea-4e.org/.

Data were submitted by seven countries covering altogether the performance of over 8,000 individual products between 1996 and 2010 for: Australia, UK, USA, Canada, Denmark and also using non-government data to cover France and Spain. In addition market average statistics were submitted for Austria, Switzerland and EU as a whole[1].

Energy performance data as declared from regional testing cannot be compared directly between USA/Canada and Australia and Europe due to significant differences in test methodology. Normalisation of declared data was carried out in a series of adjustments for initial and final moisture levels, appliance loading, fabric type and ambient conditions. Normalisation adjustments of energy performance range from 13% to over 50% for different countries. Due to non-robust evidence underlying some adjustments, comparisons should be treated as only illustrative, particularly between USA/Canada and the other countries.

Product efficiency

A consumption metric of kWh per cycle is often used, but the most useful metric is that for efficiency of kWh/kg of dry fabric which is the basis of labelling and Minimum Energy Performance Standards (MEPS) in most countries. National average efficiency levels in Europe, USA, Canada and Australia (as normalised) appear to be converging for 2010/2011 at around 0.7 kWh/kg as in Figure S1 below. But this convergence hides significant differences between countries in trends and in national spread of best to worst product performance as shown in Figure S2.

Normalised data implies that Swiss average efficiency has improved the most since 2003, when it was the worst in the study, to become the best amongst European participants by 2010 at around 0.69 kWh/kg. This has almost certainly been achieved through policy support of the market for heat pump appliances in Switzerland. The Swiss and Austrian average

[1] Data for the EU were provided by CECED, the European federation of manufacturers of domestic appliances, (see www.ceced.org). Data for France were made available from the EAIS database (previously available from www.eais.info, although the website became unavailable late 2010 or early 2011), and for Spain from IDAE (see www.idae.es).

efficiencies are on the point of overtaking that of Canada (as normalised), which has changed by less than 4% in 16 years. The small amount of Spanish data obtained from non-government sources also matches this level of efficiency.

The gap between average efficiencies of countries has narrowed significantly in recent years: In 2003 the worst lagged behind the best by 25% but by 2010 the gap had narrowed to only 6%. Looking at the spread of performance within each country, best to worst as shown on Figure S2 below, the shape of each country's profile is very different. There is a range of +/-25% on efficiency for Europe and Australia but the spread of efficiency of USA and Canadian products is only +/-7%. EU and Australian markets include products both better and much worse than Canadian/USA products (normalised), which implies significant scope for improvement in all markets.

National energy consumption

Of the six countries able to provide government estimates of national stock and annual energy consumption of laundry dryers, Canada had by far the largest at over 10 TWh per year (2007). This was followed by the UK at 4 TWh and Australia, Austria, Denmark and Switzerland with less than 1 TWh. However, Austria has over 10% annual growth in energy consumption, closely followed by Switzerland at 7% with others of these six at 5% or less per year. Usage patterns are crucial to understanding and influencing national energy consumption. Cultural differences, the effects of differing climates, some local by-laws banning drying laundry outside and differences in the built environment have resulted in very different situations: In Canada usage of dryers seems typically around 420 cycles per year, with similar levels in the USA but an average of fewer than 200 in Europe (it is known to vary across Europe) and only around 50 cycles per year in Australia. A shift in usage patterns (e.g. more use of air drying) could have a far greater influence on national consumption than any improvement in energy efficiency of appliances.

Condensing versus vented appliances

Condensing appliances account for well over 50% of European markets and there is an ongoing trend towards more condensing type appliances in Europe, probably for user-convenience reasons due to having no need for an external vent. Condensing appliances account for only a few percent of the USA/Canadian market; condensing products appear not to be available on these markets and anecdotal evidence suggests this could be due to their higher cost and reluctance of USA consumers to accept longer cycle times. Overall, evidence appears inconclusive on whether there is any significant difference in the consumption or efficiency of vented versus condensing appliances.

Heat pump appliances

Heat pump appliances are a particularly efficient variant of condensing appliances that recycle most of the heat used to evaporate moisture. They typically consume less than half the energy of conventional vented and condensing appliances, achieving an energy efficiency of between 0.4 kWh/kg to just less than 0.3 kWh/kg (normalised). This compares with between 0.6 and 0.9 kWh/kg for conventional vented/condensing appliances. Heat pump appliances account for only a few per cent of most markets but policy focus has boosted sales in Switzerland and Austria to over 25% of their markets by 2009, contributing to noticeable average performance improvements. A price premium of around 30% is typical for heat pump products from major brands, although in Switzerland and Austria local brands appear able to match non-heat pump prices.

Size of appliances

The average capacity of appliances in Australia and Canada has been around 5 kg for the past decade, with USA appliances static at that same level for at least four recent years. In contrast, the markets in the UK, Austria, and Denmark, and to a lesser extent Switzerland, have shown a steady rise to above 6 kg, having grown by around 30% in seven years. This is a growth of capacity of just under 5% per year and apparently remained an ongoing trend in 2009.

Policies

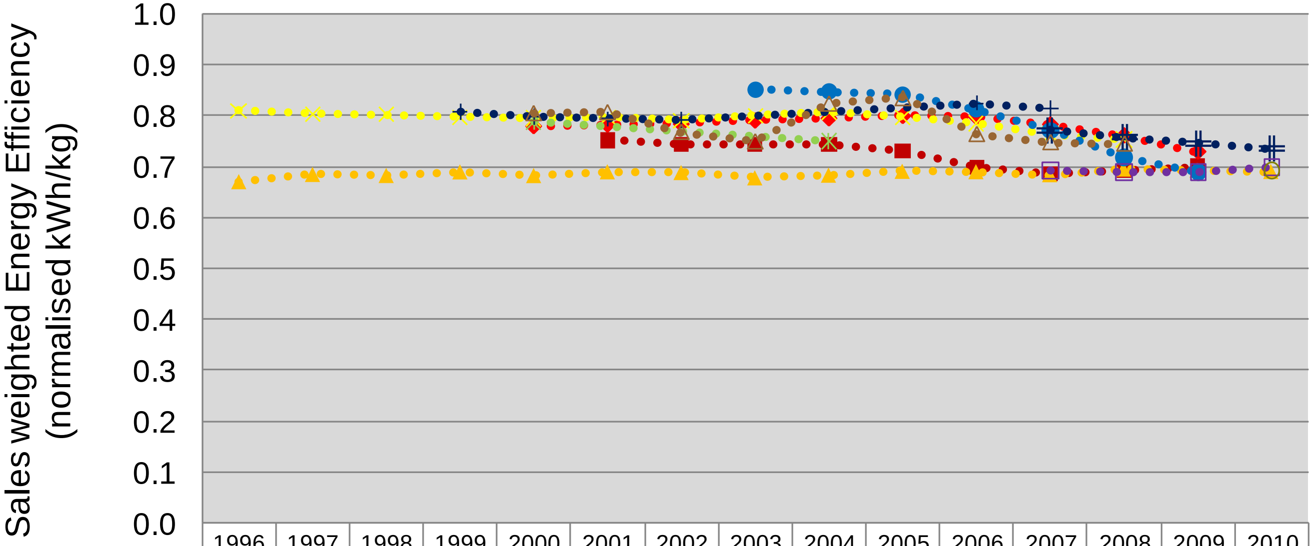
Energy labelling is in place in all of the participating countries (with significant variations in test/measurement approach as noted above). A small number of countries have mandatory standards, and levels of these MEPS varies considerably.

The long term MEPS in place since 1995 in Canada and the USA appear to have achieved improved efficiency and reduced the spread of performance in these countries; Canadian products are seen to cluster closely under the MEPS level (Figure S2 below). On the other hand, the best performing products in Canada and USA are less efficient than the best products in the UK and Australia, even disregarding heat pump products. Australia has a performance requirement less demanding than the USA/Canadian MEPS built into its labelling regulation. This requirement appears not to have significantly influenced its market compared to European countries. No standards exist EU-wide at present, but these are under consideration under proposed eco-design regulations. Switzerland will introduce a mandatory requirement for EU energy label A (requiring 0.35 kWh/kg, normalised) in 2012. All types of appliance other than heat pump appliances will be unlikely to meet this. Policies introduced by Swiss and Austrian governments have already made significant progress in promoting heat pump products and addressing the price premium. These policies appear to have been successful in achieving much improved market penetration of heat pump products, and associated improvements in average efficiency.

The average energy efficiency of European products appears gradually to have improved to match in 2010 the levels of efficiency attained in North America 15 years ago. But whilst market average performance might be similar, MEPS at the same (normalised) level as those in USA/Canada would eliminate poorly performing products from the European market. This would eliminate just over half of the combined EU, Australian and Danish products shown in Figure S2 and would lift that combined average efficiency (product-weighted) by 9%. The average product performance could then be better than that in Canada/USA due to the number of highly efficient products available in Europe and Australia.

Adopting more stringent MEPS as per those proposed in Switzerland for 2012 (eliminating all appliances with efficiency worse than 0.35 kWh/kg, normalised) would save around 60% of consumption compared to typical EU and Australian appliances in 2009 and would eliminate well over 90% of current products from markets other than Switzerland and Austria.

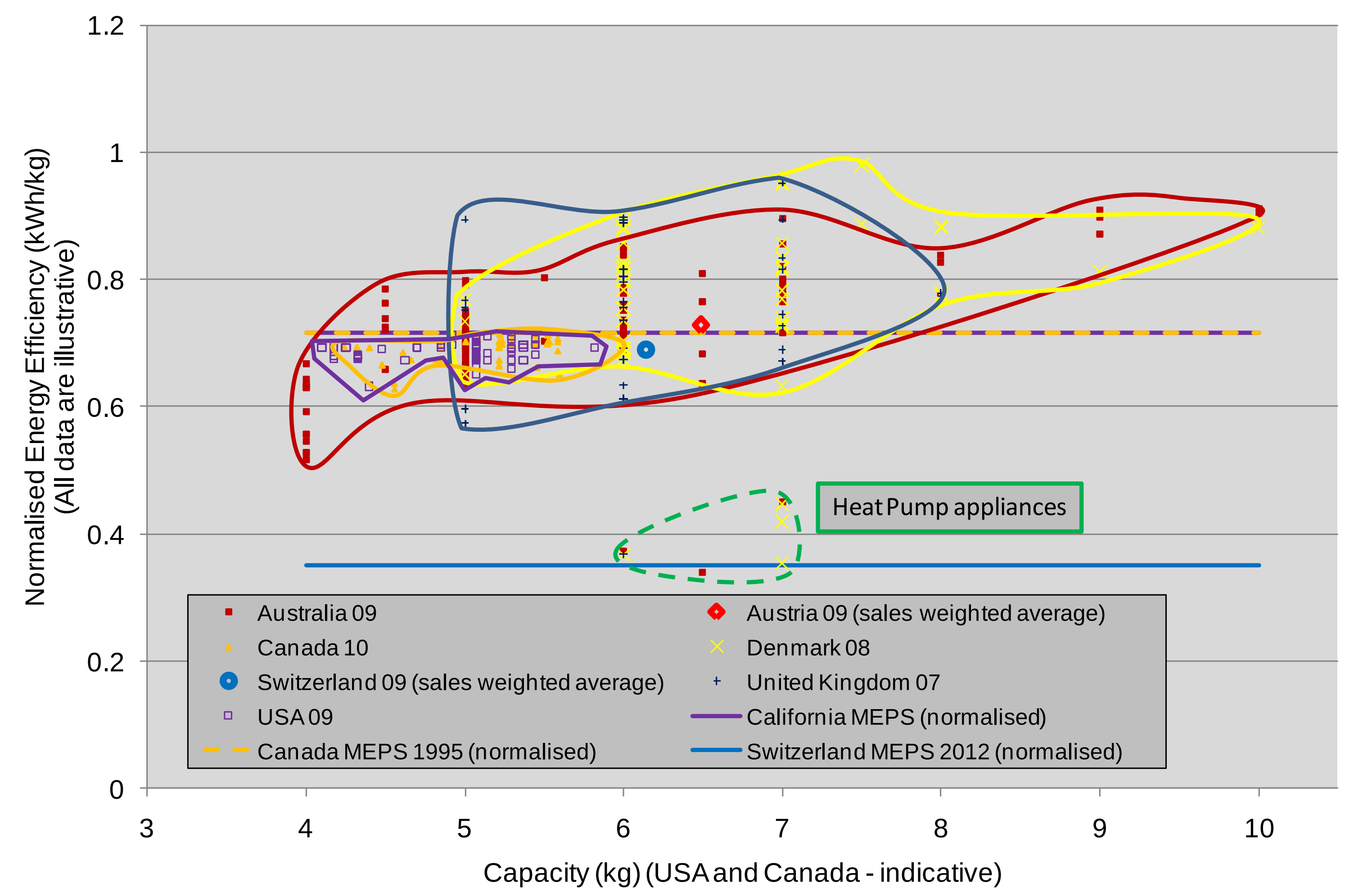
Figure S1. Sales weighted (where available) energy efficiency of laundry dryers. Data normalised (adjusted) to be mutually comparable, and are only illustrative due to uncertainties of that process (illustrative).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Australia						0.75	0.74	0.74	0.74	0.73	0.70	0.69	0.69	0.70	
Austria					0.78	0.78	0.78	0.79	0.79	0.80	0.80	0.78	0.76	0.73	
Canada (Product Weighted)	0.67	0.68	0.68	0.69	0.68	0.69	0.69	0.68	0.68	0.69	0.69	0.68	0.70	0.69	0.69
Denmark	0.81	0.80	0.80	0.80	0.79	0.80	0.79	0.80	0.81	0.80	0.78	0.76	0.75		
France - EAIS (Product Weighted)					0.79				0.75						
Switzerland								0.85	0.85	0.84	0.81	0.77	0.72	0.69	
United Kingdom				0.81	0.80	0.79	0.79				0.82	0.81			
UK - SUST-IT (product weighted)												0.77	0.76	0.75	0.73
USA - CEC (product weighted)												0.69	0.69	0.69	0.70
EU (Product Weighted)					0.81	0.81	0.77	0.75	0.82	0.84	0.76	0.75	0.74		
Spain - IDAE (Product Weighted)															0.69

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

Figure S2. Scatter plot of laundry dryer efficiency (normalised) also showing MEPS levels where they exist and perimeter of each country's dataset. MEPS levels have been normalised in the same way as their respective country's data (illustrative).



Contents

2 About the data used and analysis method

2.1 Important cautions for interpreting and using mapping and benchmarking information

Considerable efforts have been taken to ensure the integrity of the data supplied and the subsequent data manipulation and analysis. The generic approaches are detailed in the overall Mapping and Benchmarking Framework[2] and in the Laundry Dryer Product Definition[3,] However, to ensure readers are fully aware of the reliability of particular sets of data, and any associated assumptions or transformations that have been necessary, a *'Framework for Grading Mapping and Benchmarking Outputs'* has been developed that is used across all of this project's outputs. These gradings are based on a scale as follows:

- **Robust:** Datasets are representative of the full market and there is significant confidence in the transformation used to make the dataset comparable with others. Comparisons within and between such datasets are as reliable as reasonably possible within limits outlined in section 3.2 Data sources.
- **Indicative:** Datasets are not fully representative of the market and/or there are minor concerns with the reliability of the transformation used to make the dataset comparable with others. Hence indicative data provide meaningful but qualified comparisons.
- **Illustrative:** Datasets poorly represent the market and/or there is significant concern with the reliability of the transformation used to make the dataset comparable with others. Hence any associated results and conclusions must be treated with caution.

Full details of the system for grading are provided in Annex 2. The specific gradings allocated to each dataset are summarised in Table 1, Table 2 and Table 3.

[2] Refer to Annex framework at http://mappingandbenchmarking.iea-4e.org/, accessed 16 June 2011.
[3] Refer to detailed product definition at http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=6, accessed 16 June 2011.

2.2 Data sources

There are two basic categories of data used in this analysis:

- ‘Conventional data’ are those provided by the participant country representatives, usually government sources.
- ‘Alternative data’ are those sought out by the contractors undertaking this project analysis. This can be commercial or other third party providers, trade associations etc.

The data for this laundry dryer analysis were sourced for seven participating countries from Government representatives and agencies. This included data for over 8,000 individual products between 1996 and 2010 covering seven countries, plus market average statistics for Austria, Switzerland and the EU.

The total number of appliances for which data was included in the analysis broken down by year and by country is shown in Figure 1, with tabulated data on this given in Table 18 on page 62. The ‘conventionally’ sourced data are characterised by quality in Table 1 (product weighted) and Table 2 (sales weighted).

Searches were made via the Internet and by contacting key trade associations and manufacturers as part of a pilot for supplementing conventional data with those from ‘alternative’ sources. This added data for some 1,900 products from third-party databases, commercial or not for profit providers, trade associations and also sub-national initiatives including data for Spain, France and for the EU. These data from alternative sources are characterised for quality in Table 3. The alternative sources supplemented USA and UK data by adding years for which no conventional data were available.

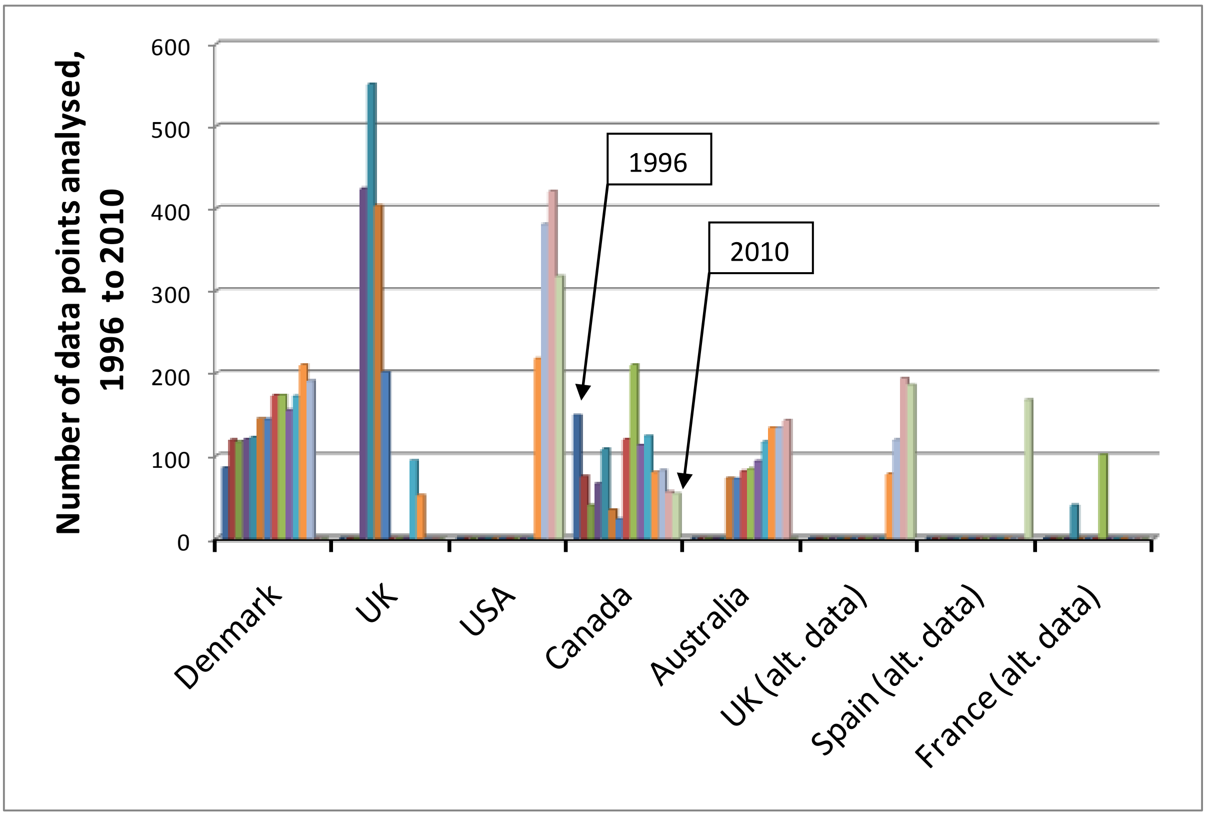
In addition, the various TopTen websites databases were used to seek best in-class products.

Several other alternative data sources were identified but rejected as being of insufficient quantity to merit analysis, or having data embedded in graphics/text and so difficult to extract, of insufficient quality, or of unknown quality/origin.

Further information about data sources is provided in the mapping document for each country.

Data quality (robust, indicative, illustrative) is assigned to data both as declared by suppliers in the databases and after normalisation. Comparisons between Canadian/USA results and EU/Australian results remain only illustrative due to remaining uncertainties relating to different fabric types used in tests and other aspects of normalisation that required significant adjustments to the original data.

Figure 1. Bar chart giving a visual overview of the relative quantity and time series spread of appliances analysed for each country. For each country's set, 1996 is at left (dark blue); 2010 at right (light green). Countries are ranked from left to right in descending order of total number of products in the datasets.



Note on Figure 1: The numbers for this graph are given in Table 18 on page 62 for a more detailed insight.

Table 1. Overview of quality of available *product* weighted data from conventional sources (i.e. data on individual products).
Note: Data quality is assigned both as declared by those who supplied the data in the databases, and after normalisation (see notes below table), see also Table 18 on page 62 for details on product data submissions.

Country	Products analysed (most recent year)	Assigned quality as declared	Assigned quality after normalisation	Source
Australia	143 (2009)	**Indicative**	**Illustrative**	Mandatory federal register
Austria	-	n/a	n/a	(No product data, only market averages)
Canada	54 (2010)	**Indicative**	**Illustrative**	Mandatory federal register
Denmark	191 (2008)	**Illustrative**	**Illustrative**	Manufacturers' data plus survey
Switzerland	-	n/a	n/a	(No product data, only market averages)
UK	52 (2007)	**Indicative**	**Illustrative**	Government modelling and GfK (commercial retail sales) data
USA	318 (2010)	**Indicative**	**Illustrative**	Federal Trade Commission data

Justification for data quality assessments for Table 1

i. No product-weighted dataset can be better than 'Indicative' as it cannot represent sales weighting.
ii. All normalised data are only illustrative due to known uncertainties in the normalisation process (see section Overview of analysis approach).

Declared product-weighted data:

iii. Australia - from a mandatory government database with well over 100 products a year in recent years (suppliers' declared data), considered representative of whole market.
iv. Canada – from a government energy labelling database, over 200 products per year in recent years, considered representative of whole market.
v. Denmark – model specific data is based on a list of products provided to government by manufacturers, with the year that they were introduced onto the market; therefore not fully representative of all products on sale in a given year.
vi. UK – product data from a commercial provider (GfK) cleaned and assimilated into modelling by government analysts. Market coverage down to around 50% for some years with a significant minority of products appearing to have inappropriate performance levels resulting in a downgrading of quality assessment. See also alternative sources table.
vii. USA - Federal Trade Commission database of manufacturers' declared data for 2010 (see also alternative sources) considered representative of the whole market.

Table 2. Overview of quality of available *sales* weighted data from conventional sources.
Note: Data quality is assigned both as declared by suppliers in the databases and after normalisation (see notes below table), see also Table 18 on page 62 for quantities of product data.

Country	Assigned quality as declared	Assigned quality after normalisation	Source
Australia	**Robust**	**Illustrative**	Mandatory federal register, normalised
Austria	**Illustrative**	**Illustrative**	Converted from energy label, over half the market covered (GfK data)
Canada	(n/a)	(n/a)	No sales data available
Denmark	**Illustrative**	**Illustrative**	Government survey and energy label data
Switzerland	**Indicative**	**Illustrative**	Manufacturer trade group data
UK	**Indicative**	**Illustrative**	Government modelling and GfK (commercial retail sales) data
USA	(n/a)	(n/a)	No sales data available

Justification for data quality assessments for Table 2:

i. All normalised data are only illustrative due to known uncertainties in the normalisation process.
ii. Australia - from a mandatory government database with well over 100 products a year in recent years (suppliers' declared data), considered representative of whole market.
iii. Austria – market average data from a commercial provider that covers just over half of market sales; energy performance data derived from assumed average consumption figure for each energy label class.
iv. Denmark – based upon household survey indicating sales combined with energy label distribution profile.
v. Switzerland – market average data provided by Swiss manufacturers' trade group, no details of derivation available.
vi. UK – sales data from a commercial provider (GfK) cleaned and assimilated into modelling by government analysts. Market coverage down to around 50% for some years, with a significant minority of products appearing to have inappropriate performance levels resulting in a downgrading of quality assessment.

Table 3. Overview of quality of available data from alternative sources. Only product-weighted data were available from alternative sources (no sales data).
Note: Data quality is assigned both as declared by suppliers in the databases, and after normalisation to take account of known flaws in the normalisation process. See also Table 18 on page 62.

Country	Source (see notes below table)	Products analysed for most recent year	Assigned quality as declared	Assigned quality after normalisation	Source and quality notes
Austria	EAIS	86 (2004)	Not used	-	Whole market but not mandatory. Methodology not known. Not used as old (2004) and less reliable than conventional data.
France	EAIS	101 (2004)	**Indicative**	**Illustrative**	Whole market but not mandatory. Methodology not known. Used, as no conventional data for France available.
Spain	IDAE	168 (2010)	**Indicative**	**Illustrative**	Mandatory government register. Used as no conventional data for Spain available. Not able to verify robustness so assumed indicative.
UK	Sust-it	186 (2010)	**Indicative**	**Illustrative**	Whole market. Used to supplement UK conventional data as this is more recent.
USA (CA only)	CEC	421 (2009)	**Indicative**	**Illustrative**	Mandatory California state register. Used to provide historical data before the FTC data for 2010.
EU	CECED	n/a	**Indicative**	**Illustrative**	Market average data for 1996 to 2009 from European manufacturers' trade association.

Notes on sources:

i. EAIS is the European Appliance Information System, a European Commission funded project. Data was obtained from the Internet site www.eais.info which was available until late 2010 or early 2011, and since unavailable.
ii. NRC is Natural Resources Canada, see http://oee.nrcan.gc.ca/residential/personal/index.cfm?attr=4
iii. IDAE is the Spanish Energy Agency, see www.idae.es/ProductosEficientes
iv. Sust-It is an independent UK based website publishing manufacturers' declared energy efficiency performance product data. See www.sust-it.net/
v. CEC is the California Energy Commission, see www.appliances.energy.ca.gov/
vi. CECED is the European Committee of Domestic Equipment Manufacturers, see www.ceced.org/

2.3 Test methodologies and metrics

The test methodologies from participating countries essentially fall into three groups as summarised in Table 4. These are similar in principle, in that a certain weight of prescribed types of textiles are loaded into the machine with a prescribed moisture content; this is then dried to a prescribed lower moisture content whilst the energy consumed is measured. However, significant differences in details of this process mean that normalisation is required before they can be fairly compared, as described in section 3.4
Overview of analysis approach below.

Table 4. Overview of test methodologies and metrics.

Country	Test methodology	Comments	Capacity metric used	Efficiency metric used
Australia	AS/NZS 2442.1	Basis of Australian MEPS	Weight of (dry) fabric (kg)	kWh/kg
Canada/USA	CAN/CSA-C361-92	Basis of Canadian and US MEPS	Internal volume of drum (cubic feet)	Energy factor (lb/kWh)
EU	IEC 61121:2005	Basis of EU energy labels	Weight of (dry) fabric (kg)	kWh/kg

Consumption metric: kWh/cycle

The most commonly used consumption metric is kWh per ‘standard cycle’, although how a standard cycle is defined varies significantly between regions. However, the efficiency metric is the most useful for comparing product performance between countries and so is more widely analysed in this study.

Efficiency metric: kWh/kg

Two metrics are used for efficiency, kWh per kilogram of dry fabric (Australia and EU) and energy factor which is effectively the inverse of kWh per weight of fabric (measured as lbs per kWh and used in the USA and Canada). kWh/kg of dry fabric has been adopted as the primary metric for efficiency in this analysis, and also as the basis for comparing minimum standards.

However, data are only comparable for consumption and efficiency if the textile load size, fabric types, initial and final moisture levels are the same for the tests. Ambient temperature and humidity will also affect results to a small extent. See the following section for how this is dealt with in data normalisation.

Significant changes were made to the EU test methodology EN61121 in 2005 that affect the energy consumption test results and efficiency data derived from them. The initial moisture content was changed to 60% (previously 70%); the ambient test temperature was changed to 23°C (previously 20°C); and the ambient humidity was changed to 55% (previously 65%).

At the same time as introducing these ambient condition changes, the formula to calculate the energy consumption figure in the test standard was modified to compensate for the energy advantage gained by vented dryers due to the increased temperature and reduced humidity of the air they draw in from the test room. Since this is also used to calculate the applicable EU energy label, the result is that labels earned after 2005 should be directly comparable to those earned before. In this analysis therefore, data based on EU energy label or energy efficiency index should be continuously comparable. In contrast, kWh/cycle data as declared on the energy label, and kWh/kg efficiency data derived from the test methodology will not be comparable before and after 2005 without adjustment (but this situation did not occur and so adjustments did not have to be made).

2.4 Overview of analysis approach

The same analysis approach was applied to both conventional and alternatively sourced data.

It was necessary to break down the market into appropriate classes such that products were fairly compared with similar ones. Heat pump appliances have very different performance levels to conventional vented/condensing appliances and so should be compared separately for the purposes of identifying best in class performers. Similarly, to understand relative performance of technologies, performance levels were separately assessed for vented and condensing products. In terms of size ranges, analysis of available products' size data show that 7 kg as a threshold divides the market roughly in half. This gave the classes as shown in Table 5 but in practice the separation between vented and condensing classes was not reliable, nor the declared categorisation of heat pump products. Note that heat pump assisted appliances are in fact a sub-type of condensing appliances (see also the Laundry Dryer definition document for further details of product types). Analysis has been cautious regarding differentiation of condensing and vented products since it was shown during verification of best in class products that labelling of dryer types was not always reliable (see section 8 Best in class products for further information on this).

Table 5. Intended classes for sub-division of appliance types.

Size	Vented	Condensing	Heat pump
4-<7kg			
7-<10kg			

Data cleaning

The following data cleaning steps were carried out:

1. Conversion of US and Canadian data to capacity in kilograms from the declared figures of internal volume of drum in cubic feet. This was necessary in order to apply the capacity limit to exclude compact and larger commercial appliances by analysing only products with a capacity between 4 kg and 10 kg (as explained in the product definition). Conversion was carried out using a look up table in a US Department of Energy Final Rule.[4] In the USA test methodology, 'standard' models are defined as units of 4.4 ft^3 or greater capacity whereas the annex definition is > 4 kg dry textile load; division was adopted for this analysis at the 4 kg equivalent threshold.
2. Dryers with a heat source from burning gas were excluded, as were washer dryers (combined appliances).

Normalisation

Normalisation of performance data was necessary in order to account for the differences in test methodology mentioned above. This involved significant adjustments and because of the inevitable uncertainties with some of these adjustments, normalised data can only be considered as illustrative.

The overall strategy for normalisation of laundry dryer data was to calculate an adjustment factor as a percentage change to be applied to individual product performance data and market averages, to account for each of the following differences between test methodologies:

a) Data are normalised to the **ambient temperature and humidity** test conditions as per the EU test methodology (EN 61121:2005) on the basis that the largest number of datasets submitted are tested to that standard.
b) Data are normalised to the textile load **moisture content (initial and final)** as per the EU test methodology (EN 61121:2005) on the basis that the largest number of datasets submitted are tested to that standard.
c) A normalisation for the different **weight of textile loaded into the drum** during testing. Data are normalised to align with the USA and Canadian methodologies (as listed in Table 4). These methodologies use a fixed textile load of 3.17 kg for standard sized products, whereas the European methodology fills products to their capacity.
d) **Fabric type** used in test: Data are normalised to be equivalent to that obtained with a 100% cotton load, as used in EU and Australian tests.

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[4] Load capacities have been converted from Container Volumes (ft^3) to loads (kg) using the table which defines test loads in the North American washing machine test methodology (page 45,504 *Federal Register*, Vol. 62, No. 166, Wednesday, August 27, 1997). A ratio of 2.5 for the relationship between the load capacity in kg of a clothes washer and a clothes dryer with the same volumetric capacity is assumed (see www.laundry-and-dishwasher-info.com/Tumble-Dryers.html).

Derivation of the normalisation adjustments is summarised in the following paragraphs, with additional detail provided in Annex 3. The magnitude of adjustments made during normalisation to the product performance data of each country is summarised in Table 6.

Table 6. Summary of magnitude of adjustments made during normalisation to energy consumption performance data, for vented appliances as applicable to each country's data.

Country	Ambient temperature	Ambient humidity	Textile load	Moisture content	Fabric types	Total change (average)
	(Vented appliances)		(Average change)			
Australia	-3.56%	0.75%	-31.2%	-29.2%	0%	**-52.7%**
Canada	1.04%	0.25%	0%	-8.2%	4.8%	**-2.5%**
EU	0.00%	0.0%	-36%	0%	0%	**-35.6%**
USA	1.04%	0.25%	0%	-8.2%	4.8%	**-2.5%**

Note: actual magnitude of adjustments made for textile load varies according to the capacity of the appliance; figures show the average for that country.

Ambient air humidity and temperature

The ambient air humidity and temperature (defined in the test methodology) affect energy consumption of vented dryers as this ambient air is drawn through the drum in the drying process. Only ambient temperature will affect condensing dryers as they do not draw the ambient air through the drum, instead recirculating the same air. Energy demand is inversely proportional to ambient temperature; but is directly proportional to ambient humidity. Normalisation is based upon equations explained in the EU Ecodesign[5] study and results in changes of between 0.25% and 4% in energy consumption, depending upon the country. For details see section in Annex 3 Ambient air humidity and temperature – normalise to EN 61121:2005 on page 48. This adjustment is based on physics and should be robust.

Initial and final moisture content

The test methodologies for Canada and USA require a larger change in moisture content than the EU tests (see

[5] *Ecodesign of Laundry Dryers*, Preparatory studies for Ecodesign requirements of Energy-using-Products (EuP) – Lot 16. Final Report - March 2009.

Table 14 on page 54) and so will require more energy per kg of textile load to complete the test. Similarly, the Australian test requires significantly more energy per kg than EU testing to fulfil test requirements. Empirical data were identified to enable estimates of the percentage change in energy consumption associated with a given change of initial moisture content, and final moisture content compared to EN 61121:2005. The two differences (initial and final) are separately calculated for each test methodology and an overall percentage normalisation for moisture content calculated to apply to all energy performance data for each country, as summarised in Table 15. This adjustment is extrapolated from one test report and should be considered illustrative.

Textile load during test

As total energy consumption depends on the base load energy necessary to heat up the appliance, to turn the drum, to control the temperature, etc, it is generally accepted that a higher loading leads to a better efficiency. Proportionately, this base load energy will be lower per kilogram for fully loaded or larger capacity appliances than for part loaded or lower capacity appliances. In general, mapping and benchmarking analysis does not normalise for variations in appliance maximum capacity because this is simply a feature of each machine as opposed to the test methodology. However, for laundry dryers the various test methodologies used to generate the data have different requirements for loading: EU and Australian products are fully loaded for testing whereas USA and Canadian products only have 3.17 kg (7 lb) of textiles during test. Energy results are therefore quite different and it is necessary to normalise before comparison of laundry dryer performance in benchmarking.

Empirical evidence was obtained that relates energy consumption to textile loading level and this was used to derive an equation used to adjust the energy performance figure for each dataset as summarised in Table 17 on page 59. As this has been extrapolated from one test report, it should be considered illustrative.

Fabric type

The energy consumption of a standard cycle carried out with 50% cotton/50% polyester fabrics is around 5% less than one with 100% cotton and the same dry weight (based on empirical evidence, see page 60). The energy consumption for US and Canadian products was increased by 5% to account for this difference in test fabrics. Australian and EU testing is already carried out with 100% cotton loads and so did not have to be adjusted. This has been extrapolated from one test result and should be considered illustrative.

Additional points on the analysis process and how results are considered

- Since two steps in the normalisation process are based upon empirical data from only one test each and extrapolated to apply to all sizes and types of dryer, all data that arise from normalisation are classified as only illustrative.
- The following differences in test methodology that may affect energy performance have not been addressed in the normalisation process: Pre-warming of water used for soaking fabrics; Inclusion of cool down period; Pre-treatment of fabrics prior to test, e.g. type of detergent. The impact of these is considered very small in comparison to the adjustments included but no evidence has been identified to support this.
- The relative comparison between USA/Canadian data and those from Europe/Australia must also be treated as illustrative due to uncertainties associated with normalisation for fabric type and conversion between capacity in cubic feet and capacity in kilograms.
- Whilst normalisation compensates for the different loading during test, a residual efficiency advantage will remain[6] for larger appliances which are tested at full load, i.e. European and Australian ones. Hence, a trend for rising capacity over the years will lead to an improved efficiency for European and Australian appliances but not for USA/Canadian appliances.
- The order in which the normalisation adjustments (as shown in Table 6) are applied does not matter as each is a percentage change (multiplication is commutative).
- In line with an agreed policy for all mapping and benchmarking analysis, no assessment is made on the specifics of tolerances built into the various test methodologies. Tolerances applied to results from testing for laundry dryers are a source of particular concern amongst some experts in Europe[7] but this has not been analysed in this study.
- The analysis of efficiency (kWh/kg) was based upon efficiency levels calculated from the declared energy consumption (kWh/cycle) data divided by capacity in kilograms, rather than using declared efficiency data.
- Further detail on the normalisation process is given in Annex 3 Details of the methodology to normalise energy performance data.
- Definitions of terminology used in this benchmarking document are provided in Annex 1.

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[6] This is because consumption is proportioned downwards according to the loading, but the baseload heat absorbed by the drum and energy used to agitate the load has inevitably been shared across the whole original load.
[7] Personal correspondence with a major test house, December 2010.

3 Types of product on the markets

It was noted during the analysis process, particularly when verifying best in class, that products were not always reliably categorised in databases. Hence, these data should be treated with caution, although the trend is likely to be realistic.

3.1 Sales of vented versus condensing appliances

In energy terms for the product itself, there is only marginal difference in efficiency and consumption between vented and condensing products (see Product Definition document). However, there are significant differences between countries in terms of market share of these products.

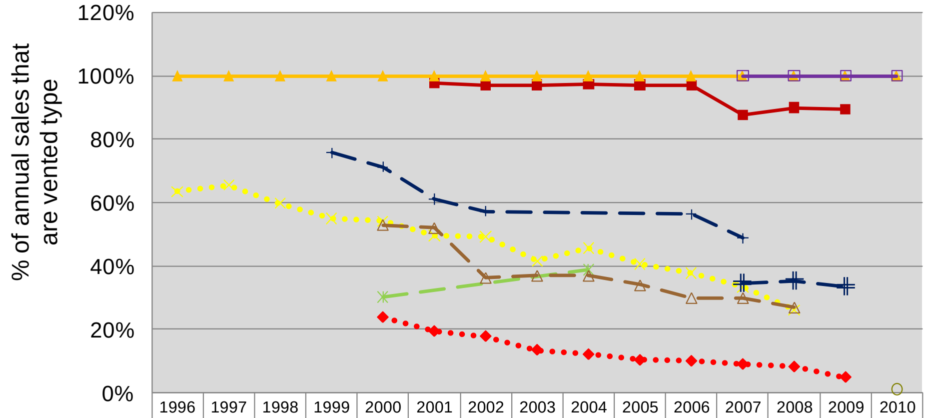
Figure 2 shows a gradual but significant trend away from vented appliances over the past decade for Austria, UK, and Denmark and also for the EU as a whole, with less than 30% of annual sales in these markets being of vented type by 2009. Australia appears to have had close to 100% vented type appliance sales until 2006, with a more recent shift to around 90% of sales. The Canadian market appears to consist almost entirely of vented type appliances, although condensing appliances are now available and their performance is discussed on the government website. US data did not include information about vented/condensing type but it does appear that no condensing products are available on that market.

A significant factor in the shift away from vented appliances is the flexibility offered by condensing appliances that do not need a vent pipe to the outside the dwelling, either through a hole in the wall or through a temporarily opened window. This feature also enables increased penetration of condensing appliances to locations not feasible for vented products.

3.2 Sales of heat pump appliances

As shown in section 5.1 Dryer efficiency, heat pump appliances can consume less than half the energy of conventional appliances. Figure 3 shows that amongst the countries analysed, heat pump appliances have taken off to a significant extent only in Austria and Switzerland, reaching around 25% of the market in both countries by 2009. Switzerland has substantial government policies supporting deployment of heat pump type dryers. A price premium of around 30% is typical for major brands, although in Switzerland and Austria local brands appear able to match non-heat pump prices, see for example laundry dryer product lists with prices at www.topprodukte.at and www.topten.ch. Heat pump products are available on several of these markets (e.g. have been available in the UK since at least 2006) and it is possible that all of the markets have a slightly higher proportion of heat pumps than indicated by these data due to mis-labelling. But the overall number of heat pump type appliances on markets other than Swiss and Austrian remains small.

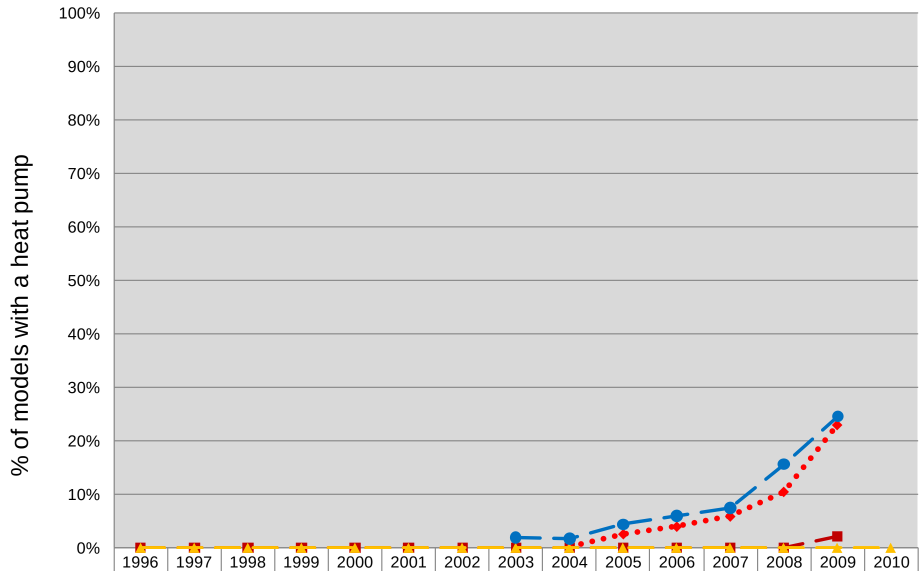
Figure 2. Percentage of each market annual sales that available data indicate is of vented type appliances (as opposed to condensing type). Data are sales weighted unless marked as product weighted (indicative).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Australia						98%	97%	97%	97%	97%	97%	88%	90%	89%	
Austria					24%	19%	18%	14%	12%	10%	10%	9%	8%	5%	
Canada (Product Weighted)	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Denmark (Product Weighted)	64%	66%	60%	55%	54%	50%	49%	42%	46%	41%	38%	33%	26%		
France - EAIS (Product Weighted)					30%				39%						
United Kingdom				76%	71%	61%	57%				56%	49%			
UK - SUST-IT (product weighted)												35%	35%	34%	
USA - CEC (product weighted)												100%	100%	100%	100%
EU (Product Weighted)					53%	52%	36%	37%	37%	34%	30%	30%	27%		
Spain - IDAE (Product Weighted)															1%

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

Figure 3. Percentages of each market that available data indicate are of heat pump type appliances. Data for Australia and Canada are product weighted; Austrian and Swiss data is sales weighted and so these types not strictly comparable (indicative).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Australia	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	
Austria (Sales Weighted)									0.1%	2.6%	4.0%	5.9%	10.5%	23.0%	
Canada	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Switzerland (Sales Weighted)								1.9%	1.7%	4.4%	5.9%	7.4%	15.6%	24.5%	

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

3.3 Comparing capacity of appliances between countries

In 2003 Switzerland had the largest average capacity appliances of all nations studied at 5.8 kg but its rate of increase is slower than the other European countries which have now overtaken it. Of these countries, the largest appliances appeared to be in Denmark in 2008, with an average capacity of 6.7 kg, being 40% larger than the average for Australian appliances at 4.9 kg. Canadian appliances average just over 5 kg and US appliances just under 5 kg capacity.

Note that capacities of US and Canadian appliances have been converted from capacities in cubic feet to capacities in kg using approximations (see section Data cleaning on page 15), and so relative comparisons of efficiency should be treated with caution between these two countries and the others.

3.4 Capacity trends

Figure 4 shows that the average capacity of appliances in Australia and Canada has changed relatively little at around 5 kg for the past decade, with US appliances appearing also to have been fairly steady for four years to 2010. Canadian appliances have increased by around 13% in average capacity over the 16 years (i.e. less than 1% a year). In contrast, the markets in the UK, Austria, and Denmark and to a lesser extent Switzerland have shown a steady rise to above 6 kg, having grown by around 30% in seven years. This is just under 5% per year and apparently remained an ongoing trend in 2009.

It has been argued also that the EU energy labelling methodology encourages manufacturers to produce larger capacity appliances in order to benefit from better energy labels from the same technology.[8]

3.5 Energy implications of capacity data

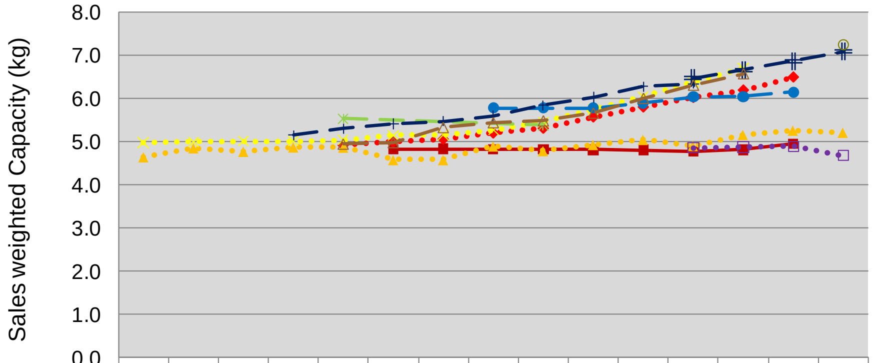
In energy terms, this would imply that the European markets could benefit from the inherent improved efficiency of increasing capacity machines[9], but this only translates to efficiency gains in the real world if they are used in the home with a full load. If the larger appliances available on the market are simply used at part load, then overall consumption will increase compared to the same loads with smaller appliances.

The efficiency gains should be apparent in the declared (and normalised) performance data because appliances are tested at full load in Europe and Australia – this effect is discussed further in section 5 Energy performance.

[8] Personal correspondence with a major test house, December 2010.
[9] For increasing capacity, the base load energy to heat the drum and agitate the load constitutes a smaller proportion per kilogram of textiles and so efficiency (kWh/kg) of the fully loaded appliance will increase.

Because their capacity has remained static over time, any change in efficiency for US and Canadian appliances is likely to be from inherent technology changes. Note that US and Canadian appliances are tested with a fixed textile load and so any changes in market average capacity will have limited impact on the declared (and normalised) efficiency data.

Figure 4. Trends in capacity of appliances (in kilograms). Note that capacities of US and Canadian appliances have been converted from capacities in cubic feet using approximations and so comparisons should be treated with caution for these two countries (indicative).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Australia						4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.9	
Austria					4.9	5.0	5.1	5.2	5.3	5.6	5.8	6.0	6.2	6.5	
Canada (Product Weighted)	4.6	4.9	4.8	4.9	4.9	4.6	4.6	4.9	4.8	4.9	5.0	4.9	5.2	5.3	5.2
Denmark (Product Weighted)	5.0	5.0	5.0	5.0	5.0	5.1	5.2	5.3	5.5	5.7	6.0	6.4	6.7		
France - EAIS (Product Weighted)					5.5				5.4						
Switzerland								5.8	5.8	5.8	5.9	6.0	6.0	6.1	
United Kingdom				5.1	5.3	5.4	5.5	5.6	5.8	6.0	6.3	6.3			
UK - SUST-IT (product weighted)												6.5	6.7	6.9	7.1
USA - CEC (product weighted)												4.9	4.9	4.9	4.7
EU (Product Weighted)					4.9	5.0	5.3	5.4	5.5	5.7	6.0	6.3	6.6		
Spain - IDAE (Product Weighted)															7.2

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

4 Energy performance

4.1 Dryer efficiency

The metric for dryer efficiency is kWh per kilogram of dry textiles and it makes an important difference whether the data are as declared or normalised. Figure 5 shows data as declared. Figure 6 shows normalised data that can be compared fairly between countries, within the limits of normalisation accuracy.

4.1.1 Comparing efficiency between countries – and the importance of normalisation

Figure 5 shows data as declared from the different test procedures in each country. The relative position of the Australian line illustrates the consequence of its appliances being required in its test to evaporate more water than those in other countries (through starting wetter and ending drier) and with the drum filled to capacity. Hence Australian testing yields much higher energy consumption per kilogram of dry textiles. However, once the data have been normalised (Figure 6), the Australian appliances have slightly lower normalised consumption than European appliances.

In contrast, Figure 5 might appear to imply that recent Canadian and US efficiencies are worse than European appliances. In fact, the Canadian and USA appliances are tested with a wetter and much smaller quantity of textiles than those in Europe, rendering the results non-comparable. After normalisation the Canadian and US efficiency appears very slightly better than that of European and Australian appliances.

Normalised data implies that Swiss average efficiency was the best in Europe by 2010, at around 0.69 kWh/kg, which matches the Canadian efficiency. The small amount of Spanish data obtained from alternative sources also matches this good level of efficiency.

4.1.2 National average efficiency trends

US and Canadian appliances have not changed significantly (less than 4%) in efficiency over the 16 years for which data are available (Figure 5 and Figure 6) at an efficiency of 0.69 kWh/kg (normalised) for 2010. Figure 4 implies that there has been an increase of around 13% in average capacity for Canadian appliances over that period which may have yielded efficiency increases in homes but would not be shown up by the test methodology because that uses a fixed load and so cannot exploit the higher capacity.

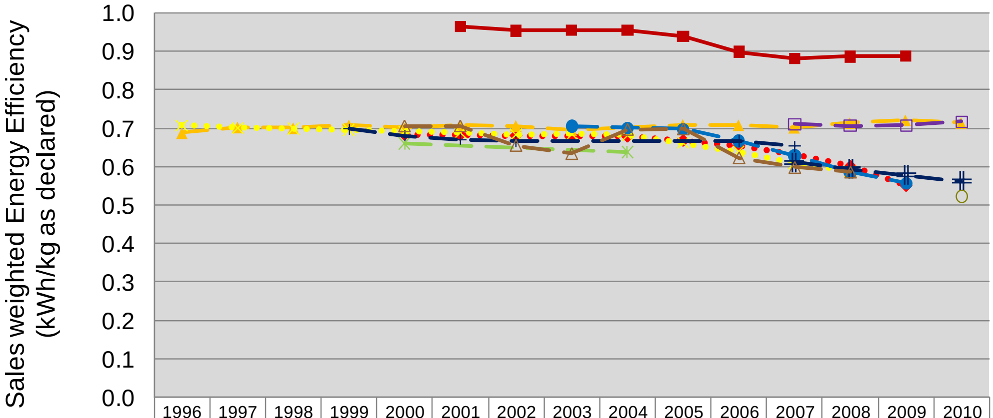
The spread of average efficiencies has narrowed significantly between 2003, when the best was 20% better than the worst, and 2010 when the best was only 5.5% better than the worst. Note that the scatter graph of Figure 7 shows that this close alignment of average efficiency hides highly contrasting spreads of best to worst individual products.

The country with the most significant increase of average efficiency is Switzerland which could be explained by the significant increase in the proportion of appliances with heat pumps. Austria, which has also seen similar growth in the proportion of heat pump appliances, closely follows the Swiss increase in efficiency. Average efficiency in Denmark and across Europe is also increasing but at a lower rate, with Austria and Switzerland overtaking in 2009. The data for average efficiency of products across Europe are only product weighted and have a significant down-up-down pattern that could have been brought about by flaws in the data for 2002 and 2003.[10]

The shape of the time series graphs such as Figure 6 cannot be related to policy changes other than for the Swiss and Austrian promotion of heat pump appliances, since no other significant policies have occurred along that time line.

[10] The data provided exhibit this pattern, but an interpolation appears not to reflect the surrounding data.

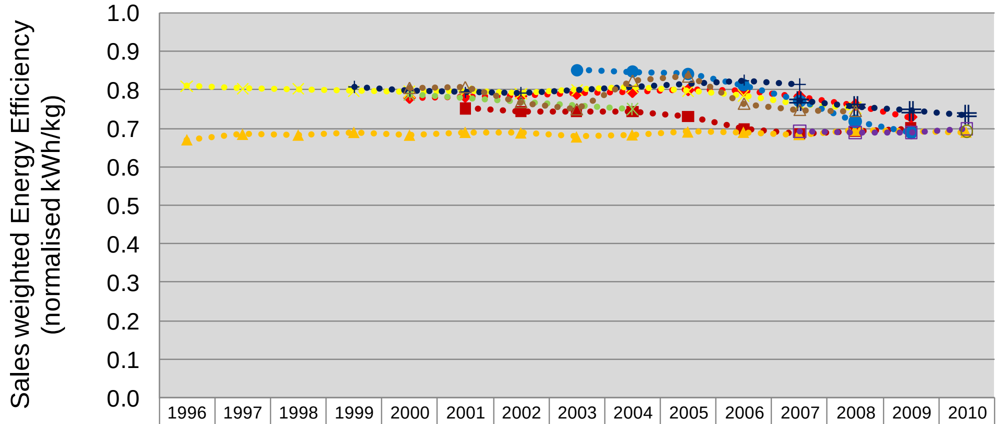
Figure 5. Sales weighted energy efficiency as declared by suppliers (indicative). Important note: Data are not normalised. Performance of USA/Canadian appliances on this graph is not comparable with EU or with Australian appliances.



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Australia						0.97	0.95	0.95	0.95	0.94	0.90	0.88	0.89	0.89	
Austria					0.68	0.68	0.68	0.68	0.68	0.67	0.65	0.63	0.60	0.55	
Canada (Product Weighted)	0.69	0.70	0.70	0.71	0.70	0.71	0.71	0.70	0.70	0.71	0.71	0.70	0.71	0.72	0.71
Denmark (Product Weighted)	0.71	0.70	0.70	0.69	0.69	0.69	0.68	0.68	0.68	0.66	0.64	0.61	0.59		
France - EAIS (Product Weighted)					0.66				0.64						
Switzerland								0.71	0.70	0.70	0.67	0.63	0.59	0.56	
United Kingdom				0.70	0.68	0.67	0.67				0.67	0.65			
UK - SUST-IT (product weighted)												0.61	0.59	0.58	0.56
USA - CEC (product weighted)												0.71	0.71	0.71	0.72
EU (Product Weighted)					0.71	0.71	0.65	0.63	0.70	0.70	0.62	0.60	0.59		
Spain - IDAE (Product Weighted)															0.52

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

Figure 6. Sales/product weighted energy efficiency after normalisation. Data are comparable within uncertainty limits of the normalisation process (illustrative).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Australia						0.75	0.74	0.74	0.74	0.73	0.70	0.69	0.69	0.70	
Austria					0.78	0.78	0.78	0.79	0.79	0.80	0.80	0.78	0.76	0.73	
Canada (Product Weighted)	0.67	0.68	0.68	0.69	0.68	0.69	0.69	0.68	0.68	0.69	0.69	0.68	0.70	0.69	0.69
Denmark (Product Weighted)	0.81	0.80	0.80	0.80	0.79	0.80	0.79	0.80	0.81	0.80	0.78	0.76	0.75		
France - EAIS (Product Weighted)					0.79				0.75						
Switzerland								0.85	0.85	0.84	0.81	0.77	0.72	0.69	
United Kingdom				0.81	0.80	0.79	0.79				0.82	0.81			
UK - SUST-IT (product weighted)												0.77	0.76	0.75	0.73
USA - CEC (product weighted)												0.69	0.69	0.69	0.70
EU (Product Weighted)					0.81	0.81	0.77	0.75	0.82	0.84	0.76	0.75	0.74		
Spain - IDAE (Product Weighted)															0.69

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

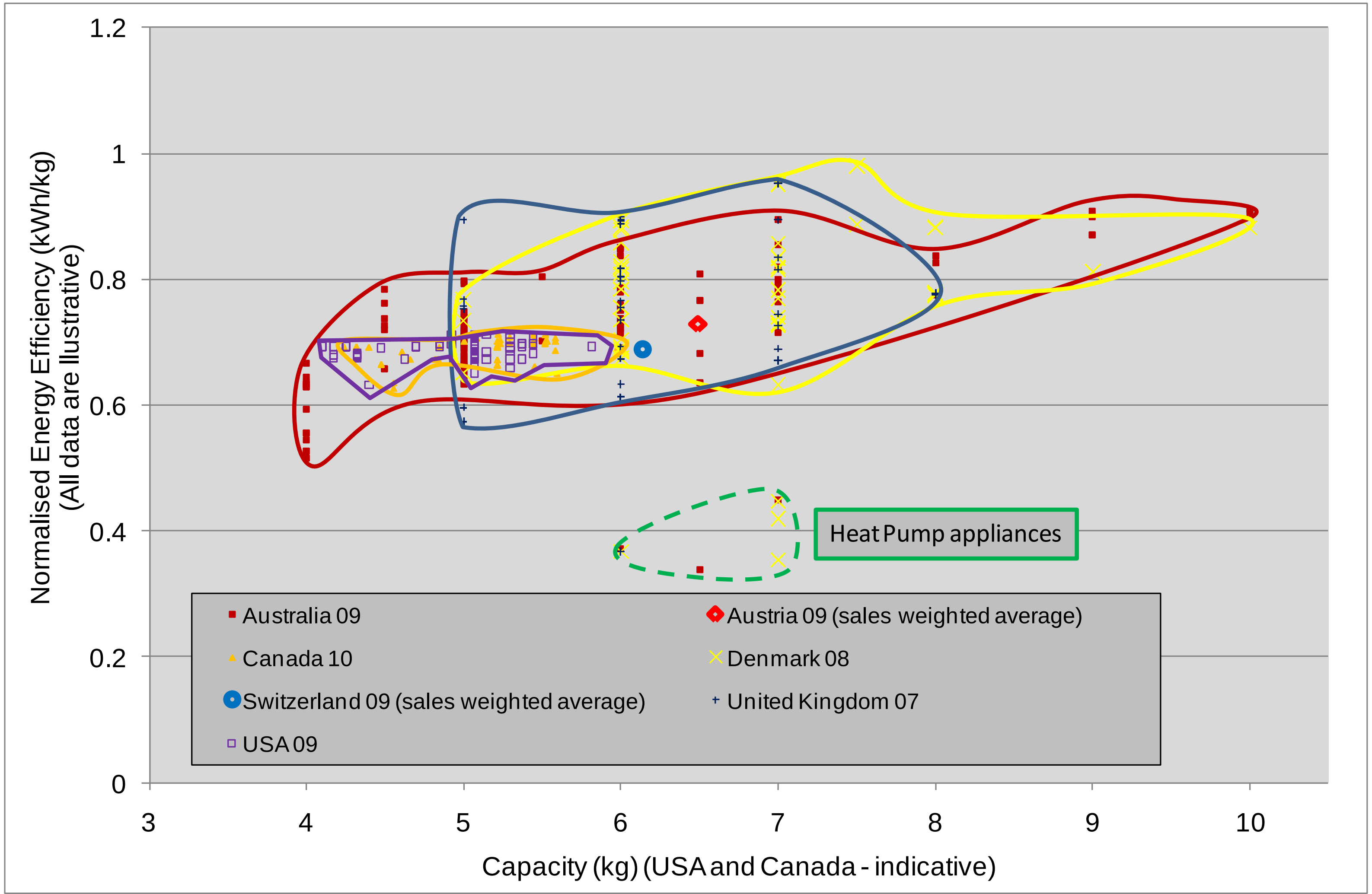
4.1.3 Scatter plots of individual appliance efficiency

Figure 7 shows normalised energy efficiency of individual appliances for all of the datasets that provided data on individual products. Data are shown for the most recent year for which a reasonable number of data points are available.

The cluster of heat pump appliances is clearly visible at much better energy efficiency of around 0.4 kWh/kg, compared to between 0.6 and 0.9 typically for conventional appliances.

Figure 7 also contrasts the relative spread of performance between countries. There is a range of +/-25% on energy efficiency for European and Australian products which implies significant scope for improvement. The spread of efficiency of US and Canadian products is only +/-7%. Interestingly, there is a large number of Australian and EU appliances performing worse on energy efficiency than Canadian and US appliances, but also some that perform much better than the best Canadian and US appliances. Another major difference between US/Canadian and Australian/European products is the scope of load capacities: No dryers with a capacity of over 6 kg (equivalent, calculated from drum volume) appear in the USA/Canadian datasets for any year, whereas European and Australian products are available up to 10 kg capacity - no explanation is available for this.

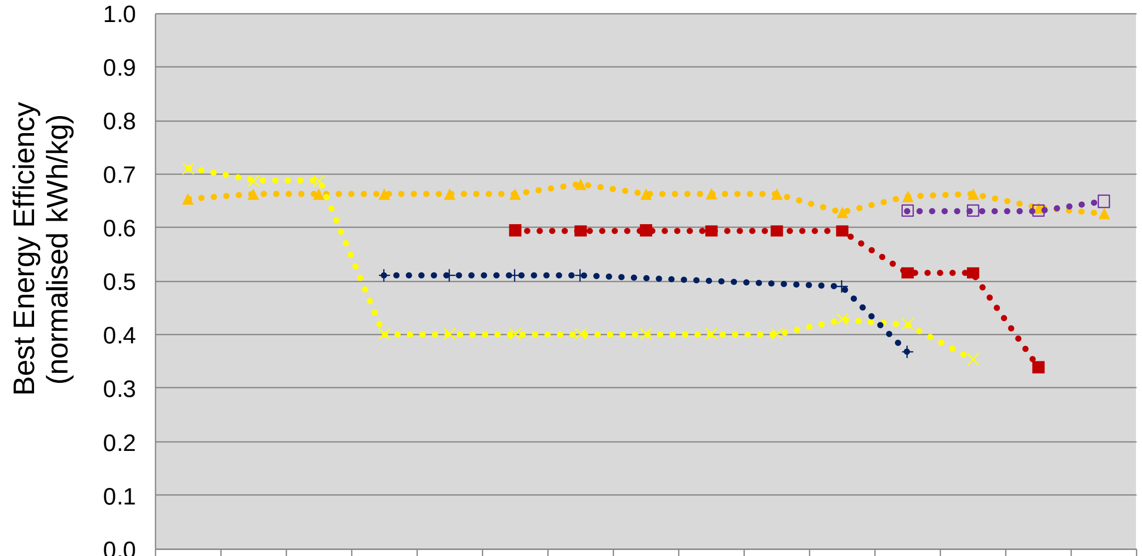
Figure 7. Scatter plot of normalised energy efficiency against capacity showing perimeter of data points for each country (illustrative). Heat pump appliances are separately grouped.



4.1.4 Best product performance levels

Figure 8 shows the normalised efficiency achieved by the best performing product in each country's dataset. Appliances at and below the level of 0.4 kWh/kg are likely to be heat pump products, and their appearance on markets demonstrates a very clear step change. It appears that Denmark has had such products on the market since 1999, and the UK and Australia have had such products since 2007 and 2009 respectively. Heat pump products appear not to have become established in USA and Canadian markets, but the reasons for this are not understood. See the section Best in class products on page 40 for further analysis on this theme. The apparent slight fall in efficiency for the USA dataset in 2010 is probably not significant.

Figure 8. Normalised efficiency of the best product in each dataset (illustrative). Better efficiency appears lower on the graph (less energy per kilogram).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Australia						0.59	0.59	0.59	0.59	0.59	0.59	0.52	0.52	0.34	
Canada	0.65	0.66	0.66	0.66	0.66	0.66	0.68	0.66	0.66	0.66	0.63	0.66	0.66	0.64	0.63
Denmark	0.71	0.69	0.69	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.43	0.42	0.35		
United Kingdom				0.51	0.51	0.51	0.51				0.49	0.37			
USA												0.63	0.63	0.63	0.65
EU															

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

4.1.5 Comparing vented and condensing consumption and efficiency

Available data are inconclusive as to any efficiency differences between vented and condensing appliances.

It was found during verification of best in class products that the labelling of declarations in the datasets about whether a product was vented or condensing was sometimes unreliable. However, two datasets with a reasonable number of data points (Australia and UK) have been picked to illustrate the comparison between vented and condensing appliances, making the assumption that more appliances will be in the correct category than in the wrong category.

The average efficiencies of datasets are compared in Table 7. The larger dataset (Australian) implies that vented products have 3.9% *worse* efficiency than condensing appliances; the smaller dataset (UK) implies that vented are 3.3% *more efficient* than condensing. Due to the fact that vented products constantly draw in air from their surroundings and benefit from its associated heat, they should arguably appear more energy efficient than condensing products, as with the UK dataset.[11] Note that ambient conditions are stipulated in the test methodology and corrected by normalisation, so relative UK/Australia climates do not affect these results.

Table 7. Comparison of vented and condensing appliance energy efficiency for Australia and UK datasets (appliances likely to be heat pumps have been removed from the datasets).

Country	Vented		Condensing		% vented is less efficient than condensing	Year of data used
	Average efficiency (kWh/kg)	Number of data points	Average efficiency (kWh/kg)	Number of data points		
Australia	0.737	60	0.708	81	3.9%	2009
UK	0.734	22	0.758	29	-3.3%	2007

Two graphs are provided aiming to give some additional insight into the datasets but these are also inconclusive. The *energy consumption* (kWh/cycle) for these datasets are shown in Figure 9 as declared data, and energy *efficiency* (kWh/kg) of vented versus condensing appliances is shown in Figure 10 as normalised data. The trend lines on Figure 9 imply very little difference in consumption between vented and condensing; Figure 10 shows some appreciable difference between vented and condensing in how efficiency varies with capacity.

Note that Figure 10 also implies that energy consumed per kilogram increases (i.e. efficiency gets worse) with increasing appliance capacity, which is counterintuitive and likely to be due to flaws in the normalisation process (normalising for load variation) rather than a real effect.

Results of Group for Efficient Appliances studies in the 1990s on dryers (GEA, published by the Danish Energy Agency) showed a small but 'structural' difference of about 0.05 kWh/kg difference between vented and condensing driers, with the lowest consumption for the air vented driers. However that was based upon EU data only. Since the effect is small, normalisation - which is based on general aspects - could mask such effects.

[11] For this reason (plus the benefits of heat ejected into the surroundings that is useful during cooler seasons) the EU energy label allows condensing appliances to consume slightly more energy but yet achieve the same energy label as comparable vented products.

Figure 9. Scatter plot of declared *energy consumption* for Australian and UK appliances. Data are shown purely for comparison of vented and condensing appliances within each country; comparisons between the two country's data are not valid.

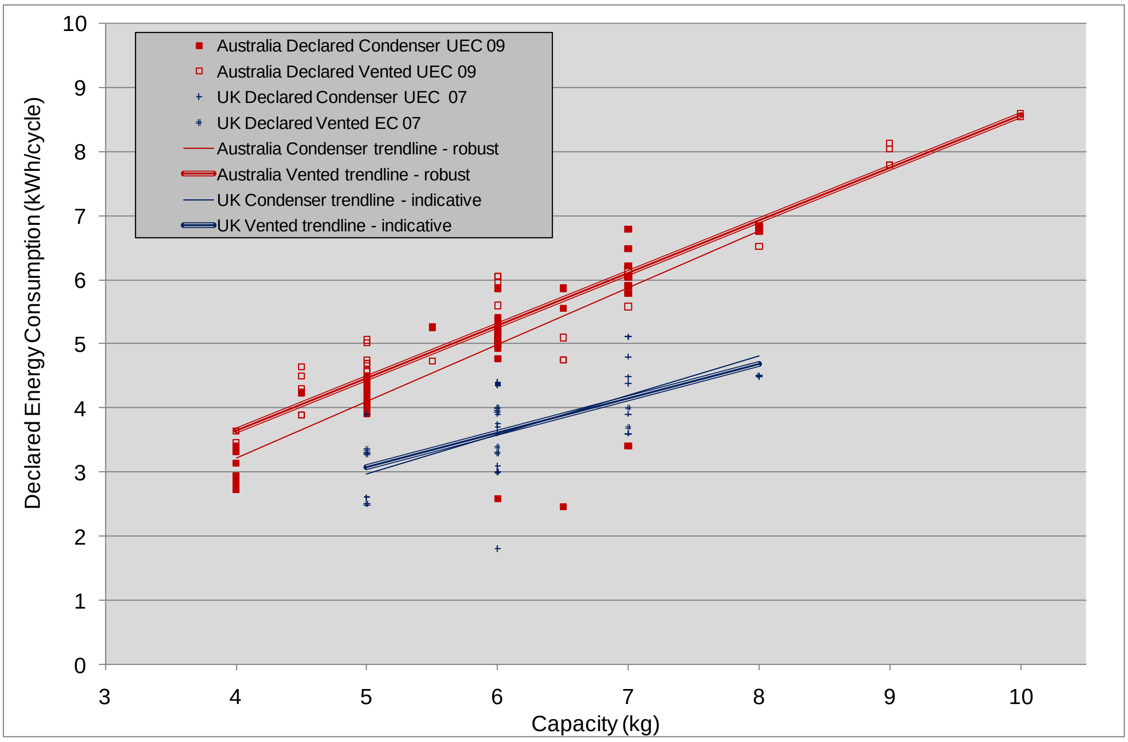
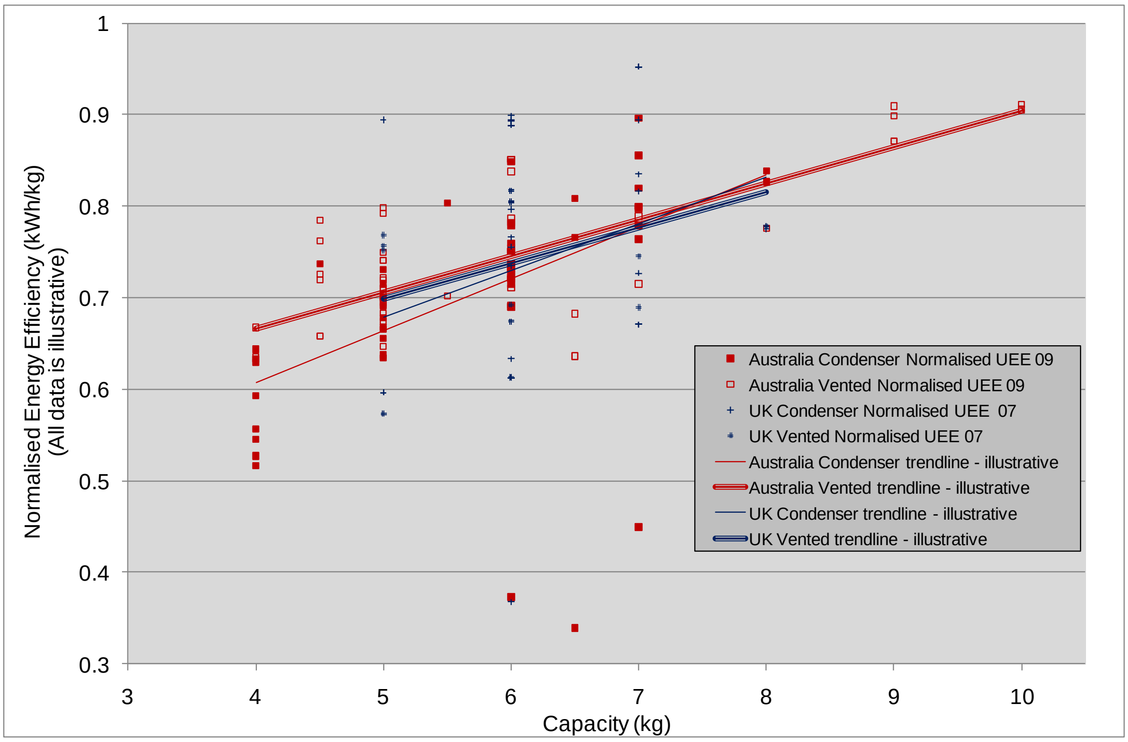


Figure 10. Scatter plot of normalised *energy efficiency* for Australian and UK appliances (illustrative). Data are normalised, but shown purely for comparison of vented and condensing appliances within each country.



4.2 Dryer energy consumption

Energy consumption of dryers is presented in kWh per standard cycle, but due to significant differences in test methodologies these data as declared by manufacturers are not at all comparable between countries. However, the non-normalised data are shown in Figure 11 for comparison with normalised data in Figure 12.

4.2.1 Comparison between countries and the importance of normalisation

As was seen with energy efficiency data, normalisation brings Australian data much more closely in line with European data. The normalisation also compresses the spread between European countries: the difference in average capacity between countries tends to spread out the data as declared, but normalisation compensates for that and brings the points closer together. Normalisation also eliminates the gap between European and Canadian data.

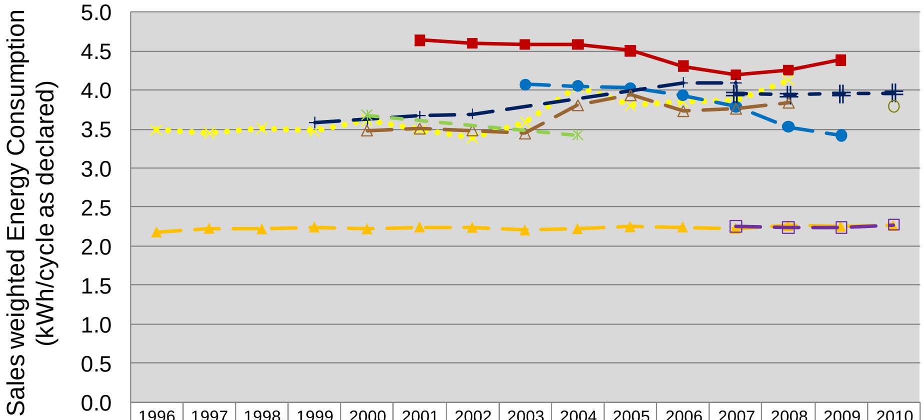
4.2.2 Trends in drier consumption

From Figure 12, European products are showing a fairly steady reduction in average consumption from around 2.6 kWh/cycle (normalised) in 2005, to below 2.4 in 2008. Australian data show a similar slight improvement over the same period, but consumption appears to rise slightly between 2007 and 2009. This could be associated with the rise in average capacity in those years. Canadian data show a very slight rise in average consumption of around 4% over the 14 years. Australian appliance consumption is 7% lower than that for European ones, but this could be at least partially explained by the 40% lower average capacity of Australian appliances (see Figure 4). Whilst normalisation compensates for the different loading during test, a residual advantage will remain for larger appliances which are tested at full load, i.e. European and Australian ones.

4.2.3 Scatter plots of appliance consumption

A scatter plot of normalised consumption is shown in Figure 13. Data are shown for the most recent year for which a reasonable number of data points are available for each country. Once again, the cluster of heat pump appliances is clearly visible at around 1.3 kWh/cycle, compared to between 1.7 and 2.7 typically for conventional appliances. Canadian and US appliances have much reduced spread of consumption compared to those of other countries.

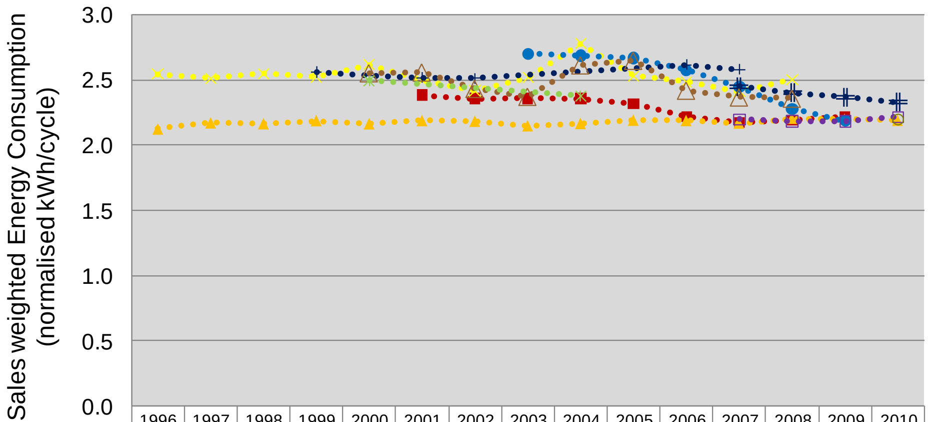
Figure 11. Sales weighted/product weighted average energy consumption as declared in the databases in kWh per cycle. Data are not normalised so performance of US/Canadian appliances on this graph is not comparable with EU or with Australian appliances (indicative).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Australia						4.64	4.60	4.59	4.59	4.51	4.31	4.20	4.25	4.39	
Canada (Product Weighted)	2.18	2.23	2.22	2.24	2.22	2.24	2.24	2.21	2.22	2.25	2.24	2.23	2.26	2.25	2.26
Denmark	3.49	3.45	3.51	3.48	3.62	3.49	3.39	3.58	4.04	3.80	3.85	3.86	4.13		
Switzerland								4.07	4.05	4.03	3.94	3.79	3.53	3.42	
United Kingdom				3.58	3.62	3.67	3.69				4.10	4.09			
UK - SUST-IT (product weighted)												3.95	3.94	3.96	3.96
USA - CEC (product weighted)												2.25	2.24	2.24	2.27
EU (Product Weighted)					3.48	3.51	3.48	3.44	3.81	3.94	3.73	3.77	3.84		
France - EAIS (Product Weighted)					3.68				3.42						
Spain - IDAE (Product Weighted)															3.79

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

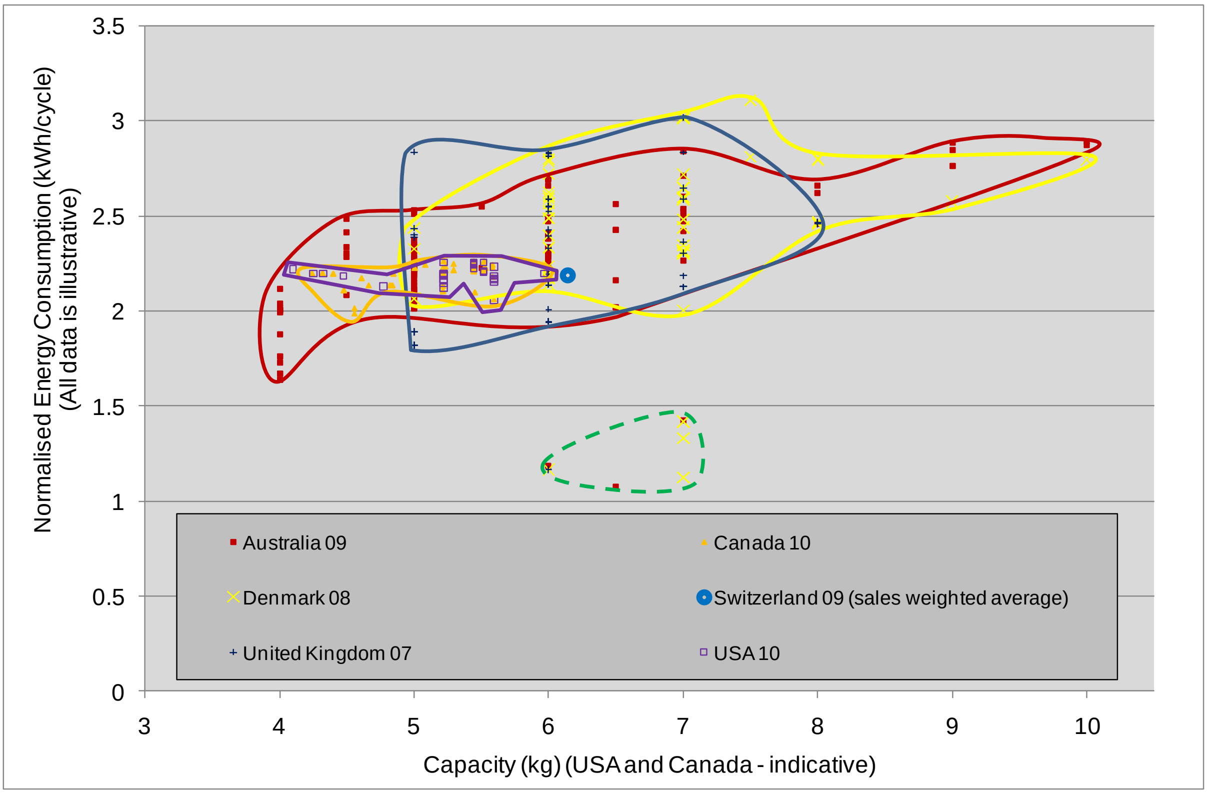
Figure 12. Sales weighted/product weighted energy consumption with normalised data, in kWh/cycle (illustrative).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Australia						2.38	2.36	2.36	2.36	2.32	2.22	2.18	2.19	2.22	
Canada (Product Weighted)	2.13	2.17	2.16	2.19	2.16	2.19	2.18	2.15	2.17	2.19	2.19	2.17	2.20	2.20	2.19
Denmark	2.55	2.51	2.55	2.52	2.62	2.49	2.42	2.518	2.779	2.530	2.483	2.411	2.501		
Switzerland								2.70	2.68	2.67	2.57	2.44	2.28	2.18	
United Kingdom				2.56	2.53	2.52	2.51				2.61	2.58			
UK - SUST-IT (product weighted)												2.45	2.40	2.37	2.33
USA - CEC (product weighted)												2.20	2.18	2.18	2.21
EU (Product Weighted)					2.55	2.56	2.43	2.37	2.61	2.65	2.42	2.37	2.36		
France - EAIS (Product Weighted)					2.49				2.38						
Spain - IDAE (Product Weighted)															2.19

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

Figure 13. Scatter plot of normalised energy consumption. All data are illustrative due to the normalisation process.



5 Stock of laundry dryers and national energy consumption

Six countries were able to provide government estimates of stock (total number of appliances in use in homes) of laundry dryers in the country (Figure 14), with the associated estimate of total annual energy consumption (Figure 15). Table 8 shows these data for 1996 and 2007, with the overall and annual growth calculated from these data.

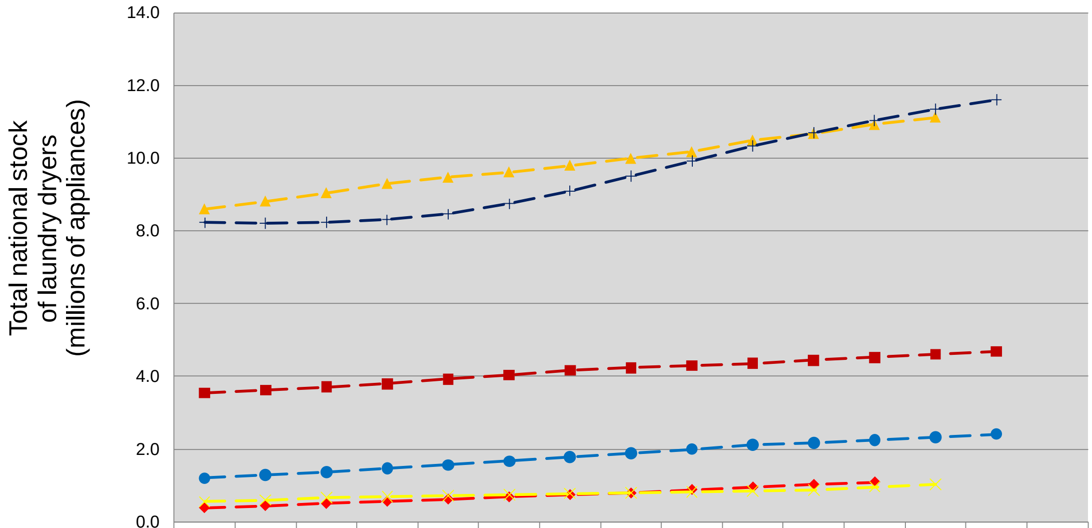
All countries for which data were available show some growth over the 11 years in total stock and consumption. The lowest growth was in Canada where the number of products grew by one third over 11 years, compared to highest growth in Austria which had three times as many laundry dryers by the end of the 11 years. Growth in energy consumption ranged from 10% (Australia) to one and a half times as much (Austria).

Canada appears to have by far the highest national consumption of those listed, at 10.4 TWh/year. This high estimated consumption appears due to significantly higher usage than in other countries (USA has similarly high usage but no reliable consumption data were identified). See also following section on Annual Usage, and Table 9 for estimated annual consumption per appliance.

Table 8. Government estimates of stock and annual consumption figures for countries for which data were available. 2007 is the most recent year for which all necessary data are available for all countries listed.

Country	Estimated stock of appliances (millions, illustrative)		Growth in stock, 1996 to 2007	Average annual growth of stock 1996 to 2007	Estimated energy consumption of stock (TWh/year, illustrative)		Growth in energy consumption 1996 to 2007	Average annual growth of energy consumption 1996 to 2007
	1996	2007	%	%	1996	2007	%	%
Australia	3.5	4.5	28%	3%	0.7	0.7	10%	1%
Austria	0.4	1.1	185%	17%	0.2	0.4	153%	14%
Canada	8.6	10.9	27%	2%	9.2	10.4	13%	1%
Denmark	0.6	1.0	75%	7%	0.3	0.5	58%	5%
Switzerland	1.2	2.3	88%	8%	0.5	0.8	78%	7%
UK	8.2	11.0	34%	3%	3.1	4.0	28%	3%

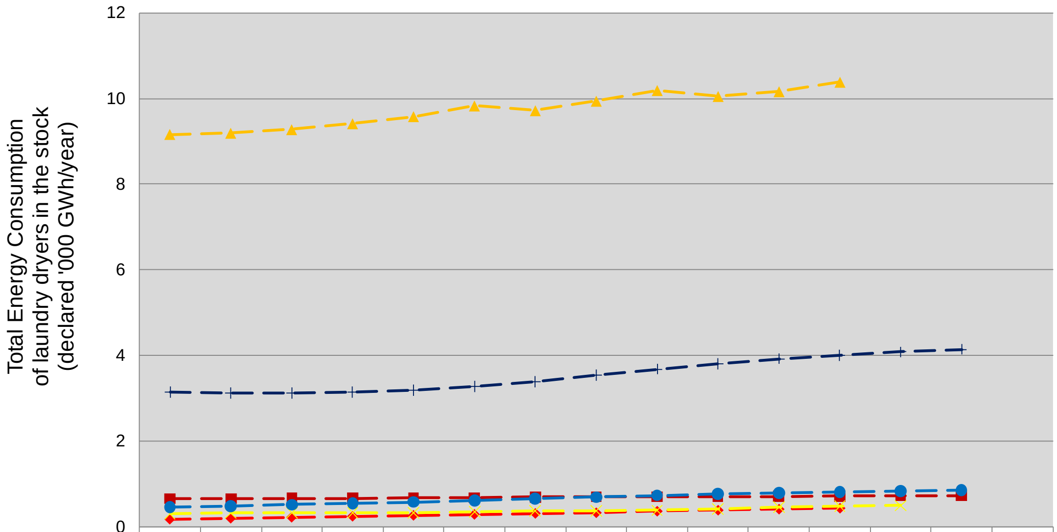
Figure 14. National government estimates of the total stock of laundry dryers in each country (millions of appliances) (indicative).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Australia	3.54	3.62	3.71	3.79	3.92	4.03	4.16	4.23	4.30	4.36	4.44	4.52	4.60	4.69	
Austria	0.38	0.44	0.50	0.56	0.62	0.68	0.74	0.79	0.88	0.95	1.02	1.09			
Canada	8.6	8.8	9.0	9.3	9.5	9.6	9.8	10.0	10.2	10.5	10.7	10.9	11.1		
Denmark	0.55	0.60	0.66	0.69	0.71	0.75	0.78	0.80	0.82	0.85	0.87	0.96	1.02		
Switzerland	1.20	1.29	1.37	1.47	1.56	1.67	1.77	1.89	2.00	2.11	2.18	2.25	2.33	2.42	
United Kingdom	8.23	8.21	8.23	8.31	8.46	8.75	9.10	9.52	9.93	10.34	10.71	11.04	11.34	11.62	

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

Figure 15. National government estimates of total energy consumption of electrically driven laundry drivers ('000 GWh/year) (indicative).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Australia	0.65	0.65	0.66	0.66	0.67	0.68	0.69	0.70	0.70	0.70	0.71	0.71	0.72	0.73	
Austria	0.17	0.20	0.22	0.24	0.27	0.29	0.31	0.33	0.36	0.39	0.41	0.44			
Canada	9.17	9.19	9.28	9.42	9.58	9.83	9.72	9.94	10.19	10.06	10.17	10.39			
Denmark	0.30	0.31	0.33	0.32	0.32	0.35	0.36	0.37	0.38	0.41	0.45	0.47	0.49		
Switzerland	0.46	0.48	0.51	0.54	0.58	0.61	0.65	0.69	0.73	0.77	0.79	0.81	0.83	0.85	
United Kingdom	3.14	3.13	3.13	3.14	3.19	3.27	3.39	3.53	3.68	3.81	3.92	4.01	4.08	4.14	

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

6 Annual usage and consumption per appliance (cycles per year)

Available data enabled the calculation of an illustrative number of uses per year in some countries. These were calculated from government estimates of total national energy consumption, which was divided by national stock of dryers in use to derive average annual consumption per appliance. This was then divided by the average consumption per cycle (as declared by suppliers in that country, sales weighted where possible as per Figure 11) and these are summarised in Table 9. It is important to bear in mind that these data reflect broad government assumptions about energy and are not based on any survey evidence. The figures should, however, indicate the governments' view of the order of magnitude of usage in their country.

Data imply that Canadian appliances are used between 2 and 4 times as frequently as in European countries, and 10 times as frequently as in Australia. These differences will be partially associated with climate, with Australia benefiting from good weather for drying clothes in much of the year. Another cultural factor in some places is a ban on outdoor clothes drying. For example, bans have been imposed by a significant proportion of American neighbourhood associations[12], though this also occurs in parts of Australia.

It is probably inappropriate to draw any conclusions from the slight differences in usage between European countries, due to the inherent uncertainties involved in the derivation of these figures.

Table 9. Average assumed annual usage of electrical laundry dryers in countries for which data were available (illustrative).

Country	Declared average consumption, kWh/cycle	Average annual consumption per appliance (kWh/year)	Implied annual usage, cycles/year	Data used from year	Government estimated annual usage cycles/year
Canada	2.23	950	430	2007	416
EU	-	-	-	-	160
Denmark	4.13	480	120	2008	-
Austria	3.8	400	110	2007	-
Switzerland	3.42	350	100	2009	-
UK	4.09	360	90	2007	140
Australia	4.4	160	40	2009	52

Notes for Table 9:

1. Average annual consumption per appliance is calculated from governments' own estimates of annual consumption divided by government figures for national stock. Annual usage is

[12] British Broadcasting Association, The fight against clothes line bans, Tom Geoghegan, BBC News Magazine, 8 October 2010, available from www.bbc.co.uk/news/mobile/magazine-11417677.

average annual consumption per appliance divided by declared average consumption, sales weighted where available (see Figure 11).
2. All data calculated for the most recent year for which all data together were available.
3. Annual consumption per appliance and usage per year are rounded to nearest 10.
4. EU average is from a draft of a new proposed EU energy label regulation for laundry dryers from 2010.[13]
5. Australian government estimated annual usage (52 cycles per year) is what is assumed on the Australian energy label.

7 Best in class products

Identifying best in class appliances is intended to bring the following advantages:

- Enables setting realistic current level of ambition for policy purposes.
- If published – provides incentive benchmarks for manufacturers to aspire to.
- Provides a suitable framework to design best product competitions.

However, this process yields only the best products that are already in the databases made available for analysis, and better products may well exist on the market. *The resultant list of best in class information should not be used as a definitive statement for promotion/prizes etc as it is not robust, as the source databases are neither comprehensive nor up-to-date.*

In addition to the conventional and alternative data sources, the TopTen Website databases were used to identify best in class products. These were not used in the main market analysis as they focus only on better products.

Appliances were divided into classes as per section Overview of analysis approach.

The available performance data on appliances was sorted into efficiency order using normalised data for comparability and the best products were selected. Internet research was carried out to verify that the product was indeed available and that performance data published by the manufacturer, or failing that another third party source, matched that present in the analysed dataset.

Overall, 32 appliances had to be investigated for verification to obtain six verified products, i.e. less than 20% of appliances investigated could be traced back to manufacturers'/third parties' performance data. Two thirds of those resolved could not be identified on manufacturers' websites or other sources to obtain performance data. Seven appliances were found to be duplicate models with slightly different model numbers and for three appliances sources showed performance over 10% worse than that in the databases used for the analysis. A manufacturer's website for one product showed performance over 20% better than the expected figure (which was counted as a verified best in class product).

[13] See Working Document on the ecodesign and labelling of household tumble driers. Presented by the Directorate General for Energy for Consultation Forum on Friday 25 June 2010. Available from http://www.eup-network.de/product-groups/drafts-regulations/ (accessed 22 June 2011).

See Annex 4 The process used to identify best in class appliances for further details.

Table 10 lists the best products in each class for which available performance data (from 2010 and earlier) corresponded with that stated on a manufacturer or third-party website researched at February 2011. Better products than these are likely to exist in many markets, in particular heat pump products claiming better levels of performance than those listed in Table 10 are now available.

Table 10. Best in class performance levels for which data in the mapping and benchmarking database matched those from manufacturer/third party websites. Other brands and products are available claiming similar performance levels (indicative).

Normalised efficiency, kWh/kg	Verified efficiency (declared), kWh/kg	Manufacturer	Model	Type	Capacity, kg	Country
Non-heat pump, less than 7 kg capacity						
0.61	0.64	Miele	T9800	V	4.6	Canada
Non-heat pump, 7 kg or over capacity						
0.65	0.47	Bosch	WTS84500	C	8	EU
0.65	0.47	Bosch	WTE84306	C	8	EU
Heat pump, less than 7 kg capacity						
0.33	0.37	Bosch	EcoLogixx 7 WTW86560AU 06	HP	6.5	Australia
0.37	0.30	Miele-Wäsche	T 8626 WP C	HP	6	EU
Heat pump, 7 kg or over capacity						
0.30	0.23	Bosch	WTW86560NL	HP	7	EU

Notes for Table 10:

1. There may be better products than these available on the market. This list simply represents the best appliances appearing in the databases made available to the project team for which performance matched manufacturer's/third parties' stated levels.
2. Appliances were selected based upon normalised efficiency, and verified through their declared efficiency.
3. Type: V = vented; C = condensing; HP = heat pump.
4. Country: this is the country/region from whose mapping & benchmarking database the product was originally identified. Appliances from European countries are simply noted as EU. The product may be available in other countries.

8 Policies and their impacts

8.1 Policies in place

Existing policies are summarised in Table 11. Energy labelling is in place in all of the participating countries. Minimum performance standards exist in Canada and the USA (the same USA MEPS appear in Californian regulations). Australia has a fairly lax performance requirement built into the labelling standard.

8.2 Impact of policies

Figure 16 shows how normalised energy efficiency of appliances relates to MEPS.

The US/Canadian MEPS level appears relatively stringent when compared with EU datasets, particularly given its early adoption (since 1995). It has compressed product efficiency levels to a narrow band of only +/-7% in Canada and USA compared to +/-25% in Europe/Australia. Canadian and US products are seen to cluster closely under the MEPS level. Some European and Australian products are better than the best Canadian products.

8.3 Future policies

Switzerland will introduce a mandatory requirement for EU energy label A in 2012, which is difficult for anything but heat pump products to achieve. It implies a normalised efficiency of 0.35 kWh/kg (although this level is only illustrative) which would appear challenging even for the best performing appliances in these datasets.

No standards exist EU-wide at present but these are under consideration under the proposed eco-design regulations[14].

A coalition of manufacturers and other stakeholders has proposed a revised USA MEPS level at 0.68 kWh/kg (normalised, illustrative), see Table 11.

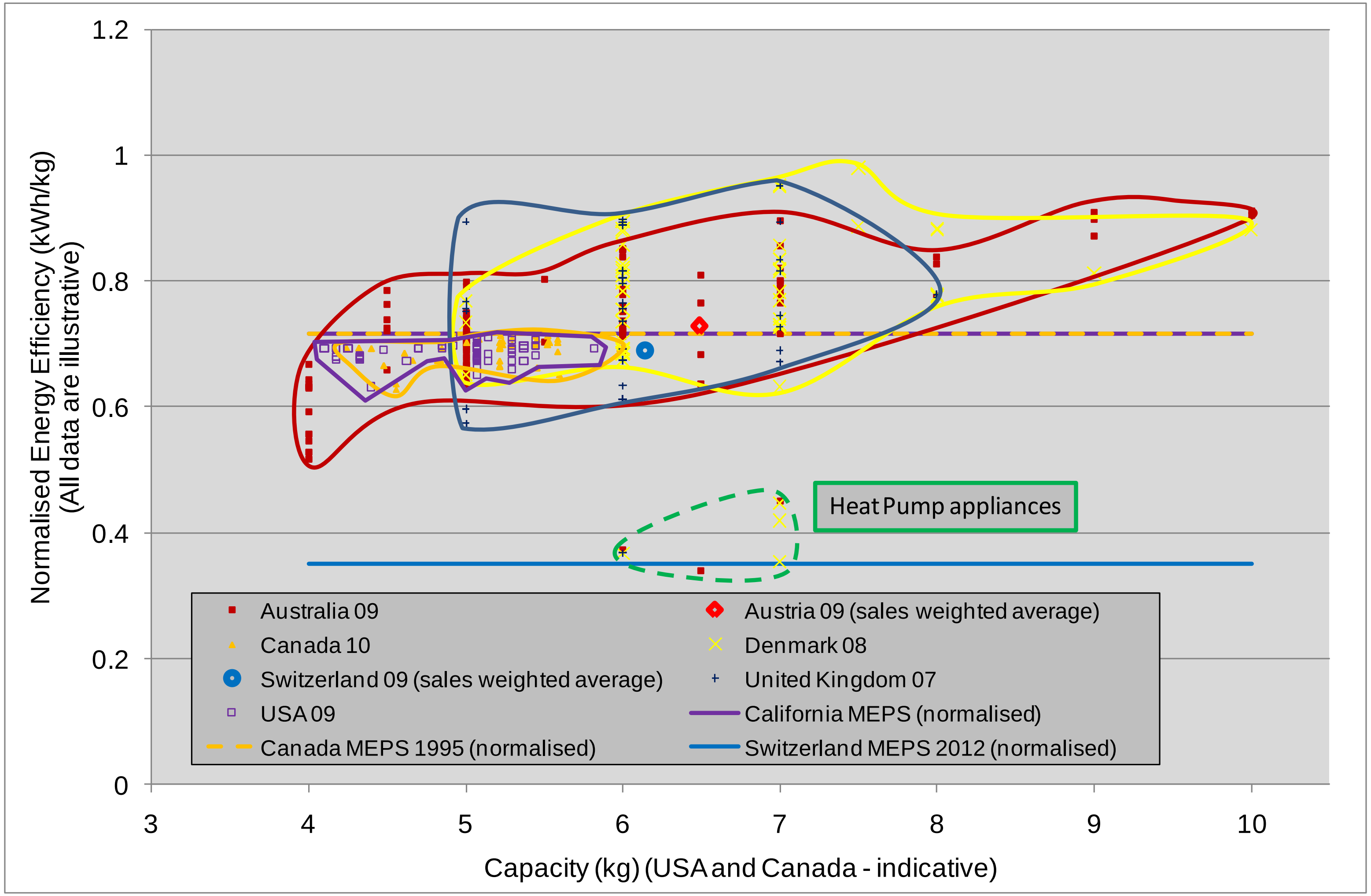
[14] An EU eco-design preparatory study was completed in March 2009, see www.ecodryers.org, and regulatory working document is being developed at March 2011.

Table 11. Summary of policies in place and planned regarding laundry dryers. These MEPS levels are illustrated in Figure 16.

Country	Minimum performance standards (MEPS)	MEPS level, kWh/kg normalised	Labels	Comments
Australia	No formal MEPS (embedded standard in label requirement[15])	0.816[16]	Yes	Label requirement for consumption of less than 1.36 kWh/kg of water removed
Canada	Since 1995, minimum Energy Factor of 1.36 kg/kWh	0.717[17]	Yes	
Switzerland	From January 2012 must be EU energy label A	0.35[18]	Voluntarily adopts EU labels	Difficult for anything but heat pump products to achieve
USA	Since 1994, minimum Energy Factor 3.01 (lbs/kWh)	0.714	Energy Factor must be declared	New rule due to be published June 2011[19]
EU	None currently in place	-	Yes since 1996	Update planned for 2011

[15] '*Energy efficiency - the dryer tested energy consumption (kilowatt hours per kg of moisture removed) shall not exceed 1.36*'. See www.energyrating.gov.au/cd1.html
[16] Given that EU moisture percentage to be dried is 60% (difference between initial and final RMC; moisture is normalised to the EU level), then 1.36 kWh/kg of moisture is equivalent to 1.36 x 0.6 = 0.816 kWh/kg of dry textile weight.
[17] 1.36 kg/kWh is equivalent to 0.74 kWh/kg which when normalised in the same way as other Canadian performance data gives 0.717 kWh/kg.
[18] See *Factsheet: Revision of Energy Regulation*, July 2009, Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation UVEK. Maximum consumption to achieve energy label A is 0.55 kWh/kg for condensing dryers (which is equivalent to 0.35 normalised); 0.51 for vented dryers (0.33 normalised)
[19] An industry coalition has published a proposed new standard of EF 3.17 lb/kWh for 2015 which is equivalent to a normalised figure of 0.678 kWh/kg, see *Agreement on Minimum Federal Efficiency Standards, Smart Appliances, Federal Incentives and Related Matters for Specified Appliances*, www.aham.org/ht/a/GetDocumentAction/i/49956

Figure 16. Scatter plot of laundry dryer efficiency (normalised) also showing MEPS levels where they exist and perimeter of each country's dataset (illustrative). MEPS levels have been normalised in the same way as their respective country's data.



9 Key issues for policy makers

This section draws together key points that should be of interest to policy makers.

Long term MEPS, in place since 1995 in Canada and the USA, appear to have significantly improved efficiency and reduced the spread of performance in these countries. The average performance of European products appears in 2010 to be finally matching levels of efficiency achieved and sustained in North America 15 years before (see Figure 16 on page 42).

Average efficiency levels in Europe, North America and Australia appear to be converging to around 0.7 kWh/kg (normalised), see Figure 6 on page 26. But this convergence belies significant differences in the spread of best to worst products between countries: spread of performance in Canada and USA is around +/- 7%, compared to +/- 25% in Europe. And so, whilst market average performance might be similar, a large number of poorly performing products in Europe would be eliminated if MEPS were to be set at the same (normalised) level as those in USA/Canada. This would eliminate just over half of the combined EU, Australian and Danish products shown in Figure 16 and would result in lifting that combined average efficiency (product-weighted) by 9%. The average performance for Europe could then be better than that in Canada/USA due to the number of highly efficient products available in Europe/Australia.

Heat pump dryers appear able to halve energy consumption. Adopting MEPS as per those to be introduced in Switzerland for 2012 (eliminating all appliances with energy label B or worse) would save around 60% of consumption compared to typical EU and Australian appliances in 2009. Switzerland and Austria have already boosted sales of heat pump appliances to account for over 25% of their national markets, despite what can be a significant price premium for such products.[20]

Usage patterns are crucial to understanding and influencing national consumption. Cultural differences, combined with the likely effects of differing climates, have resulted in usage varying from around fewer than 50 cycles per year in Australia to well over 400 per year in USA/Canada (see Table 9 on page 39). A shift in usage patterns could thus have a far greater influence on national consumption than any improvement in energy efficiency of appliances.

It is possible that the capacity of EU laundry dryers has increased in part to take advantage of better EU energy labels that can be achieved by increasing capacity without changing technology applied. The effect of this on actual energy consumption in the home cannot be known unless/until typical home loading patterns are understood. There is, however, a risk that running larger appliances at part load will result in higher overall consumption. Testing in

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[20] A price premium of around 30% is typical for major brands, although in Switzerland and Austria local brands appear able to match non-heat pump prices, see for example laundry dryer product lists with prices at www.topprodukte.at and www.topten.ch

USA/Canada uses a fixed test load and so there is no test result advantage to increasing an appliance’s capacity.

Capacities are increasing in Europe by around 5% per year whilst capacities in the USA and Canada are changing at less than 1% per year. European products appear to have an average capacity over 40% greater than that of Australia and USA/Canada (see Figure 4 on page 23).

There is a distinct shift towards condensing type appliances in Europe which in the EU energy labelling scheme are allowed higher consumption than vented products to achieve the same energy label. Analysis of available appliance data was inconclusive on any efficiency differences between vented and condensing appliances (see Table 7 on page 31). Condensing products account for well over 50% of European markets but only a few per cent of the USA/Canadian market, which remains unexplained.

Annex 1 Definitions

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 than or different from its more common usage.

Robust/Indicative/Illustrative: See Annex 2 Framework for grading mapping and benchmarking outputs.

Normalised: Data that have been adjusted to compensate for differences in test methodology in order to make them comparable with similar data.

Declared: Data quoted exactly as they are published by a manufacturer or third party source (i.e. before any normalisation adjustments).

Conventional data source: Government or government agency related source of product performance information, i.e. with direct links with national representatives on the project management committee.

Alternative data source: Data source other than those associated with national representatives, including commercial providers, Internet sites and other third parties.

Vented: A laundry dryer that draws in air from its surroundings and exhausts warm moist air.

Condensing: A laundry dryer that recirculates air between the drum and a heat exchanger, extracting moisture to a water tank and ejecting heat.

Heat pump: A type of condensing dryer that extracts heat from the moist warm air and reuses the heat in the drum.

Capacity: A metric for the size of a dryer measured as the maximum weight of dry textiles for which the drum is designed. Note that the metric for capacity used in the USA/Canada is volume of drum in cubic feet.

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.

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.

Annex 3 Details of the methodology to normalise energy performance data

This annex explains in detail the derivation of the normalisation approach. Each aspect is explained in turn in the following sections.

Ambient air humidity and temperature – normalise to EN 61121:2005

The ambient air humidity and temperature (as required in the test methodology) affect energy consumption of vented dryers as this ambient air is drawn through the drum in the drying process. Only ambient temperature will affect condensing dryers as they do not draw the ambient air through the drum, instead recirculating the same air. Energy demand is inversely proportional to ambient temperature; but is directly proportional to ambient humidity.

This analysis is based upon the method proposed in the EU Ecodesign[21] study for normalising both of these variations. Each is described below:

Air humidity (equation as quoted in the Ecodesign study):

$$\Delta EC = (0.00832 * x - 0.079) * 100$$

(With ΔEC: the deviation from energy consumption at 20°C and absolute humidity of 9.45g/kg in %, x : the absolute humidity under the test conditions in g/kg dry air)

The Ecodesign study equation above provides for variations in energy consumption due to small variations in temperature away from a base temperature of 20°C and absolute humidity of 9.45 g/kg. For this analysis we require change in energy consumption for variations in ambient temperature away from the EU test temperature of 23°C and absolute humidity of 9.6 g/kg. In the absence of data for 23°C/9.6 g/kg, it is assumed that the relative adjustments are the same as for 20°C/9.45 g/kg, resulting in the following equation:

$$\Delta EC = (0.00832 * x - 0.0799) * 100$$

(With ΔEC: the deviation from energy consumption at 23°C and absolute humidity of 9.6g/kg in %, x: the absolute humidity under the test conditions in g/kg dry air)

This was used to derive the adjustment figures listed in Table 12 to be applied to vented dryers.

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[21] *Ecodesign of Laundry Dryers*, Preparatory studies for Ecodesign requirements of Energy-using-Products (EuP) – Lot 16. Final Report - March 2009.

Table 12. Test conditions as required by various test methods, and adjustments to normalise for ambient humidity for vented dryers (no adjustments required for condensing dryers).

Test method	Temperature requirement	Relative humidity (RH) requirement	Calculated absolute humidity for that temp and relative humidity (AH)*	Percentage change in energy consumption to be applied to results from that test methodology due to humidity difference
EU	23	55%	9.6	0%
Australia	20	60%	8.7	+0.75%
Canada/ USA	24	50%	9.3	+0.25%

*Absolute humidity values as given by www.ringbell.co.uk/info/humid.htm.

Air temperature:

The Ecodesign study quotes equations for variations in energy consumption due to small variations in temperature away from a base temperature of 20°C. For this analysis we require change in energy consumption for variations in ambient temperature away from the EU test temperature of 23°C. In the absence of data for 23°C, it is assumed that the relative adjustments are the same as for 20°C, resulting in the following equations:

For air vented dryers:

$$\Delta EC = (-0.0115*T + 0.2656) *100$$

For (air) condenser dryers:

$$\Delta EC = (-0.0021 *T + 0.0494) *100$$

(Where: ΔEC = Deviation from energy consumption at standard conditions in %, T = ambient temperature under the test conditions in °C)

If the test temperature in a given country is **higher** than that in the benchmark test methodology, then the assumed energy consumption of the dryers in that country will be **increased** by the calculated percentage. If the test temperature is **lower** than that in the benchmark test methodology, then the energy consumption will be **decreased** by the calculated percentage. Differences in humidity change energy consumption in the opposite direction.

These equations were used to derive the adjustment figures listed in Table 13 below.

Table 13. Test conditions as required by various test methods, and adjustments to be made to normalise for ambient temperature.

Test method	Temperature requirement	Percentage change in energy consumption to be applied to results from that test methodology due to temperature difference – VENTED DRYERS	Percentage change in energy consumption to be applied to results from that test methodology due to temperature difference – CONDENSING DRYERS
EU	23	0%	0%
Australia	20	-3.56%	-0.74%
Canada/ USA	24	+1.04%	+0.1%

Initial and final moisture content – normalise to EN 61121:2005

The energy demand of the laundry dryer depends on the water held in the clothes after spinning in the washing machine, i.e. the initial moisture content at the start of the drying process, and on the moisture that is allowed to remain in the clothes at the end of the drying process, i.e. the final moisture content. In testing, the initial and final moisture contents are specified in the test methods. Not only do both of these vary by region, but the scales on which moisture content is measured vary too.

International Standard IEC 61121 will in due course provide a methodology to compare energy performance derived from different initial and final moisture contents, but this standard is not yet available. A draft of the standard, however, asserts that '*the energy* consumption *of most dryers is highly linear with respect to initial moisture content*' for initial moisture contents between 45% and 90% Residual Moisture Content (% RMC). As the fabric becomes drier it requires an increasing amount of energy to remove the last few per cent of moisture. The last residue of water is quite firmly attracted to the textile fabric, especially for cotton, and less so for synthetic fabrics. Test results were identified from the USA that provided the cumulative energy consumption as the test load is dried [22], see Figure 18.

Adjustments were made on the energy performance of each dryer based on the assumption that all other dryers show the same relationship between energy consumption and change of moisture content as the US dryer that was measured to generate the data in Figure 18. The resultant changes in energy consumption required to be made to each energy performance result are summarised in Table 15.

The steps involved in deriving this methodology are explained in more detail in the following sections.

[22] Department of Energy: 10 CFR Part 430 - Energy Conservation Program for Consumer Products: Test Procedures for Clothes Dryers and Room Air Conditioners; Proposed Rule, June 29, 2010. It is explained in this document that the scale used is % RMC of bone dry.

Moisture level scales – '% bone dry' and 'RMC for a 'normalised' load'

EU test methodologies use a moisture measurement scale of 'remaining moisture content' (RMC) compared to a textile load that is allowed to reach equilibrium in an ambient temperature of 20°C with 65% relative humidity. This is referred to in the standards as a 'normalised [textile] load'. To minimise confusion in the context of this document about 'normalisation' of data, this will be referred to as an 'RMC (20°C/65%rh) scale', rather than the usual 'RMC (normalised load) scale'. On this scale, 0% RMC is when the textiles are as dry as they were after being 'normalised' and so some moisture does remain in the textiles. It is possible to make the textiles dryer than this, which would be measured as negative % moisture content on the RMC (20°C/65%rh) scale.

Australia, Canada and USA use percentage of bone dry. This has 'bone dry' as the base level (0%), which is when the textile weight changes by less than 1% on successive measurements every 20 minutes during a hot drying cycle. It is difficult (but not impossible) to get the textiles dryer than this, so 0% on this scale is for practical purposes 'bone' or absolutely dry.

The offset between percentage bone dry and percentage RMC (20°C/65%rh) moisture content scales depends upon the fabrics in the load.

For 100% cotton loads and offset of 7% has been adopted[23], which coincides with the average figure from IEC 60456 Annex G.[24] The relationship is therefore:

[% Bone Dry] = [% RMC normalised load] + 7%

For the USA/Canadian mix of 50% cotton/50% easy care the offset has been estimated at 3.65%[25] and so the relationship is therefore:

[% Bone Dry] = [% RMC normalised load] + 3.65%

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[23] Recommended in personal correspondence from Lloyd Harrington (Australian expert) 21 December 2010. *'Various practical tests have been done to establish the bone dry factor. It is typically 6% (not so hot dryer) to 7.5% (large commercial dryer). Typical values are 6.5% to 7%. If you used 7%, you would be pretty close'.*

[24] IEC 60456 Clothes washing machines for household use – Methods for measuring the performance, 5th Edition Annex G. This standard defines the test loads for washing machines and for laundry dryers and quotes between 6% and 8% depending on temperature of drying cycle.

[25] IEC 60456 quotes that for a European synthetic load of 35% cotton/65% polyester there will be a 2.5% residual moisture content in a standard 20°C/65%rh conditioned load (i.e. the difference between moisture content from conditioned and moisture content from bone dry). Assuming a linear relationship, this implies a 3.65% offset for 50% cotton/50% easy care.

Normalisation of data for initial and final moisture content

The different requirements for initial and final moisture contents for testing in the various countries are explained in

Table 14.

Table 14. Initial and final moisture levels required by the three main types of test methodology, quoted in local and comparable units.

Requirement	EU	Canada and USA	Australia
Initial moisture – local units	60% RMC (20°C/65%rh)	70% of bone dry	90% of bone dry
Final moisture – local units	0% RMC (20°C/65%rh)	2.5% to 5% of bone dry, so typical 3.75%	6% of bone dry
Initial moisture – % bone dry	67%	70%	90%
Final moisture – % bone dry	7%	3.75%	6%
Initial moisture – RMC (20°C/65%rh)	60%	63%	83%
Final moisture – RMC (20°C/65%rh)	0%	-4.5% to -2%, so typical -3.25%	-1%
Difference in initial to final (indicative measure only)	*60%*	*66.25%*	*84%*

Note: A formal process for normalising dryer performance for differing initial moisture contents is under development in the planned revision of the International Standard IEC 61121. However, this process is complex and requires access to a range of data unavailable to this analysis.

The draft standard does assert however that '*the energy consumption of most dryers is highly linear with respect to initial moisture content*' for initial moisture contents between 45% and 90% Residual Moisture Content (% RMC). This assertion is reinforced in a recent proposed rule change for the test procedures for clothes dryers in the USA.[26] Figure 17 is taken from this document and shows the results of a test run for a vented baseline electric standard dryer with a 7 lb (3.17 kg) load[27], showing the cumulative energy consumption as the test load is dried. While energy consumption in the range of 70% to 10% Residual

[26] Department of Energy: 10 CFR Part 430 - Energy Conservation Program for Consumer Products: Test Procedures for Clothes Dryers and Room Air Conditioners; Proposed Rule, June 29, 2010. It is explained in this document that the scale used is % RMC of bone dry.
[27] The DOE source document explains that the actual tests were done with an 8 lb load, but implies that data were corrected as if it was done using a 7 lb load (p37,618). The test load comprised '*different materials and articles of clothing*'.

Moisture content (RMC) shows a linear relationship, as described earlier, the last moisture requires more energy to remove below around 5% RMC (bone dry).

At the ‘wet end’ of the cycle, it is therefore fairly straightforward to apply a factor derived from the slope of this graph, to account for different initial moisture contents. However, at the ‘dry end’, changes in final moisture content will result in proportionately much larger changes to total energy required, and so errors introduced would be proportionately larger.

Figure 17. Cumulative energy consumption measured against moisture content for a 3.17 kg load in a vented dryer, according to USA Department of energy published results.

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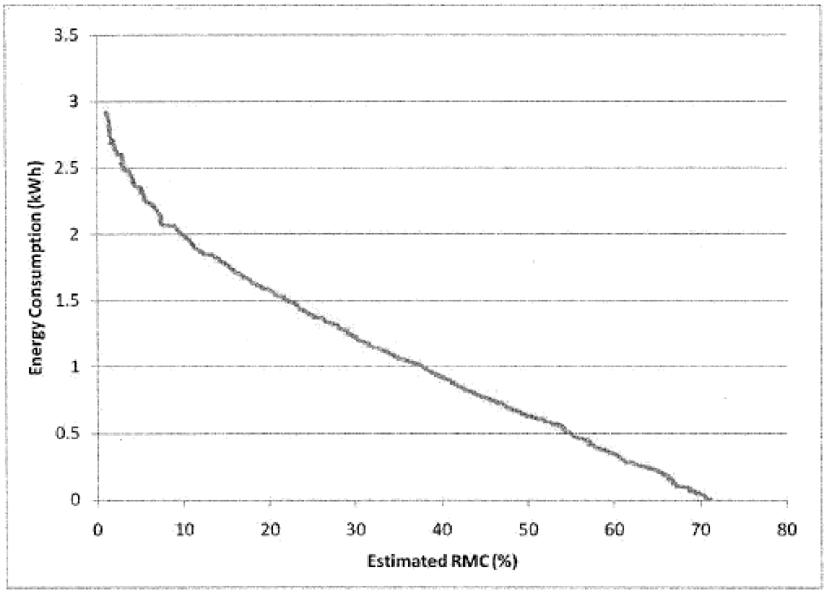
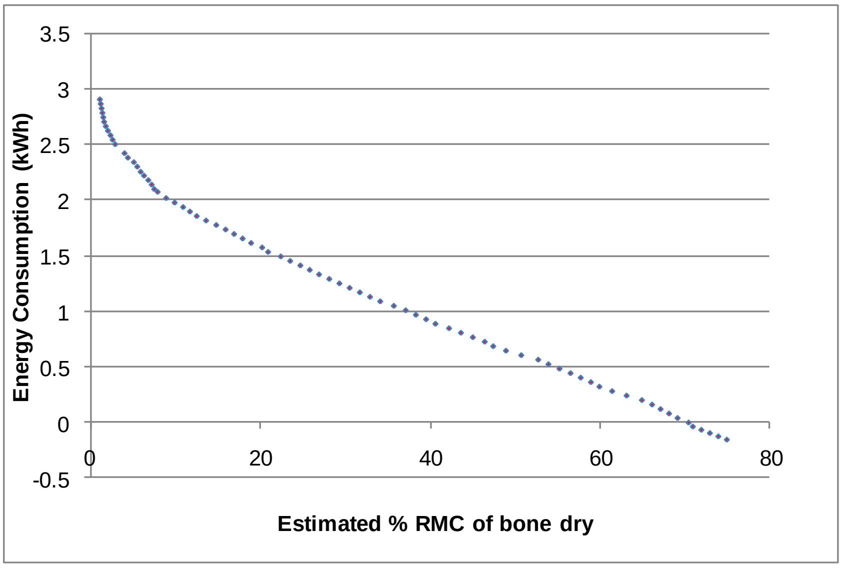


Figure 0.2 Automatic Cycle Termination Test Energy Consumption versus Estimated RMC during the Test Cycle

The vertical axis for this graph is in kWh energy consumption for a 3.17kg load. The horizontal axis is in ‘RMC compared to bone dry’. I.e. for a 100% cotton load, 0% bone dry on this graph is equivalent to -7% RMC (20°C/65%rh); for a 50% cotton/50% easy care load, 0% bone dry is equivalent to -3.65% RMC (20°C/65%rh). To serve this analysis, the results above were replicated and extended to the highest RMC required (Australia at 90%) as in the graph below:

Figure 18. Cumulative energy consumption against moisture content measured in percentage residual moisture content of bone dry. This figure is derived from Figure 17.



Two possible approaches to analyse this were assessed, but the following one was selected as the most appropriate. This is based on the assumption that all other dryers show the same proportional reduction in energy consumption when initial and final moisture levels are adjusted as if the same adjustments were made to the US dryer in the graph above.

In Figure 18 the energy required to move from 90% to 67% of bone dry (the Australian initial condition to EU initial condition for a 100% cotton load) is around 26.5% less energy. Measured off the same graph, the change in energy by moving from 6% to 7% of bone dry (Australian to EU condition) is around 2.6% less energy. This gives a total of 29.2% less energy. It is therefore assumed that converting any Australian energy consumption to a consumption based on the EU moisture contents is achieved by subtracting 29.2% of the declared Australian energy consumption. This percentage change in energy consumption is then applied to all declared Australian energy consumption data to normalise values for differences in initial and final moisture content.

For USA/Canadian results, the target adjustment is slightly different due to the different fabric mix. If such a mix was tested under the EU test method of 60% to 0% RMC (20°C/65%rh), this is equivalent to 63.65% to 3.65% bone dry, compared to the USA/Canadian figures of 70% and 3.75% of bone dry. Energy adjustments are calculated as above using Figure 18, giving -8.2% for the adjustment to initial condition, and zero change for the final condition, and a total of -8.2%. This percentage change is applied to all USA/Canadian test results.

Table 15. Summary of normalisation adjustments to be made for differences in moisture content.

Adjustment for moisture content	Australia		USA/Canada		EU	
For initial moisture level	Change from 90% to 67% of bone dry	-26.5%	Change from 70% to 63.7% of bone dry	-8.2%	No change	0%
For final moisture level	Change from 6% to 7% of bone dry	-2.6%	Change from 3.75% to 3.65% of bone dry	0%	No change	0%
Total adjustment	Range 84% down to 60%	-29.2%	Range 66.25% down to 60%	-8.2%	No change	0%

Limitations to this approach include:

- It is based on results from a single vented machine. There will be variations and while this machine is supposedly typical of vented machines, differences in condensing machine behaviour are unknown and therefore less robust.
- The exact mix of fabrics used in the USA DOE test of Figure 18 is not known, and in any case not the same as the 100% cotton of the Australian test methodology. Therefore Australia's results (particularly at the FMC stage) are likely to be adjusted too little, resulting in normalised Australian energy consumption results probably being higher than they should be. US results should be adjusted by a more correct amount.
- The bigger the shift in moisture content, the less accurate the results are likely to be (as differences between the appliance for which results are being adjusted and the appliance used to generate the graph will become proportionately more influential on the overall energy consumption). Hence errors introduced for Australian results will be higher than for USA results.

Load – normalised to 3.17 kg as per USA/Canadian test method

It is generally accepted that a higher loading leads to a better efficiency as the total energy consumption also depends on the base load energy necessary to heat up the appliance, to turn the drum, to control the temperature, etc. Proportionately, this base load energy will be lower per kilogram for fully loaded or larger capacity appliances than for part loaded or lower capacity appliances. This analysis does not normalise for variations in appliance maximum capacity because this is simply a feature of each machine as opposed to the test methodology.

However, the various test methodologies used to generate the data have different requirements for loading. Energy results are therefore quite different and it is necessary to normalise before comparison of laundry dryer performance in benchmarking.

The European and Australian test methodologies require the appliance to be filled to its maximum declared capacity, whereas the USA/Canadian test methodologies[28] require a fixed weight of dry textiles (3.17 kg for standard sized dryers) regardless of the capacity of the appliance. USA and Canadian test results will therefore always show lower energy consumption for the test cycle than European/Australian results. USA/Canadian results may also show a higher specific energy consumption, equivalent to a lower energy efficiency, because of the influence of loading level during test and the proportional impact of the base-load energy described above.

Although the standard approach in this Annex is to normalise to the most commonly used test methodology in the datasets (i.e. in this case the EU), a robust means of assessing the rated *capacity* of dryers in kilograms of dry textiles for the North American data is not known at the time of this analysis, making this impossible. Therefore, the approach used in this analysis is to normalise European data to the equivalent result if a test load of 3.17 kg had been used.

Only one set of empirical evidence has been identified that could enable scaling of energy consumption in this way: the European Ecodesign study quotes research by Öko-Institut e.V. (2004) in which the effect of loading on energy consumption is assessed. These data are reproduced as Table 16 below.

Table 16. The total and the specific energy demand against loading for a dryer of 5 kg rated capacity, from Öko-Institut e.v. (2004)[29].

Loading	5 kg	4.5 kg	4 kg	3.5 kg	3.2 kg	3 kg
Total energy demand (per cycle)	100%	93%	85%	78%	73%	70%
Specific energy demand (per kilogram)	100%	103%	106%	111%	114%	117%
Data quality	m	m	m	m	i	m

m = measured data for ‘cotton dry’ programme
i = interpolation

It is assumed that the data from Table 16 can be used to adjust the declared energy consumption/efficiency of a fully loaded 5 kg machine under test to an equivalent

[28] e.g. National Standards System of Canada test method of measuring energy consumption and drum volume of electrically heated household tumble-type clothes dryers – CAN/CSA-C361-92
[29] Original data appears in report: Rǘdenauer & Gensch (13 January 2004) ‘*Energy demand of tumble driers with respect to differences in technology and ambient conditions*’, Final Report commissioned by European Committee of Domestic Equipment Manufacturers (CECED), Ǒko-Institut e.V, p7.

consumption/efficiency for a partial load in the range 5 kg down to 3 kg, including to the normalised loading of 3.17 kg. Furthermore, it is assumed that these data can be extrapolated to adjust the declared energy consumption of an appliance of capacity above 5 kg down to the normalised loading of 3.17 kg. Given that the annex has no data on machines of any other capacity or type, the approach taken is to use the data in Table 16 to normalise all results despite the limitations of this approach, which include:

- Only one capacity of appliance was tested.
- Only one particular appliance of unknown specification was tested (vented/condensing).
- Tests only covered 100% cotton loads.
- It has not been verified that similar percentage change in energy with loading would be found for other sizes and designs of appliance.
- It has not been verified that these results can be extrapolated upwards (above 5 kg) with the same form of relationship.

The process used is:

1. The approach assumes that all dryers will have the same proportional (percentage) change in energy consumption with changing part-load percentage as this dryer.
2. The loading levels above (4.5 kg, 4 kg, 3.5 kg etc) were converted to 'percentage loading', i.e. 4 kg load is equivalent to a 4 kg/5 kg = 80% loading.
3. Thus it is assumed that a dryer loaded at 80% of full load yields a Total Energy Demand (TED) of 85% of that when tested at full load; and Specific Energy Demand (SED) of 106% of that for full load.
4. This relationship was plotted as a graph and the equation of the curve derived and extrapolated. The relationship is given by:

   % Total Energy Demand = 0.7522 * % Loading + 0.25

5. This was used to modify each EU and Australian test result by calculating for each dryer what percentage load a load of 3.17kg is equivalent to. E.g. for a 6 kg capacity dryer, the load level is 3.17/6 = 52.8%. The equation above yields an adjustment of 64.7% for this percentage load.

This process resulted in adjustments to individual product performance levels. The maximum, minimum and average adjustments made are summarised in Table 17.

Table 17. Summary of the maximum, minimum and average adjustments for loading made to individual product performance data (kWh/cycle) as a result of normalisation to a 3.17 kg textile load.

	Australian data	EU data	USA/Canadian data
Maximum adjustment	-51%	-45%	No adjustment required
Average adjustment	-31%	-36%	
Minimum adjustment	-15%	-27%	

Fabric type – 5% adjustment for USA/Canada

Some types of fabrics retain water more than others, thus increasing the energy needed to dry them. The fabrics used in the different test methodologies are:

- 100% cotton: Australia, EU, Switzerland;
- 50% cotton, 50% polyester: Canada, USA.

The energy consumption of a standard cycle carried out with 50% cotton/50% polyester fabrics is around 5% less than one with 100% cotton and the same dry weight.[30] The energy consumption for USA and Canadian products was increased by 5% to account for this difference in test fabrics. Australian and EU testing is already carried out with 100% cotton loads.

[30] Personal correspondence with a major UK test house, based upon technical expert analysis of practical tests on one vented dryer in 2010. Average energy consumption was calculated for five drying cycles with each of two mixes of fabric test loads from which a figure of 5% difference was calculated. The test results are not in the public domain.

Annex 4 The process used to identify best in class appliances

The original intention was to identify the best performing product in each of the classes defined in Table 5. However, the labelling of products as being vented/condensing/heat pump type proved sometimes unreliable. Instead, for best in class analysis, vented and condensing products were considered together and divided into products below 7 kg capacity and above 7 kg capacity. Significant product-specific research was necessary to ensure that no heat pump-based products appeared in the conventional vented/condensing category, and that these were considered in the separate heat pump category.

It is important to note that the best performing products were selected based on their normalised consumption in kilowatt hours per cycle. Only the declared data, however, can be verified back to the manufacturer's source data. The uncertainties and any flaws in the normalisation methodology therefore also directly affect the selection of best in class products. As a result, best in class data should only be viewed as illustrative.

The process to identify best in class was as follows:

1. Data for all individual products were integrated into a single database.
2. Data were sorted into the two size categories and divided into heat pump type and condensing/vented type.
3. The best performing three or four products according to consumption were identified each class.
4. Starting with the best performing model in each class, Internet searches were used to retrieve where possible original manufacturers' declared performance data. It was considered necessary to verify that the appliance was of the appropriate capacity and type (vented/condensing vs. heat pump), and was available for commercial sale, as well as ensuring that the efficiency level matched what was declared in the database used for market analysis.
5. Appliances that achieve high efficiency through extremely long, low-temperature drying cycles (e.g. over four hours) were not considered eligible to compete in these appliance classes.
6. Appliances that could not be traced as available on the market were rejected from the best in class analysis. Also rejected were any products for which energy performance source did not match very closely that declared in the database used for market analysis.
7. Appliances found to be in the wrong category were moved to the appropriate category (often occurred for heat pump models).
8. When a candidate best in class appliance was rejected or moved to a different class, the next best performing product was selected for verification. This process was repeated until a product could be verified in that class.

Annex 5 Table of number of products analysed for each country in each year

Table 18. Number of individual appliances included in the analysis for each country and each year.

Country	Total	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Australia	931	0	0	0	0	0	73	72	81	84	93	117	134	134	143	0
Canada	1,334	149	75	40	66	108	34	23	120	210	113	124	80	82	56	54
Denmark	1,926	85	119	117	120	122	145	144	173	173	155	172	210	191	0	0
France (alt. data)	141	0	0	0	0	40	0	0	0	101	0	0	0	0	0	0
UK	1,726	0	0	0	424	551	404	201	0	0	0	94	52	0	0	0
UK (alt. data)	577	0	0	0	0	0	0	0	0	0	0	0	78	119	194	186
USA (Federal and Californian)	1,338	0	0	0	0	0	0	0	0	0	0	0	218	381	421	318
Spain	168	0	0	0	0	0	0	0	0	0	0	0	0	0	0	168
Austria	n/a	no product data - only market average														
Switzerland	n/a	no product data - only market average														
EU	n/a	no product data - only market average														
Total	8,141	234	194	157	610	821	656	440	374	568	361	507	772	907	814	726

Note that more products than these were included in the original datasets supplied, but some products had to be excluded from the analysis due to missing or dubious data.
This information is shown in graphical form in Figure 1 on page 10.

Annex 6 Change log

This section records the changes made since original publication.

Changes in Version 2 from Version 1:

1. Update to Table 6 to correct average adjustments for USA and Canadian dryers for differences in moisture content. Was -18%, changed to -8.2% in line with Table 15 of the Annex. Table 15 was correct; Table 6 had not previously been updated in line.
2. Deletion of brief introduction on cover page, with additional information incorporated into summary.
3. Addition of Change Log.

No further changes made.

Change in Version 2.1 from Version 2:

1. National consumption units corrected in summary and section 6 – were stated as GWh, corrected to TWh (or '000 GWh as shown correctly in Figure 15).
2. Issue number, date and change log updated.

No further changes made.