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

Benchmarking report for Dishwashers
Issue Date: 4 April 2014

For further information refer to http://mappingandbenchmarking.iea-4e.org/matrix or email operating.agent@mapping.iea-4e.org
1 Summary overview and outcomes

Dishwashers, often grouped with washing machines as wet appliances, have been the subject of energy-focussed regulation in many countries starting in the early 1990s. Whilst they are not one of the larger energy users in a domestic setting, the prevalence of regulation along with some technological differences between the major international markets mean that identifying areas of potential improvement has benefits for individual households and governments alike.

This benchmarking report examines:

- Variations in the scope and stringency of national minimum performance levels required for dishwashers, and a summary of additional national policies seeking to promote dishwasher efficiency;
- Key differences in product performance between countries over the 1996-2012 period and any links to the policies in place over that period;
- Areas of opportunity where additional or modified policy intervention may be desirable in the future to improve product energy performance;
- The potential energy savings that are currently possible, and may be possible in the future if aggressive policy intervention is undertaken.

The analysis has been undertaken as part of the Mapping and Benchmarking Annex, operating under the IEA’s Efficient End-Use Electrical Equipment (4E) Implementing Agreement. In addition to this quantitative-based analysis, members of the 4E Implementing Agreement can access separate additional qualitative insights into some of the policy drivers, barriers and resulting opportunities that exist regarding dishwashers and other domestic appliances at the national and regional level.¹

Coverage and limitations of the analysis

The analysis is based on data supplied from Australia, Austria, Canada, Denmark, the European Union (EU), the Republic of Korea, Switzerland, the UK and the USA. Data was collected on all dishwashers with capacity of 6-16 places, including built-in, portable and drawer-type units but excluding table-top dishwashers.

To enable comparison of the energy performance of products between countries, data was 'normalised' based on the differences in the inlet water temperature and the load specified in each of the local test methodologies. North American² data was also adjusted to show the full cycle energy consumption including that used for powered drying³. There are a number

¹ This qualitative analysis is confidential and restricted to Mapping and Benchmarking Annex participants only. The analysis can be downloaded by participants from http://login.mapping.iea-4e.org/policy-benchmarking.
² For the purposes of this analysis and report, North America refers to Canada and the USA.
³ Powered drying is the introduction of electrically generated heat into the washing chamber for the purpose of improving the drying performance of the dishwasher. For models with this option, declared results in North America normally show the average of a test cycle with and without the powered drying in use.
of other differences in the various regulations (for example variations in soiling regime and different reporting requirements) but these have not been adjusted for.

To minimise uncertainties in the normalisation process and allow use of an Energy Efficiency Index (EEI) which has the flexibility to compare appliances of differing capacities, all country data was normalised to the EU regulations in force in 2013 and the associated EN methodology EN50242. However, due to some limitations in the normalisation methodology, the reported values for countries that required normalisation must be viewed with some degree of caution (Australia, Canada, Republic of Korea and the USA).

This is particularly true for the USA and Canada where the normalisation steps about which there is some uncertainty have the largest impact, although direct comparisons between these countries remain robust. Caution should also be taken with the normalised results for Australia where differences in the reporting requirements, for which there is no reliable method to adjust, mean that normalised energy metric results (UEC, UEE and EEI) are likely to appear better than they are in reality, although to what extent is unknown.

Aside from this issue, the overall degree of impact on the comparability of normalised values across all countries is likely to be limited, and will have very little impact on direct comparisons between the EU countries and Switzerland who test to EN50242.

Summary of policy actions
The first mandatory requirements for labelling and/or minimum energy performance standards (MEPS) in the countries studied were those introduced by Canada and the USA in 1994/95. Since then, all countries in the analysis have introduced mandatory comparative labelling with MEPS now in place in everywhere except Switzerland, which is planning to introduce them in 2014, and Australia. At the time of analysis, the MEPS in North America and Korea had been strengthened, as had those in the EU most recently in late 2013.

Different metrics are regulated in each of the major markets, with the North Americans using Total Annual Energy Consumption while different types of Energy Efficiency Index (EEI) are used in the EU and the Republic of Korea, the latter using a combined energy and water efficiency index. The Korean and Australian governments have set minimum performance standards for cleaning and drying, as has the EU from late 2013. These variations are also reflected in a variety of approaches to labelling which, aside from energy, include information on some combination of cleaning/drying performance, CO₂ emissions, cost and water use, the latter on a separate label in Australia.

The integration of water efficiency in the Korean EEI makes direct comparison impossible but, by normalising North American MEPS it is possible to compare them on a like for like basis with the EU EEI. Although the assumptions that are necessary make the comparison illustrative, it is clear that the 2013 MEPS in Europe require significantly more energy efficient dishwashers than those in North America, by approximately 30% for standard size.
dishwashers. There are a number of market differences that account for this significant variation in MEPS which are investigated below.

In addition to these mandatory regulations, all countries have a number of other supporting policies. In particular, many countries have voluntary labelling to identify premium products (ENERGY STAR in North America and Energy Saving Recommended in the UK). Often these product labelling programmes are used as the focus for financial incentive schemes to encourage the adoption of these premium products. Other national-level activities range from mandatory reporting requirements to more generalised awareness campaigns.

**Comparative energy performance of dishwashers**

The average unit energy consumption for new dishwashers has fallen steadily in all countries/regions over the period for which data is available. When normalised to account for differences in local test methodology, dishwasher energy consumption has improved by an average of 1.9% each year across all countries. Despite this consistent pattern of widespread reductions throughout the period, Figure 1 shows that there remains a significant difference in average UEC between the North American market and the rest of the world. Comparing the performance of products in Denmark (the other dataset that runs over the same period) shows that in 1996 Canadian models used 47% more energy whereas by 2012 that value had fallen but only to 43%.

The scale of this difference is so significant that a separate evaluation was undertaken to establish whether the additional energy consumption could be accounted for and therefore whether the results were realistic. Although this was only a first order analysis, the results showed clearly that the difference in energy consumption is genuine and the scale of difference is reasonable.

There are some fundamental differences in the North American dishwasher market that account for the extra energy. Firstly, North American dishwashers are almost always installed to take a hot feed whereas a cold feed is used elsewhere. As certain stages of a dishwasher’s cycle do not require hot water, much of the embodied energy in a hot feed water supply is wasted during those stages, leading to an energy penalty. The second major difference is the predominance of powered drying function in North America, again a technology that is almost unused elsewhere. This functionality, which speeds up the drying process, is energy intensive and so again entails an additional energy cost.

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4 The introduction of electrically generated heat into the washing chamber for the purpose of improving the drying performance of the dishwasher.
However, as is always the case for the Mapping and Benchmarking Annex, the analysis is based on delivered energy efficiency. Given that dishwashers use a large proportion of energy for water heating, it may be that the primary energy use is lower in the North American models if the hot water source is a very efficient boiler in close proximity to the dishwasher. Policy makers in all regions should consider also assessing the primary energy use to establish under which circumstances hot water feeds may save primary energy. It may also be beneficial to encourage both hot and cold fill options in a single machine so that energy performance can be optimised to the local circumstances.

However, in terms of delivered energy, there are still significant differences and North American policy makers should look closely at the opportunities to bring performance in line with other markets. Within the bounds of the legal framework in North America, in which regulators are required to ensure that any market intervention meets a number of criteria such as not precluding product classes or characteristics that are widely available, a number of options seem worthy of immediate review. These include: encouraging the introduction of new low energy powered drying; evaluating the extent to which water consumption can be reduced without negatively impacting on wash performance; and publicising the use of longer eco cycles from cold feed models so that consumers can choose lower energy options if they wish to.

Comparing the better performing dishwashers in the rest of the world, European models are all very closely aligned, with Korean dishwashers performing similarly. Australian dishwashers appear to be the lowest energy consumers, using on average 5% to 12% less energy per cycle than those in Denmark for example. It is thought that the improved performance of Australian products can be attributed to some combination of differences in reporting requirements for wash and dry quality and consumer purchasing preferences, although the relative contributions of these are unknown.

The first of these (the difference in reporting requirements \textsuperscript{5}) means that this result should be treated with caution. It allows test cycles to be better optimised for energy performance. This has not been normalised for and will contribute to some extent to these lower test results.

\textsuperscript{5} Australia has a minimum performance requirement for wash and dry quality but, unlike in the Republic of Korea and the EU, the result is not declared on the energy label (although since this analysis was undertaken, the EU has changed to an approach similar to Australia).

Figure 2: Comparing UECs of the average product available to that of the average product purchased in Australia (refer to Annex 8 for data table).

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure2.png}
\caption{Comparing UECs of the average product available to that of the average product purchased in Australia.}
\end{figure}

\textsuperscript{iv}
for UEC. Secondly, it is possible that some of the difference is genuine and attributable to Australian purchasing preferences, which can be interpreted from Figure 2. One aspect of this is that slightly larger dishwashers are more popular in Australia and, perhaps counter-intuitively, these consume less energy than the slightly smaller models that are more popular in Europe. Another aspect may be that Australian consumers are proactively buying the more efficient products although the evidence for this is not clear.

The preference for larger dishwashers in Australia is shown clearly when looking at overall average capacity data. Figure 3 shows that while in most countries the average dishwasher capacity has remained fairly steady at between 11 and 12 place settings, Australian consumers are buying dishwashers with an average capacity of between 12 and 13 place settings. This is simply driven by a much greater market share of products with a capacity of 14 place settings compared to the other markets in the study.

Having said that, there is a definite trend in most markets towards the purchase of larger capacity units which, despite being somewhat offset by a concurrent increase in the numbers of very small dishwashers being purchased, leads to a slight increase in average capacity in markets across the EU. While no capacity data is available for Canada, the data available from the USA suggests that this trend is not as apparent in North America where the range of capacities available on the market has remained fairly constant. The cause and significance of the relatively volatile capacity trend in Korea is unknown although the fact that it is a much smaller market may be a factor.

Given that Australian dishwashers have both the lowest average unit energy consumption and the highest average capacity of the datasets analysed, it is no surprise that it is also the best performing market for energy efficiency. This is most apparent for the simple metric of Unit Energy Efficiency (UEE kWh/cycle/place setting) but remains true even when looking at an EU Energy Efficiency Index (which is designed to remove any inherent scale effects in energy consumption). The relatively consistent capacities of dishwashers in other parts of the world mean that the relative performance of the other countries is very similar to that for

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6 While Canada does not collect model-specific capacity data, the markets are considered to be similar, with common products being sold in both markets. In general, the Canadian average capacity is expected to follow a similar trend to that shown for the U.S.
energy consumption, including the very different performance of North American dishwashers.

An unusual characteristic of dishwashers is that in many markets the largest models have lower UECs than the most popular mid-sized models. Figure 4 shows this in the UK where EU MEPS were introduced in 2011 and were scheduled to be tightened in 2013. Because the larger capacity models offer greater functionality to the consumer, they are often sold at the top end of the market, allowing manufacturers to sell them at a higher price point. One reason for this improvement in performance at the higher capacities may be that manufacturers are using these premium products to invest in the product developments that are necessary to improve energy performance.

It is also possible that the design and technology changes implemented by manufacturers to create additional capacity coincidentally deliver better performance. Changes such as improvements to filter design, pump motor efficiency, alternating pumping to upper and lower spray arms (thereby reducing the volume of water needed) or moving the heater from the tub to the water sump will create space and improve efficiency. Policy makers should work with manufacturers to understand these technologies and the other market drivers that allow larger units to consume less energy and develop policies that will encourage similar efficiency improvements in smaller capacity units.

There are two non-energy metrics that can also shed some light on the drivers behind dishwasher energy performance over the period of the analysis. Firstly the water consumption of dishwashers has been reducing at a very similar rate to the energy consumption. This reinforces the importance of water use and suggests that it may be useful for regulators to incorporate water performance standards into their regulations, provided they are set alongside, and not in the place of, energy regulations.

Although little data was available to the study, it seems that in Europe and Australia the programme cycle times for dishwashers under test have increased enormously since 1996. In Denmark, for example, it is estimated that cycle time has gone up by more than 200% in that period. There are a number of energy benefits to longer dishwasher cycles, but regulators should be aware that they will not be reaped if consumers are using faster wash cycles. Policies should therefore address this risk in some way, either by increasing the
likelihood that consumers use the eco cycles or by making the test better reflect consumer use.

The impact of regulations on performance

Evidence of the effectiveness of regulations to improve efficiency in the markets studied is variable but the consistent trend towards improved product energy efficiency suggests that regulations have been effective in all countries. For example, Figure 5 shows that the average EEI of standard sized dishwashers in the EU and Swiss markets has fallen consistently since the introduction of energy labels in 1999. The enforcement of EU MEPS in late 2011 with the introduction of new premium label classes can also be seen to be driving further improvements in both the Austrian and EU-wide results. The recent impact in the UK and Denmark is less clear, but a closer review of the UK situation suggests that average UK EEIs are almost certain to have improved significantly between 2011-13. It is also apparent that the introduction of more stringent EU MEPS in 2013 will significantly improve UK dishwasher efficiency again. Overall, this clearly suggests that the regulations in Europe are working effectively.

Figure 6 compares the spread of product performance over the label classes in Australia in 2009 and the UK in 2011, just before the introduction of the new premium labels in the EU. UK products and sales were mostly clustered in the top category of the old label whereas the products in Australia are more evenly spread across the different classes. This suggests that regular updates of energy labels are important and that the EU update of its label classes was needed when it was implemented. Regulators in all markets should look to ensure that labels retain sufficient differentiation of performance so that consumers can continue to choose the most efficient models.
Updating MEPS regularly is also likely to drive improvements in the market and the most recent model data in Australia, North America and Korea shows that there is still a wide range of energy performances in those markets. This is less clear in the EU due to a lack of recent product data, although the 2012 data from Denmark does have a reasonable spread of performance. This suggests that the option to introduce or strengthen MEPS remains viable in most markets and should remain under review.

**Current best performing products**

The opportunity to continue to strengthen MEPS to help maintain the steady improvements in energy performance will depend on the development of new, more efficient products. The extent to which this is feasible is not addressed in this report, but policy makers could gain some insight into what may be possible by knowing the performance of the most efficient products found on the market at the time of data collection.

For those countries where model-level data was available (Australia, Canada, Denmark, the UK and the USA), an analysis was undertaken to identify the most efficient dishwashers in the market. This analysis looked at all models (using the EU EEI metric to compare) and models by capacity (using normalised UEC). Figure 7 shows the best products identified.

**Figure 7: Best performing dishwashers in the markets covered. Overall product ranked by EU EEI, each capacity ranked by normalised UEC (kWh/cycle).**

<table>
<thead>
<tr>
<th>Country on sale</th>
<th>Capacity</th>
<th>Normalised unit energy consumption (kWh/cycle)</th>
<th>Declared unit energy consumption (kWh/cycle)</th>
<th>Energy efficiency index (EEI)</th>
<th>Water consumption (litres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All dishwashers in scope</td>
<td>Australia</td>
<td>14</td>
<td>0.69</td>
<td>0.62</td>
<td>41.5</td>
</tr>
<tr>
<td><strong>Dishwasher by capacity:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 place settings</td>
<td>Denmark</td>
<td>8</td>
<td>0.74</td>
<td>0.74</td>
<td>65.4</td>
</tr>
<tr>
<td>10 place settings</td>
<td>Australia</td>
<td>10</td>
<td>0.71</td>
<td>0.63</td>
<td>45.2</td>
</tr>
<tr>
<td>12 place setting</td>
<td>Denmark</td>
<td>12</td>
<td>0.82</td>
<td>0.82</td>
<td>51.2</td>
</tr>
<tr>
<td>14 place settings</td>
<td>Australia</td>
<td>14</td>
<td>0.69</td>
<td>0.62</td>
<td>41.5</td>
</tr>
</tbody>
</table>

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These results reinforce the hypothesis that even within the existing products available on the market there is scope for increasing the efficiency of dishwashers. For example, the average performing Australian dishwashers with capacities of 12 and 14 places respectively use 35% and 30% more energy than the current best performing product. Given that these two capacities account for the majority of the market in many countries, the potential energy savings by moving the market towards the existing best performer would be substantial.

Australia has a relatively wide spread of performance but is also the best performing market so the opportunities to improve energy performance in other locations are probably similar. Thus, policy makers can be assured that, in the short to medium term, aggressive policy intervention should not to lead to the inability of manufacturers to supply products to market.

**Long term potential energy savings**

Having established the opportunity for energy savings through greater uptake of the best products already on sale, there is value in briefly investigating the potential magnitude of energy savings that may be achieved through continued vigorous policy intervention.

A forward projection of energy consumption of dishwashers in Australia, Canada, the Republic of Korea, Switzerland, the USA and the 27 member states of the EU has been undertaken on behalf of the Mapping and Benchmarking Annex using a derivative of the Danish ELMODEL-bolig (domestic) model.\(^7\) Using information presented in this report as input data, the projections examine two potential future scenarios for energy consumption from 2010 to 2050. The two scenarios presented are:

- **Baseline scenario:** This scenario assumes a ‘business as usual’ baseline where the efficiency of dishwashers continues to improve at current rates.

- **BAT/BNAT scenario:** This scenario uses the same input data but attempts to estimate the maximum theoretical potential, by coercing the markets to offering only the currently best available technology (BAT), and future best technology that is not currently available (BNAT) which is assumed to improve at a rate of 1% per year.

The resulting projections are shown in Figure 8. While it is clear that the full BAT/BNAT scenario will not be reached in the timescales used in the projections, it is at least useful for policy makers to see an estimate of the maximum theoretical savings potential. Despite assumed improvements in the efficiency of new dishwashers under the baseline scenario, the BAT/BNAT scenario projects that total consumption would be reduced to 25 TWh/yr by 2020 (approximately 30 TWh/year below baseline) and achieve compound energy savings of no less than 1,200 TWh by 2050.

While this is not as significant as for some other domestic appliances, it still suggests that ongoing policy intervention in the dishwasher market is very much worthwhile and will be necessary if some of the energy saving potential available in the full BAT/BNAT scenario is to be realised.
The information and analysis contained within this summary document is developed to inform policy makers. Whilst the information analysed was supplied by representatives of National Governments, a number of assumptions, simplifications and transformations have been made in order to present information that is easily understood by policy makers, and to enable comparisons with other countries. Therefore, information should only be used as guidance in general policy – it may not be sufficiently detailed or robust for use in setting specific performance requirements. Details of information sources and assumptions, simplifications and transformations are contained within the document or the related Mapping Documents.

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Issue date: 4 April 2014
3 Introduction

Dishwashers, often grouped with washing machines as wash appliances, have been widely studied by energy policy groups and have been subject to regulation in many countries since the 1990s. Whilst they are not one of the larger energy users in a domestic setting, the prevalence of regulation, along with some technological differences between the major international markets, mean that they are an interesting product to review in the Mapping and Benchmarking Annex.

This benchmarking report outlines the primary policies implemented, and provides an analysis of the associated improvements in the energy performance of dishwashers over the period 1996-2012. It also investigates the potential for future improvement in dishwasher efficiency. The analysis is based on data supplied from Australia, Austria, Canada, Denmark, the European Union (EU), the Republic of Korea, Switzerland, the UK and the USA.

The benchmarking has been undertaken as part of the activities of the Mapping and Benchmarking Annex, operating under the IEA’s Efficient End-Use Electrical Equipment (4E) Implementing Agreement.

3.1 Objectives of the benchmarking analysis

The analysis compares the performance of new and installed dishwashers in various markets over a period of years, and seeks to provide policy makers with evidence-based analysis of:

- Variations in the scope and stringency of national minimum performance levels required for dishwashers, and a summary of additional national policies seeking to promote dishwasher efficiency;
- Key differences in product performance between countries over the 1996-2012 period and any links to the policies in place over that period;
- Areas of opportunity where additional or modified policy intervention may be desirable in the future to improve product energy performance;
- The potential energy savings that are currently possible, and may be possible in the future if aggressive policy intervention is undertaken.

In addition to this quantitative-based analysis, members of the Mapping and Benchmarking Annex can access separate, additional qualitative insights into some of the policy drivers, barriers and resulting opportunities that exist for dishwashers and other domestic appliances at the national and regional level.\(^8\)

\(^8\) This qualitative analysis is confidential and restricted to Mapping and Benchmarking Annex participants only. The analysis can be downloaded by participants from http://login.mapping.iea-4e.org/policy-benchmarking.
3.2 Product coverage

To enable like-for-like comparisons of products from markets subject to different regulatory definitions and culturally specific product specifications, a generic product definition was created to ensure that the products analysed in the different market datasets were of the same type. Figure 9 provides a summary of this product definition.9

Figure 9: Summary product definition, categorisation and basis for analysis.

<table>
<thead>
<tr>
<th>Definition:</th>
<th>Description:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definition and scope</td>
<td>A machine which cleans, rinses, and dries dishware, glassware, cutlery, and, in some cases, cooking utensils by chemical, mechanical, thermal, and/or electric means, normally through the use of water and detergent. The machine may or may not have a specific drying operation at the end of the programme. The scope is to primarily include:</td>
</tr>
<tr>
<td></td>
<td>• Single door built-in (this includes freestanding units in European definitions), portable and drawer-type dishwashers;</td>
</tr>
<tr>
<td></td>
<td>• Both non-soil-sensing and soil-sensing units.</td>
</tr>
<tr>
<td></td>
<td>The scope will exclude:</td>
</tr>
<tr>
<td></td>
<td>• Table top dishwashers (with fewer than 6 place settings).</td>
</tr>
<tr>
<td>Rated Capacity</td>
<td>6-16 place settings</td>
</tr>
<tr>
<td>Other characteristics to be noted/analysed</td>
<td>Analysed:</td>
</tr>
<tr>
<td></td>
<td>• Wash Cycle Time</td>
</tr>
<tr>
<td></td>
<td>Insufficient data to analyse:</td>
</tr>
<tr>
<td></td>
<td>• Cleansing Performance;</td>
</tr>
<tr>
<td></td>
<td>• Drying Performance;</td>
</tr>
<tr>
<td></td>
<td>• Standby Functionality and Power Levels (Delayed Start, End of Cycle and Off).</td>
</tr>
</tbody>
</table>

Based on this product definition, significant efforts were made to gain information on all dishwashers from all countries/regions participating in the Annex. Information was sought at the individual model level to allow the most accurate analysis of each of the markets. When model level data was not available, market average data was sought. All participating countries were able to provide data on the primary energy metrics and capacity (with the exception of Canada). Data on each of the other characteristics was only available for some countries.

3.3 Approach to benchmarking dishwashers, data quality and associated cautions

Simply comparing the declared average annual unit energy consumptions, or other measures of appliance performance, can be very misleading. This is primarily due to:

- Significant differences in testing methodologies used in the various countries/regions. In particular, the inlet temperature of the water used for the dishwasher and the size and make-up of the dishwasher load;
- Differences in the requirements for data declarations in each country/region resulting in apparently similar (for example) energy consumption values actually providing values that differ substantially from the original test results.

Thus, to enable effective comparison, source data has to be ‘processed’. The following subsections provide an outline of the data processing undertaken to enable effective cross-border analysis of dishwasher performance, and the associated cautions for interpreting the resulting outcomes due to limitations in the original data available, and the degree of processing required.

3.3.1 Approach to benchmarking of dishwashers

A full description of the analysis undertaken is provided in Annex 2. However, Figure 10 provides an overview of the stages in the process with a summary description following.

![Figure 10: Summary of stages in the mapping and benchmarking of domestic appliances.](data:image/png;base64,iVBORw0KGgoAAAANSUhEUgAAA....)

#### 3.3.1.1 Data cleaning and pre-processing

Data cleaning and pre-processing is best described as a mechanism for aligning all datasets to have comparable data to those received from elsewhere. These actions are country-specific, but include:

- Creation of annualised datasets and removal of duplicate entries where necessary;
- Classifying product type and functionality in a manner consistent with the product definition (refer to section 3.2);
- Adjusting reported values to be equivalent to test values based on national/regional regulatory regimes.

In almost all cases, a number of assumptions were required in the data cleaning and pre-processing activity. These are detailed in the individual country/region mapping reports (refer to section 3.3.1.2).
3.3.1.2 Production of graphical mapping outputs

Once the source data has been converted to a consistent format, this information is presented in individual mapping documents. These documents provide a summary of new appliance (and where possible stock) performance under local test conditions and include details of:

- The average Unit Energy Consumption (UEC) of appliances in kWh/cycle;
- The average Unit Energy Efficiency (UEE) of appliances in Wh/cycle/place-setting;
- The average capacity of dishwashers in number of place settings; and
- The average water use in litres.

The mapping documents also provide summary information on the test methodology in place, product policy implemented, and cultural information relevant to dishwashers.

Where possible data presented is based on a sales weighted average as this provides the clearest indication of the appliances purchased and entering the stock in an individual country. However, this has not always been possible and, in some cases, average product weighted information is presented (i.e. an average of all models available in the market not weighted by the sales of each model).  

3.3.1.3 Normalisation of product performance to enable international comparisons

To move from the position where all product performance data is based on the differing national/regional regulations, to a position where products’ performance is more directly comparable, a further process is required to account for the differences in the test methodologies used in the different datasets analysed. This process is referred to within the 4E Mapping and Benchmarking Annex as ‘normalisation’.

The individual unit energy performance of appliances from each country/region has been normalised to the requirements detailed in the 2008 EU regulations, the test method for which is EN50242 which is largely based on IEC 60436:2004. This benchmarking ‘standard’ has been selected due to:

- The number of reporting countries included within the analysis which test using this (or similar) methodologies, hence minimising the risk of introducing error during the normalisation process;
- The inclusion of a methodology for the calculation of an Energy Efficiency Index (EEI) which has the flexibility to compare appliances of differing capacities.

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10 All dishwashers mapping documents are available at: http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=11.
11 Where datasets of different types are used, this is indicated in the graphics.
The specific process for normalisation is somewhat complex and is detailed in Annex 2. In summary however, while there are a number of differences in the test method that may have an impact on energy consumption, adjustments were made for only three of these differences:

1. **Conversion of truncated cycle UECs to full cycle UECs**: in North America **powered drying** is commonly available on dishwashers. The North American product performance declarations for models with this functionality are the average of Unit Energy Consumption (UEC) for two test cycles; one in which the powered drying is switched on and one in which it is switched off (known as a truncated cycle). This analysis adjusts the declared UEC values to estimate the full cycle energy consumption with the powered drying switched on. An estimate of the adjustment needed is made using a small sample of data from an international test house that shows the percentage of energy used in each cycle stage, including powered drying.

2. **Differences in inlet water temperature**: the various test methodologies require different nominal cold water inlet temperatures, which has a direct impact on the energy needed to raise the water to the temperature required at the various stages of the dishwasher cycle. However, there is a well understood methodology for adjusting the water inlet temperatures to comparable levels based on the specific heat capacity of water. All results in this report are therefore adjusted to have the same nominal inlet water temperature of 15°C.

3. **Differences in load size and content**: the test methodologies used for measuring product performance included in the datasets used in this analysis specify slightly different load types (ie the type of crockery and cutlery which define a standard ‘place setting’, the inclusion of serving utensils, etc). Perhaps more importantly, all tests other than the North American test require that dishwashers are loaded with the number of place setting equal to the rated capacity of the appliance, while in North America a standard unit is always loaded with eight place settings. The difference in total thermal mass of the various loads has an impact on tested energy consumption as the load absorbs and releases some of the heat from/to the water at the different stages of the dishwasher’s cycle. An adjustment has been made to all results (other than those tested to benchmarking methodology) based on an

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13 The introduction of electrically generated heat into the washing chamber for the purpose of improving the drying performance of the dishwasher.

14 It is Annex policy to normalise for differences in test methodology that alter the UEC of the appliance so that the normalised result is an approximation of the result if the machine had been put through the benchmarking test method. While this might suggest that the powered drying energy should be removed from the North American results, the EU test method has no requirement for powered drying because this technology is mostly not available in the EU. However, the EU regulations do have a minimum standard for the dryness of the load at the end of the programme cycle. EU models tend to use a very high temperature final rinse to aid the drying process through evaporation which also has an energy cost. It is unclear whether a load in North America will be dry when a truncated cycle is used which would also make the results incomparable. Given that powered drying is very common in North American dishwashers and is most likely used by many consumers, it has been decided to use the full cycle energy in this analysis to ensure that the load is dry as is the case in the benchmark test. This approach will overstate to some degree the actual average UEC of dishwashers as used by consumers in North America but is the most comparable result to the benchmarking test.

15 This is defined in North America as a unit with a capacity of 8 or more place settings. In the EU test, the definition of standard is 10 or more place settings, while in Korea it is 7 or more place settings.
estimate of the difference in energy required to raise the temperature of the load through a typical EU test cycle. This estimate requires a series of assumptions about:

a. the mass of the different components of the load;
b. the specific heat capacities of those load components; and
c. the temperature profile through which the load is heated in a typical EU cycle.

3.3.2 Original data quality, impact of the normalisation and the grading of resulting outputs

Significant efforts were made by all participants to obtain information on the performance of products within their national/regional markets, and to ensure the integrity of the data supplied. However, inevitably the specific nature of each dataset is different. For example, some datasets are based on detailed information on individual models while others are based on aggregated data across a market. Even where datasets are based on individual models, the specific content may differ either in the product attributes captured during original data collection, or in the method of capture, e.g. compulsory product registration as products originally enter a market compared with somewhat less comprehensive surveys of the actual products sold within a market in a particular year.

In an effort to assist readers in understanding the degree of confidence they may place in each of the results presented, the Annex has developed a system for ‘grading’ the outputs associated with individual datasets, and the comparability of those outputs with outputs from data sourced elsewhere.

3.3.2.1 Approach to grading of data and associated analysis

The grading system developed by the Annex to provide a measure of the confidence in the reliability of analysis and associated outputs is based on an appraisal of the type and quality of the initial data input, the degree to which any consequential manipulations are likely to have degraded the reliability of the original data, and/or the comparability of outputs with those of other countries. While expert opinion is used to formulate the specific grading allocated to individual data sets or outputs, this expert opinion is formed based on a consistent framework outlined in Annex 3.

The system enables the allocation of a ‘robust’, ‘indicative’ or ‘illustrative’ grading to each output.

3.3.2.2 Grading of outcomes and cautions when interpreting data

Based on the grading system outlined above, each output used in this report has been allocated a robust, indicative or illustrative grading. The justification for the grading of each output is provided in Annex 4, but the key elements of the analysis that introduce uncertainty are described below.

It is strongly recommended that readers familiarise themselves with the gradings allocated to each output to ensure they have an understanding of the degree of confidence they may place in individual outputs and associated observations. To aid
transparency and understanding, unless otherwise stated, all graphic outputs in this report that compare new product performance show the grading by use of solid, dashed and dotted lines to represent outputs that are robust, indicative and illustrative respectively.

Uncertain aspects of the analysis approach
When normalising the unit energy consumption of dishwashers for differences in the test procedures between regions, the primary impacts on energy consumption are believed to be those that have been normalised for as described in Section 3.3.1.3. The cautions associated with these different steps are as follows:

1. **Conversion of truncated cycle UECs to full cycle UECs:** Readers should be aware that normalised North American results show an estimate of full cycle UEC which include powered drying. The adjustment used to move from declared to full cycle UEC are based on an assumption drawn from the analysis of a small sample of test results. While expert opinion suggests the adjustment is reasonable, the precise accuracy is unknown and consequently this reduces confidence in the relative position of the North American results to other datasets.

2. **Differences in inlet water temperature:** This aspect of the normalisation approach can be viewed with a high confidence because the methodology for adjusting results is well understood and widely used.

3. **Differences in load size and content:** The theoretical approach used for this normalisation step has been reviewed by a number of dishwasher experts from the participating countries and is considered a reasonable approximation for the impact of this difference in test methodology. However, again the precise accuracy is unknown and consequently the confidence with which this adjustment can be viewed is uncertain. This reduces confidence in the relative positions of the following country results to all other datasets: Australia, Canada, Republic of Korea, USA.

The impact of these three different normalisation steps for the different datasets is summarised in Figure 11. This table shows the range of average adjustments made for each normalisation step (from the largest reduction in UEC to the largest increase in UEC) across all years for which data was normalised in each country. This range of UEC adjustments gives an indication of the scale of impact that the uncertainties described above for each normalisation step have on the final results for each country.

**Figure 11: The range of impact of three main normalisation steps on the annual average Unit Energy Consumptions (UECs) for each country dataset.**

<table>
<thead>
<tr>
<th>Normalisation step</th>
<th>Australia</th>
<th>Canada</th>
<th>Republic of Korea</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powered Drying</td>
<td>N/A</td>
<td>5.3% to 6.1%</td>
<td>N/A</td>
<td>2.9% to 4.9%</td>
</tr>
<tr>
<td>Differences in load (place settings)</td>
<td>-2.0% to 4.6%</td>
<td>5.9% to 10.8%</td>
<td>3.4% to 3.7%</td>
<td>8.7% to 10.3%</td>
</tr>
<tr>
<td>Inlet water temperature</td>
<td>5.7% to 6.8%</td>
<td>-8.9% to -5.7%</td>
<td>N/A</td>
<td>-7.0% to -6.5%</td>
</tr>
</tbody>
</table>

Issue date: 4 April 2014:

The information and analysis contained within this summary document is developed to inform policy makers. Whilst the information analysed was supplied by representatives of National Governments, a number of assumptions, simplifications and transformations have been made in order to present information that is easily understood by policy makers, and to enable comparisons with other countries. Therefore, information should only be used as guidance in general policy - it may not be sufficiently detailed or robust for use in setting specific performance requirements. Details of information sources and assumptions, simplifications and transformations are contained within the document or the related Mapping Documents.
It should be noted that in both Canada and the USA the normalisation steps for powered drying and load variation combine to increase normalised UECs by 11.1%-19.4%. As the assumptions for these normalisation steps are less certain than for inlet water temperature, it is likely that the accuracy of these normalised North American results have the greatest uncertainty associated with them. **However, North American results are still directly comparable.**

During the course of the analysis, another difference in the way dishwashers are regulated was identified that has an impact on energy consumption and should be noted specifically. The Australian and Korean regulations have a minimum performance requirement for washing and drying quality but these metrics are not declared on the label in Australia. This allows Australian manufacturers to tune their dishwasher test cycles to optimise energy consumption while just meeting the wash and dry quality standards. The EU has set minimum wash performance standards since late 2013 (albeit at a potentially higher level i.e. the old A class level) but before then, when the data in this report was captured, the EU approach was different. There was no minimum standard for wash and dry quality but, as in Korea, wash and dry quality were shown on the label, meaning that manufacturers had an incentive to use additional energy to achieve better cleaning and drying performance results. This is known to have an impact on the relative energy performance of Australia to the EU and Korea but the scale of that impact is unknown and cannot be normalised for.\(^{16}\) This means that relative to the normalised results of the other countries analysed, Australian energy performance results are **likely** to appear better than they are in reality, although to what extent is unknown.

A number of other differences in test methodology that are not adjusted for are described in the product definition for dishwashers\(^ {17}\) and include differences in soiling regimes and the requirements for water hardness and the use of detergents. No adjustments were made for the other differences identified in the product definition because either their impact was considered too small to allow reliable normalisation and/or because neither empirical nor theoretical methods for normalisation were known to the Annex at the time of publication. While in most cases, it is likely that ignoring these differences will not have a significant impact on the comparability of results from the different datasets, **differences remain between the results shown from different test methodologies and readers should be aware of this when using this report.**

The data gradings allocated to each result on the basis of the justifications provided in **Annex 4** are shown in Figure 12. Please refer to the notes below the figure which explain each of the annotations in the table.

\(^{16}\) Any difference in the minimum standards in Australia and Korea will also affect energy consumption but as no comparison of the stringency of these standards is available, the impact is of unknown scale. North American models will benefit even further from having no wash or dry quality requirements but this is a minor aspect of the differences in that test compared with the other markets.

\(^{17}\) Available from: [http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=11](http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=11)
In summary, the most important cautions to be aware of when reviewing the energy metrics results (UEC, UEE and EEI) presented in this report are:

- Comparisons between countries originally testing to the benchmarking test methodology (EU and Switzerland) can mostly be considered robust.

- Results from other test methodologies require varying degrees of normalisation in order to be comparable to the EU test method. Data is normalised for differences in inlet water temperature and composition of the load. This reduces slightly the confidence in the comparability of the energy metrics to the benchmarking test method for the results from Australia, Canada, Korea and the USA.

- Confidence in the comparability of the North American (Canada and the USA) results to the benchmarking test method is reduced further due to the additional normalisation step required to adjust UECs to those for a full cycle including the powered drying functionality.

- A different approach to reporting wash and dry quality metrics in the EU regulations that other datasets cannot be normalised for is likely to cause EU results to appear worse in comparison to other countries than they are in reality, although to what extent is unknown.

- Confidence in the comparability of Canadian data is significantly affected by the absence of capacity values, which are not required for compliance under its regulatory regime. This has knock-on impacts on both UEE and EEI results, leading to illustrative gradings in an otherwise robust dataset.
4 Summary of policy interventions

4.1 Overview of dishwasher policies by country

Among the countries analysed, dishwashers first saw policy intervention related to energy efficiency in the mid 1990s. In 1994/95, mandatory requirements for labelling and minimum energy performance standards (MEPS) were introduced in both Canada and the USA.

Australia had introduced energy mandatory labelling by 1998, the first region to do so using an Energy Efficiency Index (EEI) method. At the same time, Minimum Performance Standards (MPS) were introduced, although these did not address energy efficiency, but rather focused on the minimum performance levels for both wash and dry quality.

The European Union introduced mandatory energy labelling in 1999, using a different EEI method to that used in Australia. This was mirrored by Switzerland in 2002/3. The Republic of Korea also followed in 2002, using a third EEI methodology that incorporates water efficiency, and simultaneously introduced MEPS based on that EEI metric. The Korean regulations also have minimum performance standards for washing and drying performance.

Twelve years after introducing labelling, the EU became the last region in this study to introduce MEPS, doing so in 2011 with a revised EEI methodology that includes standby power in off and left-on modes. This EEI was also used to update the labelling requirements. The EU MEPS were to be tightened in late 2013 (and 2016 for compacts) introducing a minimum requirement for wash and dry quality and removing those from the energy label. At the time of the publication of this report, Switzerland was planning to bring its regulations in line with those of the EU in August 2014.

Since the introduction of regulations in these markets, a number of updates have been made which increase the stringency of the MEPS and/or revise the labels to allow the identification of ever more efficient products. The most significant of these was the introduction of more stringent MEPS in USA and Canada in 2010, the USA version including water consumption performance standards. These were strengthened again in 2013 in the USA, with Canada planning to align again in 2014. Australia introduced MPS for water use, which has a direct impact on energy, in 2006 and for standby power in 2007.

In addition to this mandatory regulations, all countries have a number of other supporting policies. In particular, many countries have voluntary labelling schemes to identify premium products (e.g. ENERGY STAR in North America). Often these product labelling programmes are used as the focus for financial incentive programmes to encourage the adoption of these premium products. Other national-level activities range from mandatory reporting requirements to more generalised awareness campaigns. Additional local and/or national actions targeted at specific social groups are numerous in many countries.

Figure 13 provides a summary timetable for the introduction of MEPS and labelling within participating countries, with Annex 5 providing a more detailed summary of the major national and pan-national policy interventions that have occurred to date, or that are anticipated in the near future.
The information and analysis contained within this summary document is developed to inform policy makers. Whilst the information analysed was supplied by representatives of National Governments, a number of assumptions, simplifications and transformations have been made in order to present information that is easily understood by policy makers, and to enable comparisons with other countries. Therefore, information should only be used as guidance in general policy - it may not be sufficiently detailed or robust for use in setting specific performance requirements. Details of information sources and assumptions, simplifications and transformations are contained within the document or the related Mapping Documents.

### Metrics:
- **EEI** = Energy Efficiency Index
- **(T)AEC** = (Total) Annual Energy Consumption
- **EF** = Energy Factor
- **EOC** = End of Cycle standby Power
- **Off** = Off mode standby power  
- **g/c** = gallons/cycle

### Other notes:
- EEI methods vary by country. For details see the country mapping reports.\(^8\)
- EU shows late 2013 regulations. Previously wash and dry quality were on label and not Minimum Standards.

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**Size:** Definitions of standard (Std) and compact (Com) dishwashers vary by test method as follows:

- **Canada/USA:** 1998
- **EU Countries:** 2002
- **Republic of Korea:** 2010
- **Switzerland:** 2014
- **USA:** 2014

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**Figure 13: Summary table of MEPS and labelling schemes with implementation dates for each region.**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>✓ ✓ Jan ’95 - Energy Factor: Std* &gt; 0.46 kWh/cycle Com* &gt; 0.62kWh/cycle</td>
<td>Jan 2010: TAEc + water Std* &lt; 355 kWh/yr + 6.5 g/c Com* &lt; 260 kWh/yr + 4.5 g/c May 2013: TAEc + water Std* &lt; 307 kWh/yr + 5.0 g/c Com* &lt; 222 kWh/yr + 3.5 g/c</td>
<td>1995 for EF 2010 for TAEc</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>EU Countries</td>
<td>✓ ✓ Dec 2011 – local EEI: Std* &lt; 71 Com* &lt; 80</td>
<td>Dec 2013/16 - local EEI: Std* &lt; 63/63 Com* &lt; 71/63</td>
<td>March 1999</td>
<td>December 2011</td>
<td>✓</td>
</tr>
<tr>
<td>Republic of Korea</td>
<td>✓ ✓ 2002 - local EEI: Std* &lt; 10 Com* &lt; 8</td>
<td>2010: local EEI: Std*: &gt; 10 Com*: &gt; 5</td>
<td>2002</td>
<td>Regular revisions</td>
<td>✓ ✓ ✓</td>
</tr>
<tr>
<td>USA</td>
<td>✓ ✓ 1994 - Energy Factor: Std* &gt; 0.46 kWh/cycle Com* &gt; 0.62kWh/cycle</td>
<td>Jan 2010: TAEc + water Std* &lt; 355 kWh/yr + 6.5 g/c Com* &lt; 260 kWh/yr + 4.5 g/c May 2013: TAEc + water Std* &lt; 307 kWh/yr + 5.0 g/c Com* &lt; 222 kWh/yr + 3.5 g/c</td>
<td>1995 for EF 2010 for TAEc</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

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**Country** | **Standard:** | **Compact**
---|---|---
Canada/USA | rated capacity ps ≥ 8 and 6 serving pieces | rated capacity ps < 8 and 6 serving pieces |
EU | rated capacity ps ≥ 10 and width > 50 cm | rated capacity ps ≤ 9 or > 9 and width ≤ 50 cm |
Republic of Korea | rated capacity ps > 6 | rated capacity ps ≤ 6 |

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\(^8\) See: [http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=11](http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=11)
4.2 Comparison of MEPS and energy labels

The minimum energy performance standards (MEPS), and corresponding label schemes, are based on a different metric in each country. Whilst Canada and USA use total annual energy consumption, Australia (labels only), the EU and the Republic of Korea use a locally specific form of energy efficiency index (EEI). For Australia and the EU this EEI is derived by comparing the annual energy performance of a dishwasher to a standard machine of the same capacity. The Korean EEI is a little more complex as it combines a similar EEI for energy consumption with an equivalent comparison for water consumption.

The net result of these variations in the approach to regulation is that it is not simple to compare directly the stringency of the regulations in the different markets. However, using the normalisation approach described in section 3.3.1.3 and some assumptions on typical values for water consumption for a given capacity and standby power, it is possible to estimate the equivalent EEI values for the North American MEPS\(^{19}\) as well as for the highest and lowest Australian label boundaries and the North American ENERGY STAR levels. These comparisons are as shown in Figure 14.

\(^{19}\) European and North American MEPS are both different for ‘compact’ and ‘standard’ models but the transition point is at a different capacity. This creates an unusual step effect for the normalised North American MEPS which is not informative and so the comparison only shows larger models. This is still useful however as these models form the bulk of the market in both regions anyway.
As a result of the uncertainty in the normalisation approach and the assumptions made, this comparison can only be regarded as illustrative. However, despite this, it is clear that the MEPS in place during the period of this analysis and planned for 2013 are more stringent in the EU than in North America (by around 32% in 2013). This is a significant difference that reflects the different technology in use and different consumer expectations in the North American market, as will be investigated further in section 5.1.2 and in more detail in Annex 6. Even the requirements for being awarded the Premium ENERGY STAR label allow a 29% higher EEI than the EU MEPS and 44% higher than the top EU label boundary. A more comprehensive assessment of the differences described in Annex 6 would be necessary to understand whether or not this indicates that North American MEPS and ENERGY STAR levels could be tightened but given the magnitude of difference, this is an exercise that North American regulators may wish to pursue.

While Australia has no MEPS, the lowest EEI value awarded to the worst energy label category (1.5 Star) is somewhat higher than the EU MEPS but the highest label boundary is significantly better than the EU best label (A+++). This again reinforces the opportunity for review in North America but may also point to a similar opportunity in the EU, provided Australian models are achieving the higher energy label categories, as is investigated in Section 5.7.3.

Figure 15 shows the same comparison of regulations for dishwashers but for all capacities within the scope of the analysis. The comparative stringency of the regulations is similar for the less common compact dishwashers but, as can be seen, differences in the way the different regulations treat the transition from compact to standard sizes makes comparison very complex. Standard size models in North America have a capacity of 8 or more place settings and have higher total annual energy consumption allowances in the MEPS. In addition, the MEPS in the EU are different for compact and standard sizes (transitioning to standard at 10 place settings) but the EEI calculation is also different, so there is an impact at 10 place settings for the normalised North American MEPS and the normalised Australian SRI label boundaries.

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20 As described in more detail in Annex 6, the difference is still considered statistically significant in that it is believed to be considerably larger than the uncertainty introduced by the normalisation process.
4.3 Key observations for policy makers

Comparing the different policies in place raises a number of issues to be considered by policy makers in each of the countries:

- The clearest question is whether or not MEPS in North America can be tightened in order to come more into line with the rest of the world. Despite the differences in the marketplace, the scale of difference suggests that a detailed review of this opportunity would be worthwhile in that region.

- Comparing performance required to achieve the top rating in the Australian label scheme with that in the EU suggests that the Australian label offers greater differentiation of the better performing products. It may also be possible for policy makers in the EU to look again at energy labels and set levels for the better performing products at a more stringent level.

- Aside from the opportunities to implement more stringent standards and labels, there are a number of other differences in the way dishwashers are regulated and tested in the various markets. These different approaches to regulation are almost certainly implemented in each market with sensible rationales. It is therefore worth summarising them here so that the rationale behind each of them can be reviewed by policy makers:
  - **Metrics for regulating**: North America regulates energy consumption using a value for total annual energy consumption while all other markets use an Energy Efficiency Index (EEI). The Korean EEI includes a metric for water use while the North Americans regulate this separately. All markets except Korea include standby power within their regulated energy metric but different approaches to standby power are used.
  - **Approaches to testing**: the loading regime for a standard dishwasher in North America has 8 place settings irrespective of the capacity while all other regulations require models to be loaded to capacity. There are benefits to both, the North American approach aiming to more closely replicate real consumer use while the others allow the clean and dry quality assessment which must be done at the worst case to ensure it cleans and dries properly when loaded to capacity. The North American tests do not have a test for cleanliness or dryness and, for models without soil-sensing, also run with a clean load which makes the test simpler and less costly.

Understanding the rationale behind these different approaches may also offer insight into ways regulations can be improved. Furthermore, if it is established that some of the differences are not essential, e.g. due to differences in local market conditions, the opportunity to harmonise the regulations can be assessed, which would improve the comparability of dishwasher energy performance in different markets.

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Note that at the time of publication, the ENERGY STAR program was developing a cleaning performance test method.

Expert opinion suggests, however, that a significant proportion of dishwashers in Canada and the USA now have a soil-sensing functionality, while the Canadian data suggests it is approximately one third of models.
5 Comparison of dishwasher energy performance

5.1 Unit energy consumption

5.1.1 Unit energy consumption of dishwashers under local test conditions

The average unit energy consumption for new dishwashers tested under local conditions has fallen consistently in all countries/regions over the period for which data is available (see Figure 16). Where data is available for the whole period, these improvements have been significant, typically with annual reductions in energy consumption of 2-3%. Over the whole period, this amounts to a compound reduction in UEC of as much as 35% in the USA.

For some of the European countries, where data is only available for more recent years, the annual reductions have been smaller at closer to 1%. However, the larger reductions in the UK and Denmark, which have data over a longer period, suggest that this may have been mirrored in the other EU markets. Overall, average annual reduction in unit energy consumption across all countries over reported years was 1.9%.

Despite this consistent pattern of widespread reductions throughout the period, there remains a significant difference in average UEC between the North American market and the rest of the world. However, looking at declared unit energy consumption can be very misleading due to the significant differences in test methodologies in use in the different countries/regions. It is necessary to review the normalised results to understand whether this difference reflects reality.
5.1.2 Unit energy consumption of dishwashers normalised to the EU test

Figure 17 displays the same time series of average unit energy consumption for all dishwashers, but normalised to account for differences in local test methodology described in Section 3.3.1.3. It is immediately apparent that even after normalisation, dishwasher unit energy consumptions are still much higher in North America.

Comparing performance with Denmark (the other dataset that runs over the same period) shows that in 1996 Canadian models used 47% more energy than those in Denmark whereas by 2012, that value was 43%. For USA, the additional energy consumption is slightly higher. This difference in energy consumption is so significant that it is worth investigating the causes of the apparent additional energy use in order to be confident that they reflect reality.

5.1.2.1 Exploring the causes of higher normalised UECs in North America

In order to understand whether or not the increased energy consumption in North America is real, an analysis was undertaken to look at the possible causes of the additional energy use. This high-level analysis, a full description of which is shown in Annex 6, first looked at whether it was simply because North American machines had larger capacities but, as can be seen in section 5.2, this is not the case. However, the analysis did identify two other fundamental differences in the way dishwashers work in North America as the cause of the additional energy consumption. The use of more water from a hot feed and powered drying are believed to be the main causes as described below.

Note that if the same capacity models have significantly different dimensions between the markets, this could have an impact on energy consumption. Data was only available on product dimensions in Australia but a brief survey of current models in North America and the EU suggests that the dimensions are broadly similar.
**Additional hot water**
North American dishwashers almost always use hot feed water and so are tested with a hot feed, whereas in the rest of the world dishwashers take in cold water which they heat internally. Having a cold feed allows dishwasher designers to only heat the water when absolutely necessary and therefore pre-rinse and intermediate rinse fills are usually not heated. While some of the heat within the load is lost to the cold water as a result of these cold fills, this only offsets slightly the energy premium needed for using heated water at the stages. The size of this energy penalty for North America is increased by the fact that North American machines also have significantly higher water consumptions overall as can be seen in section 5.6.

**Powered drying**
The second difference is that the vast majority of North American machines include the option for powered drying which, as described in Annex 2, incurs a significant energy penalty. This option is not available on most, if not all, machines in other markets and the additional energy contributes significantly to the higher average UECs in North America. The explanation for the inclusion of the powered drying energy in this analysis is given in Section 3.3.1.3.

**Accounting for the difference**
In a comparison of Canadian results with those from the UK (see Annex 6 for details) the contribution of each of these differences was estimated. The analysis was very high-level but the results shown in Figure 18 do suggest that removing the additional energy used by Canadian dishwashers on the extra hot water and powered drying takes the average UEC of Canadian dishwashers down, to be in line with those in the UK. Consistently across all years, the additional hot water accounts for around 70% of the additional energy whilst the powered drying accounts for around 30%.

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24 The introduction of electrically generated heat into the washing chamber for the purpose of improving the drying performance of the dishwasher.
Whilst this analysis requires some significant assumptions, the approach has been reviewed by a number of dishwasher experts who concluded that the orders of magnitude were realistic, i.e. that the scale of the difference in UEC was far more significant than the uncertainty introduced by the normalisation process. It can therefore be reasonably concluded that North American dishwashers do in fact use significantly more energy than those in the other markets analysed.

It is worth emphasising that the Annex focuses on delivered energy, i.e. the energy used by the appliance itself, rather than the primary energy used, e.g. including losses back to a power station upstream. Given that so much energy is used in water heating in this instance, it may be that the picture is very different for primary energy consumption. For example, if the hot feed water is generated by a very efficient boiler system in close proximity to the dishwasher, it may be that the primary energy use is better, or at least is more in line with other markets, in the North American models.

5.1.2.2 Review of UEC in the better performing markets

Having established that the striking difference in energy consumption in North America is most likely genuine, it is worth looking at whether there are any notable trends in dishwasher performance in the other markets, i.e. products on sale in countries that do not use hot feed dishwashers or powered drying. Of those, the normalised UEC results suggest that Australia has the best performing models in all years with, for example, consumptions being between 5%-12% lower than those of Denmark.

As has already been stated in section 3.3.2.2, the difference in the Australian reporting requirements for wash and dry quality are likely to make Australian UEC results look better relative to the normalised results from other countries than they are in reality. It is possible that a combination of this and the uncertainties caused by the normalisation process are the cause of this apparent better performance in Australia. However, as this cannot be certain, it is worth exploring other possible reasons.

The first thing to consider is whether or not Australian dishwashers have a different capacity to those in the rest of the world that may cause a reduction in energy consumption. It is clear from Figure 22 that Australian dishwashers are on average larger than those in the rest of the study. This is important because, as can be seen from Figure 19, dishwashers with capacities of 14-15
places use slightly less energy than those with room for 12-13 places in Australia.\textsuperscript{25} Also, compared with those in the UK, it appears that Australian consumers are more likely to purchase these low UEC 14-15 place setting models. Given that the relatively high UECs for the 12-13 place models are more pronounced in the UK market (see Figure 28), it appears that the larger capacity dishwashers bought in Australia are contributing to the lower average unit energy consumption in that market.

Another possible driver for better energy consumption may be the regulations that are in place in the Australian market. Interestingly, considering that Minimum Energy Performance Standards have been key to driving efficiency improvements for most products studied in the Mapping and Benchmarking Annex, Australia is the one market in this study that does not have MEPS in place. This may be because dishwashers are not manufactured in Australia but ‘European style’ dishwashers are imported from other countries.

\textbf{Figure 20: Comparing the UEC of the average product available to that of the average product purchased in Australia (refer to Annex 8 for data table).}

![Graph showing comparison of average unit energy consumption for available and purchased dishwashers in Australia over years 2001 to 2009. The graph indicates a trend where the purchased product uses less energy compared to the available product.]  

However, Australia does have a strong mandatory labelling program in place for dishwashers which not only requires the product to display a mandatory energy label, but also requires the display of a separate water consumption label, water consumption being culturally important in Australia and linked to energy consumption. It could be that these labels are driving consumer preferences towards the more energy efficient dishwashers on the market. On the surface, Figure 20 would appear to support this hypothesis as it shows that the average product bought in Australia uses considerably less energy than the average product available. This is normally seen as a sign that consumers are making efficient choices and there is significant evidence that labelling programmes are effective.

However, there are two issues that may shed doubt on drawing such a conclusion in this case. Firstly, Australia has a very thorough product registration system that captures the sales of legacy products in small numbers better than most other markets. As a result, these older models, which mostly consume more energy, can push up the product weighted average value contributing to the difference shown in Figure 20. Secondly, as we have already seen, dishwashers are an unusual example where the larger models actually use less energy. It is possible that Australian consumers choosing larger models is a driver for this difference as well as or instead of the impact of labels.

\textsuperscript{25} This is also the case in the UK as described in section 5.5 where possible reasons for this, perhaps counter intuitive, trend are investigated.
In summary, while this analysis clearly shows that Australian dishwashers use less energy than those in other countries, the reason for this is not clear. The most likely contribution comes from the difference in regulatory requirements around reporting wash and dry quality metrics in Australia compared with the EU that allow Australian test cycles to be better optimised for energy performance. As outlined above, a number of the other possible reasons for the better UEC performance may also play a role in isolation or in combination with others but it is not possible to be certain which, if any, are genuinely responsible.

5.1.2.3 Other observations on normalised Unit Energy Consumption

European models are all very closely aligned but rapid reductions in energy consumption in the late 1990s have tailed off with improvements slowing down in more recent years. Korean models are also closely aligned with those in Europe as best shown by the proximity of the product weighted average results in Figure 21. However, there is a marked difference in Figure 17 which clearly shows that, compared with Europeans, Korean consumers have purchased dishwashers that use less energy in recent years despite the average UEC of models on the market being similar. The market for dishwashers in Korea is very small and it is not clear why this improvement has taken place.

Finally, as would be expected given the similarity in the markets, the UEC of dishwashers in Canada and the USA is very similar in all years. Comparing the product weighted averages and sales weighted averages of these markets reveals little difference in the average energy consumption, suggesting that the North American consumer is not yet showing any discernible preference for the more efficient dishwashers available in the market.

Figure 21: Normalised Product Weighted Average Unit Energy Consumption (refer to Annex 8 for data table).

Confidence in comparison to EU test: Solid line: robust, Dashed line: indicative, Dotted line: illustrative
5.2 Product capacities

The variation in energy consumption caused by variations in capacity is not as large for dishwashers as it is for some other domestic appliances. A large proportion of the energy consumed in a dishwasher is used to heat the water. Unlike, for example, washing machines in which a larger load absorbs and therefore uses more water, a larger dishwasher load does not require much extra water. The load will require heating however and this increases energy use although only in proportion to its contribution to the overall mass, which includes the water and dishwasher fabric. There will be an impact however and, given that the capacity of the dishwasher will have a direct impact on efficiency metrics, it is worth considering what the trends are in dishwasher capacity.

Figure 22 shows that the average capacity of dishwashers in most markets has remained relatively stable over the time period of the analysis. Other than in Australia, where as has been stated, consumers buy slightly larger models, most countries have a similar average capacity of between 11 and 12 place settings. The EU markets have seen a slight but discernible increase in capacity over the period while the Australian market has seen a slight downward trend. Dishwashers in Korea, and to a lesser extent the USA, appear to have both increased and decreased in capacity during the period.26 While Canada does not collect model-specific capacity data, the markets are considered to be similar, with common products being sold in both markets. In general, the Canadian average capacity is expected to follow a similar trend to that shown for the U.S.

![Figure 22: Average capacity of dishwashers 1996-2012 (refer to Annex 8 for data table).](image)

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26 Although it should be noted that the Korean dataset is small and therefore subject to more variation when dishwashers are removed from or added to the market.
However, looking under the headline average figures reveals a slightly more complex picture in most markets. Figure 23 shows a breakdown of the percentage of products and sales in the different capacity ratings in the United Kingdom. It suggests that in recent years the market has seen a significant increase in the availability of larger capacity dishwashers (those with 14 place settings), with sales of these models increasing also, although not to the same degree.

However, the impact this has on average capacity is offset somewhat by a concurrent increase in the number of smaller products available. Meanwhile the percentage of products with the most common capacity (12 place settings) has diminished. This combination of factors is replicated in other EU markets for which data is available and appears to be what is driving the slight upward trend in average capacity.

Figure 23: Market share of different capacity dishwashers in the United Kingdom (products and sales).
The same data is presented in Figure 24 for the products available in the USA, and is thought to be representative of Canada also. Data is only available for the years since 2007 but in that time things have remained relatively stable, with a slight recent increase in models with a capacity of 16 place settings being offset by a co-incident increase in models with 8 place settings.\(^{27}\)

![Figure 24: Market share of different capacity dishwashers in the USA.](image)

Figure 25 shows the sales breakdown for Australia where again the story is slightly different. The most striking aspect is the much greater proportion of sales in the 14 place settings category. Although this decreased between 2001-2005, numbers increased again until 2010. The sales of small models have switched from 7 place settings in the earlier years to 6, 8 and 9 place settings more recently, with a surge in demand for the six place setting model in 2010. Again, these variations account for the overall average trend shown in Figure 22.

![Figure 25: Market share of different capacity dishwashers in Australia.](image)

27 The US data also suggests a one-off increase in the number of models with 14 place settings in the year 2010 which will contribute to the slightly higher average capacity in that year. It is not known whether this is a genuine anomaly in the market or whether there is some issue with the database in that year.
5.3 Unit Energy Efficiencies (UEE) of dishwashers

There is no standard metric used internationally to calculate the efficiency of a dishwasher but we can look at efficiency trends using a couple of well understood measures. The first of these is a unit energy efficiency (UEE) which is a simple calculation to look at the energy consumption required to clean a single place setting (i.e. UEC/capacity giving a result of kWh/cycle/place setting). Figure 26 shows this metric for all countries normalised to the EU test methodology.

As would be expected given the similarity in the capacities across the markets, there is still significant difference between the efficiency of the North American dishwashers and those in the rest of the world. Also, because those capacities have not changed significantly, the downward trend that was clear from the Unit Energy Consumption (UEC) results is still apparent in all markets.

Whilst European dishwashers and those in the Republic of Korea appear to have very similar efficiencies on average, the Australian models appear significantly more efficient, with their average UEE being between 13%-21% better than Denmark over the period. The better performance identified with the UEC results in Section 5.1.2, which is believed to result from a combination of the different reporting requirements for cleaning and drying performance and consumer purchasing preferences, is enhanced by the larger capacities of Australian dishwashers as described in section 5.2. Again, the extent to which each of these different factors influences the overall better performance in Australia is unknown.

![Figure 26: Normalised average Unit Energy Efficiency of new dishwashers 1996-2012 (refer to Annex 8 for data table).](image-url)
### 5.4 Unit Energy Efficiency Index (EEI) of dishwashers

An Energy Efficiency Index (EEI) is a mechanism through which products of different types and size can be compared. The index aims to do this by removing any inherent effects that increasing capacity may have on the efficiency of a product. The index chosen for this study is the European version as it is taken from the benchmarking test methodology and the results can be seen in Figure 27. Note that for dishwashers in the EU a product with a lower EEI is more efficient.

#### Figure 27: Normalised average Unit Energy Efficiency Index of new dishwashers 1996-2012 (refer to Annex 8 for data table).

Once more the picture is very positive, with continual improvements in the EEI values across all countries at an average of 2% per year. The impact of the EEI methodology can clearly be seen as the Australian results, from on average larger dishwashers, are consistently closer to those in Europe and Korea than was the case for energy efficiency which does not take into account scale effects. Even so, the Australian dishwashers are once more the standout performers on the market.

### 5.5 Energy performance for different capacity products

As has already been stated, in theory the variation in energy consumption with varying capacities is not as large for dishwashers as it is for some other domestic appliances. However, given we know that larger dishwashers in Australia are consuming less energy than elsewhere, it is worthwhile to look in more detail at products of different capacity to see how the energy performance does in fact vary.

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**Issue date: 4 April 2014:**

The information and analysis contained within this summary document is developed to inform policy makers. Whilst the information analysed was supplied by representatives of National Governments, a number of assumptions, simplifications and transformations have been made in order to present information that is easily understood by policy makers, and to enable comparisons with other countries. Therefore, information should only be used as guidance in general policy - it may not be sufficiently detailed or robust for use in setting specific performance requirements. Details of information sources and assumptions, simplifications and transformations are contained within the document or the related Mapping Documents.
Figure 28 shows the energy performance of products in the UK. The top graph shows unit energy consumption dropping for all capacities (except 6 places). There is not a direct relationship between capacity and energy consumption, although in the past larger models tended to use more energy.

However, in more recent years the largest UK models (14-15 places) have reduced energy consumption to be equal to or less than the most common models (12-13 places). This is reinforced in the first bar chart (showing 1999 data alongside 2009-11). The energy use of these large dishwashers is closer to the 10-11 place models than it is to the 12-13 units.

As would be expected, the third graph shows that the unit energy efficiency of these large models is therefore even better compared with the smaller models. The final graph shows water consumption, for which the largest models use the equivalent to units with a capacity of 8-11 place settings. This highlights again the importance of water use to energy consumption.

These UK results are replicated, to a lesser extent, in the Danish data and so it appears that this unexpected outcome might be mirrored in a number of EU countries. It is not clear why these larger models are performing so well but two potential reasons are described below.

**Technological necessity.** It is possible that in order to design a dishwasher that can accommodate the additional place settings, the extra space is found by making a small number of technological changes such as improvements to filter design, pump motor efficiency, alternating pumping to upper and lower spray arms (thereby reducing the volume of water needed) or moving the heater from the tub to the water sump which requires less standing water. Each of these is done to allow more
space but would have efficiency benefits, some as a result of lower water use, and an inevitable by-product of this would be a reduction in unit energy consumption.

**Larger capacity models can carry a price premium**

Accommodating additional capacity in a dishwasher requires some complex design solutions that incur a price premium at the design stage. Manufacturers tend to launch these innovations at the premium end of the market where they can recoup costs before rolling the technologies out to the rest of their models over time. This is particularly true for the premium brands which have the greatest opportunity to see returns for such innovations.

Following the same principle in the EU market between 2010-11, it is also likely that these manufacturers were using the premium larger models to develop technologies to meet the December 2013 MEPS. Although unit energy consumptions tend to be lower across all capacities in dishwashers at the top end of the market, the premium manufacturers' focus on larger models and the greater number of lower cost models at other capacities mean that on average the larger models are more efficient. A brief review of the UK dataset suggests that this is at least to some extent true.

![Figure 29: Declared Unit Energy Consumption of USA dishwashers by capacity (refer to Annex 8 for data tables).](image)

The story is more pronounced in the other major region in the study, with data from the USA suggesting that the larger models here (14-16 place setting units) seem to use less energy than all the smaller units other than the very small six place setting machines (see Figure 29). Even though the two marketplaces are clearly very different, it's possible that the same reasons identified above for the better performance of larger products in the EU also apply in North America.

Having said that there are some specific reasons that could explain the performance of the 14 place setting machines. The USA data suggests that these machines have significantly lower water consumption than the other capacities but, more interestingly, they have virtually no powered drying functionality, which is present in almost all of the other standard model sizes. Both of these things are also true for the 16 place setting models but to a fraction of the extent that is true for 14 place setting units. It appears that this very clear split in functionality by capacity is caused by certain manufacturers, who do not use powered drying and whose models use less water, offering the majority of products at these capacities.
5.6 Other metrics relevant to energy consumption

This analysis attempted to track a number of secondary metrics which impact on the energy consumption of dishwashers. In many cases, e.g. wash and dry quality performance, insufficient data was available to undertake any analysis. However data was available on water consumption and a small amount on cycle time, both of which play a role in determining the energy used by a dishwasher.

5.6.1 Product water consumption

There is a strong correlation between energy consumption and water consumption in dishwashers because, as has been stated before, a large proportion of the energy goes into heating up water for the various stages of the wash cycle. This correlation is clear to see when looking at the average water consumption across the different countries as shown in Figure 30.

In most markets, water consumption has been falling at very similar rates to energy consumption (2-4% per year). Within Europe, for example, the additional water used in the UK compared with Denmark tracks quite closely to the additional UEC in the UK. There are, however, some notable differences.

Whilst Canadian water consumption is much higher than that in Europe, the percentage extra is not as much as it is for unit energy consumption. This reflects the contribution of powered drying to the additional UEC in North America.

Australian water consumption is higher than in Europe until the most recent year which in theory should not be the case given that Australian dishwashers have lower average unit energy consumptions. This reinforces the evidence that part of the reason for Australia’s
better performing products lies in the differences in the regulations in Australia, i.e. the ability of manufacturers to tune their test cycle to minimise energy consumption while just achieving the minimum performance requirements for wash and dry quality. This is likely to be done in part by running at lower temperatures than in the EU thereby allowing the use of additional water without an energy premium.

The close correlation between water consumption and energy use might suggest that regulators could use minimum standards for water consumption and achieve a double benefit of reduced water and energy use. However, while water standards are worthwhile in their own right, they may not achieve energy consumption goals if introduced on their own, as manufacturers could for example increase temperatures to reduce washing times and UECs would increase. It is important therefore that any water regulations are introduced in conjunction with energy regulations. One example of this approach is to integrate water efficiency into a single metric with energy efficiency as is the case in the Republic of Korea (see section 5.7.4). This allows manufacturers to optimise the reduction in water and energy use in order to meet the overall aims of the regulations.

5.6.2 Dishwasher programme cycle times

Manufacturers looking to reduce energy consumption whilst maintaining or improving cleaning and drying performance must optimise a number of variables. Energy consumption can be reduced by lowering water temperatures and volumes and reducing drying energy. For a given wash performance, lower wash temperatures can be achieved through more effective mechanical action (improved pump/motor efficiency, spraying technology and electronic controls), more and or better detergents or simply longer wash cycles. Similarly, drying energy can be reduced by better drying technologies (such as increased ventilation and ad/absorption techniques) and again, longer cycle times. Average programme cycle times were only available for a small number of countries, but as can be seen from Figure 31, there is a very clear and dramatic upward trend in the length of programmes being used by dishwasher manufacturers during product testing. Although caution is needed as it is

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28 Where programme cycle time is the time taken for the unit to complete a full washing, rinsing, and drying process and return to a steady state condition. Although programme time (to when the unit indicates that the load is finished) may be more relevant to consumers, data was only available on the cycle time as presented here.
based on a very small sample size, in the extreme case Denmark has seen an average of 13% increase in cycle times per year or more than 200% during the time of the analysis.

It is unfortunate that no cycle times were available from North America but given the dominance of dishwashers with powered drying in that market it is safe to assume that programme cycle times in that market are significantly shorter.

Unlike washing machines, where fast programmes are valued by consumers who want to run several washes in sequence, longer dishwasher programmes are less difficult and in fact many European consumers run their dishwashers overnight. However, despite this, for various reasons consumers may not choose these eco programmes especially with the increasing prevalence of soil sensing programmes which are often described as the automatic programme. In fact, a study for the EU Ecodesign Preparatory Study\(^{29}\) for dishwashers suggests that eco washes are only used often by less than a third of consumers while over half use higher temperature programmes.

Particularly in the EU therefore, regulators should be aware that any energy benefits associated with these longer programme cycles will not be reaped if consumers are using faster wash cycles than those used in the test. Regulators should look to counter this trend with a suitable mix of policy interventions that could include:

- Add cycle time to the information provided on the energy label;
- setting limitations on programme time;
- requiring that manufacturers make the eco washes more prominent for consumers or even the default programme; and
- some other form of energy control on other programmes on the dishwasher.

5.7 The impact of regulations on Energy Performance

As described in section 4, all the countries analysed regulate dishwasher markets in order to try to encourage the development and uptake of more efficient dishwashers. This section reviews data from the individual marketplaces and assesses how much impact the regulations have had.

\(^{29}\) http://www.ecowet-commercial.org/index.php
5.7.1 Implications of the results for EU and Swiss regulations

The main policy interventions in the EU and Switzerland were the introduction of energy labels in 1999 which were revised in 2011 to coincide with new Minimum Energy Performance Standards (MEPS) which were due to be tightened in December 2013 (and further for compact models in 2016). Figure 32 shows the European Energy Efficiency Index (EEI) results for standard size dishwashers (where data is available) alongside the energy label and MEPS boundaries as they evolve over time.

In the UK and Denmark, there was a clear and sustained improvement in efficiency following the introduction of the first labelling scheme in 1999. The Danish results were improving before the labels came into force but it is quite possible that this was in preparation for the introduction of the new energy label. Although insufficient data is available before the introduction of labels to be certain, it appears that the new label at least had some influence on the improvement in efficiency in the market.

The impact of the first MEPS and the revised label in late 2011 is less clearly visible although there is a clear downward trend in the 2012 datasets (the EU and Austria). Given the visibility of these changes in the European market where new regulations are signalled well in advance, it seems likely that the ongoing tightening of the regulations would continue to have an impact on product performance in the other markets too.

Figure 32: The impact of MEPS and labelling regulations on the average EEI of standard size dishwashers in the EU (refer to Annex 8 for data table).
As data stops in 2011, the impact is less clear in the UK. However, looking at that data more closely suggests that the impact will be clearer in 2012/13. Figure 33 shows the EEI of individual UK products from 2011 in relation to the late 2011 label classes and two tiers of EU MEPS introduced in 2011 and 2013. The first thing to note in the first graph is that by 2011 most models met the (late) 2011 MEPS and a number were already attaining the EEI of the highest label class (A+++), introduced the following year.

This may imply that the EU MEPS were not sufficiently stringent but again, the EU signals regulations some time in advance and therefore it is likely that these models have been developed to meet these MEPS.

Looking at the next graph, it is clear that while most UK models with a capacity of 12 place settings in 2011 met the 2011 EU MEPS, hardly any of those models meet the 2013 MEPS. As was shown in Figure 25, models with a capacity of 12 place settings are by far the most common in the UK and so this is likely to have a significant impact on the products in the market.

This is emphasised in the final graph by showing the 2011 sales for each of the models (the area of the circle is proportionate to the number of sales of each model). It can be seen that nearly all of the sales in 2011 would not meet the minimum performance standards in 2013. On the surface, it would be easy to conclude from this that by the end of its life, the old EU energy label (up to A class) appears to have worked in the UK with consumers buying mostly the best class available.

However, it also appears that by the end of this original energy labelling scheme, most of the dishwashers available in UK shops were A class, so the consumer could not easily buy any lower, or higher, class units. Because there was no way to claim a higher energy efficiency, the manufacturers had no regulatory incentive to make such models available. This is...
emphasised by the fact that in 2011, very few people were buying dishwashers that met the new premium classes, possibly because it was not clear from the label that they were better performing.

Figure 34 shows how the percentage of models with each label class in the UK developed over time. Despite a slight issue with data quality, it is clear to see the increasing availability of the top label category (A) from 2002 onwards. So, while the labels appear to have driven change in the products available in the UK in earlier years, it seems that their impact diminished over time and that there was scope to revise the label categories significantly earlier, perhaps as far back as 2006-7.

Looking at more recent regulations, it is almost certain that if data was available from more recent years in the UK, the average EEI curve shown in Figure 32 would improve significantly in 2011-13 as the 2013 EU MEPS came into force with a large number of 2011 sales becoming non-compliant.

It seems therefore that in the UK, EU regulations on dishwashers have successfully driven efficiency improvements and will do in the future. However, given that compared with the majority of European consumers, people in the UK are known to be more influenced by purchase price than lifetime costs, it is likely that the predominance of top label models occurred at least as early in other EU markets. This suggests that regulators need to be watchful to ensure that the timing of revisions to regulations is optimised to maintain the pace of these improvements.

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30 And the products bought, as sales track products very closely in the UK results.
5.7.2 Implications of the results for North American regulations
The main issue to consider for North American regulators is how to address the significantly higher UECs of dishwashers in that region described in Section 5.1.2.1. Intervention may not be simple however. In the USA regulators face a number of legal hurdles around how they can set standards.\(^3\) For example, they are legally required not to intervene in a market in a way that is likely to result in the unavailability of a product class or characteristic that is substantially the same as those generally available. Furthermore, regulators must determine whether the benefits of the standard exceed its burdens and these include any lessening of the utility or the performance of the products likely to result from the regulation.

This means that any regulation to address these issues would most likely need to maintain product performance, including the following characteristics:

1. **Cleaning performance:** As no comparable metrics are available on cleaning performance, it is not clear whether there is a performance benefit from using more hot water in the cycle. This is something that would need to be investigated before regulating to encourage the use of less water and switching to cold feed systems.

2. **Drying performance:** Similarly, no comparable metrics are available on drying performance although it is clear that a dishwasher with powered drying will dry the load more quickly. However, there are now low energy powered drying systems available\(^3\) and it would be worth assessing whether these can deliver a similar performance to the traditional heated method.

3. **Programme cycle time:** While no data is available on the average programme time for North American models, given the clear trend described in section 5.6.2 of ever-longer programmes in the other markets, it is very likely that US dishwashers have shorter programme times. Changing to cold feed or away from the current method of powered drying is very likely to extend US programme times which would impact on utility. However, it may be possible to retain the option for shorter washes whilst encouraging the use of longer times by consumers.

Another potential barrier of changing to cold feed dishwashers is that it would require some if not many consumers to re-plumb their dishwasher feed systems. However, this may not be much of an obstacle if, as is often the case, dishwashers are situated near hot and cold feeds. The problem could be overcome by fitting hot and cold feeds to dishwashers (at a small additional cost). This would allow those who had cold supplies available to benefit, while those who only have hot supplies could connect both inlets to the hot supply.

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\(^3\) In reality the North American markets are quite homogenous and so these regulatory requirements will impact strongly on the Canadian market also.

\(^3\) This system uses pellets: At the beginning of the wash cycle the pellets which are stored in a separate compartment, are heated to dry them out. The final rinse receives very little heating. At the end of the final rinse, the air from inside the dishwasher is blown through the pellets and recirculated back into the dishwasher. The pellets absorb moisture and in doing so release heat, warming the re-circulating air. Thus the dishes are dried quickly with little additional energy being used.
Looking specifically at the impact of the regulations in place in North America, Figure 16 shows clearly that products have improved their energy performance continuously since 1996. Given that the products are so different from those elsewhere, it is unlikely that any external influence has contributed significantly to this, and therefore it is likely that the regular regulatory interventions in this market have at least contributed to this improved energy performance. However, North American dishwashers do use considerably more energy and so, as well as the opportunity to review the feasibility of tightening water use regulations as a means of driving down energy consumption as described in Section 5.1.2, it is worth considering closely where else current regulations might be strengthened.

Figure 35 shows energy consumption of 2012 products in both the USA and Canadian datasets, alongside the 2010 and 2013 MEPS. It can be seen that most of the 2012 models in the USA are already compliant with the 2013 MEPS and many of them, particularly in the 14 place setting capacity, are already outperforming the MEPS significantly, the best by as much as 50%. There are also a significant number of Canadian models which are easily outperforming the new MEPS and so it would appear that there may be room to apply more stringent regulations. However, to be certain that this would not impact too negatively on consumers, it would be necessary to assess the sales volumes of these products as well.
5.7.3 Implications of the results for Australian regulations

Australia is the only market in the study that does not have Minimum Energy Performance Standards (MEPS) in place for dishwashers (other than for standby power), and yet it appears to have the most efficient dishwashers in the study. This may be partly down to the combined energy and water labels that have been in place in Australia since 1998. The energy label uses a local energy efficiency index called the Star Rating Index for which the product weighted average has improved at an average rate of 3.5% per year since 2001.

Figure 36 shows sales33 data for all Australian dishwashers in 2009 against the Star Rating Index label classes (note that a higher index is a better performing product). In the two dominant size categories, i.e. 12 and 14 place settings, consumers appear to be buying the better performing products for the 14 place machines but the reverse is true for 12 place machines, even accounting for the fact that they have a worse range of performance anyway. Given that larger machines tend to be at the premium end of the market, this may imply that consumers in this demographic are more inclined to purchase these more efficient premium models, and that the labelling strategy in Australia is working differently with different demographics.

Despite the market leading performance of dishwashers in Australia without MEPS, the spread of performance in this recent data suggests that there is still scope to improve average performance further by the introduction of MEPS, providing there are sufficient annual sales to make the introduction of MEPS cost effective.

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33 Sales are in proportion to the size of the circle.
5.7.4 Implications of the results for Korean regulations

Both MEPS and energy labels in the Republic of Korea are based on an Energy Efficiency Ratio which takes into account both energy and water consumption. As such, it is slightly different from the approach taken in other countries. As in all markets, Korea has seen a downward trend in the energy consumption of dishwashers and, given regulations and labels have been in place since 2002, it is likely that this has contributed to this improvement.

However, looking at the most recent data for the Korean EER, it appears that there is room for more stringent regulation. Figure 37 shows 2012 sales\(^{34}\) data from each model in the Korean marketing year. The MEPS require that the EER is greater than 5 for small units and 10 for larger units. As can be seen, most models are significantly more efficient than this, with very few even close to the MEPS. Sales are even more skewed towards the more efficient ratings with a large proportion of models achieving the best energy label class. It appears therefore that despite previous successes in improving energy performance, there may still be potential in this market to strengthen MEPS and reset label boundaries.

\[\text{Figure 37: The Energy Efficiency Ratio of Korean dishwashers compared with current MEPS and energy label classes.}\]

\(^{34}\) Sales are in proportion to the size of the circle.
5.8 Key observations for policy makers

The analysis of data from each of the regions leads to the following summary observations for policy makers:

- While in all markets there is a consistent improvement in energy consumption over the period of the analysis, there are significant differences between the performance of dishwashers in different countries.

- Most notably, North American dishwashers consume significantly more energy than those in the rest of the world. This appears to be primarily due to the use of large quantities of hot water and the prevalence of powered drying. North American policy makers should investigate the options for bringing these aspects of energy performance in line with the rest of the world, specifically reducing overall water consumption and looking at alternative powered drying approaches.

- However, as is always the case for the Mapping and Benchmarking Annex, the analysis is based on delivered energy efficiency. Given that dishwashers use a large proportion of energy for water heating, it may be that the primary energy use is better in the North American models if the hot water source is an efficient heat source in local proximity to the dishwasher. Policy makers in all regions should consider assessing the primary energy use of dishwashers alongside delivered energy use to establish under which circumstances hot water feeds may save primary energy. It may also be beneficial to encourage manufacturers to allow both hot and cold fill options in a single machine so that energy performance can be optimised to the circumstances at the installation point.

- Energy performance in the markets outside North America is comparable, with Australian dishwashers perhaps performing best of all although this may be primarily due to differences in regulations between Australia and the EU and Korea that make Australian dishwashers appear relatively more efficient.

- There is evidence that regulations have helped in driving improvements in performance in all markets with both MEPS and energy labels changing the products available for purchase in the markets. However, there is also evidence that there may be scope for more stringent MEPS in many markets.

- Furthermore, policy makers should try to ensure that label schemes in particular are implemented with sufficient frequency to ensure consumers have the choice to buy the most efficient models, not allowing too high a proportion of the market to achieve the premium labels.
- Average dishwasher capacities are similar in all markets although Australia has slightly larger capacities on average. Average capacities have remained relatively stable during the period in analysis. There appears to be a slight increase in average capacity in the European markets, a trend that would be stronger if a market for very small units had not emerged to counter increasing sales of large capacity models.

- Consequently, while the trends for dishwasher efficiency are similar to those for consumption, the Australian models perform relatively better, again due to their larger capacities.

- The increase in larger capacity models is a driver of overall efficiencies as, in most markets, the larger models are not only more efficient but in absolute terms use less energy than the mid-sized standard capacity models. This may be down to a combination of the need for more efficient technologies to create space for additional capacity and the ability of manufacturers to charge a premium for larger capacity models allowing them to recoup investment in more expensive efficiency gains. Policy makers should work with manufacturers to understand the technologies and market drivers that allow larger units to consume less energy and develop policies that will encourage similar efficiency improvements in smaller capacity units.

- There have also been significant reductions in water use in all markets, although again North American models appear to use more than those in the rest of the world. Policy makers in all markets, but particularly North America, should consider introducing or strengthening water use regulations but only in conjunction with appropriate energy regulations so as to ensure that outcomes are complementary. For example, in the Republic of Korea, the efficiency index combines metrics for both energy and water efficiency.

- In the small number of markets where data is available, dishwasher programme cycle times have increased substantially over the period which is most likely driven by the energy benefits achieved. Policy makers should look to ensure that these energy-saving cycles are in fact being used by consumers rather than the more energy intensive short programmes.
6 Current best performing products and long term potential energy savings

As is clear from the previous sections, there have been significant improvements in the energy performance of dishwashers in all markets over a long period of time. Further, while the next phase of planned policy interventions should have a further effect in improving dishwasher efficiency, it appears that there is scope in many markets to consider more stringent regulations based on the products available now. To understand exactly what future regulations might be possible, policy makers need to understand what is currently feasible and/or cost effective for dishwashers, or what might be technologically possible or cost effective in the future.

This benchmarking report makes no attempt to conduct a technical analysis in order to address that issue, as it is not within the aims of this work. However, to provide some insight for policy makers on what may be possible at present, the performance of the most efficient products on the market at the time of data collection has been identified.

Further, to provide policy makers with a vision of what might be possible from continued vigorous policy intervention, projections have been made on the potential magnitude of energy savings that could be possible across international markets by 2050.

6.1 Individual appliance ‘best in class’

For those countries where model level data was available (Australia, Canada, Denmark, the UK and the USA), an analysis was undertaken of all models to find the ‘best in class’. To ensure comparability, dishwashers were ranked overall based on their Energy Efficiency Index, and then for the main capacities using their normalised Unit Energy Consumption. Finally, a review was undertaken to identify the dishwasher that had the lowest total water consumption.

Once the best performing products were identified from all available data sources, they were checked to verify the products were on sale in at least one of the markets analysed. Figure 38 shows the results of this review by metric and class.

---

35 Analysis was based on the models listed in each country in the most recent year data was available. 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 (see http://www.topten.info/) were used to identify best in class products. These were not used in the main market analysis as they focus only on better products.
### Figure 38: Best performing dishwashers in the analysis (based on the most recent available data).

<table>
<thead>
<tr>
<th>Class:</th>
<th>Metric</th>
<th>Brand</th>
<th>Model</th>
<th>Country on sale</th>
<th>Capacity</th>
<th>Normalised unit energy consumption (kWh/cycle)</th>
<th>Declared unit energy consumption (kWh/cycle)</th>
<th>Energy efficiency index (EEI)</th>
<th>Water consumption (litres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All dishwashers in scope</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All markets</td>
<td>EU UEC</td>
<td>Siemens</td>
<td>SN56M332AU</td>
<td>Australia</td>
<td>14</td>
<td>0.69</td>
<td>0.62</td>
<td>41.5</td>
<td>12.3</td>
</tr>
<tr>
<td>North American models</td>
<td>EU UEC</td>
<td>L G</td>
<td>LDF7558**</td>
<td>USA</td>
<td>14</td>
<td>0.99</td>
<td>0.84</td>
<td>59.5</td>
<td>9.5</td>
</tr>
<tr>
<td>Dishwasher by capacity:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 place settings</td>
<td>EU UEC</td>
<td>Bosch</td>
<td>SCE 63M15 EU</td>
<td>Denmark</td>
<td>8</td>
<td>0.74</td>
<td>0.74</td>
<td>65.4</td>
<td>8.5</td>
</tr>
<tr>
<td>10 place settings</td>
<td>EU UEC</td>
<td>MIELE</td>
<td>G 6570 SCW</td>
<td>Australia</td>
<td>10</td>
<td>0.71</td>
<td>0.63</td>
<td>45.2</td>
<td>12.5</td>
</tr>
<tr>
<td>12 place settings</td>
<td>EU UEC</td>
<td>Electrolux</td>
<td>0.8 680 ROW</td>
<td>Denmark</td>
<td>12</td>
<td>0.82</td>
<td>0.82</td>
<td>51.2</td>
<td>10.2</td>
</tr>
<tr>
<td>14 place settings</td>
<td>EU UEC</td>
<td>Siemens</td>
<td>SN56M332AU</td>
<td>Australia</td>
<td>14</td>
<td>0.69</td>
<td>0.62</td>
<td>41.5</td>
<td>12.3</td>
</tr>
<tr>
<td>Water use: all dishwashers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All markets</td>
<td>Litres</td>
<td>Bosch</td>
<td>SMU 55M12 SK</td>
<td>Denmark</td>
<td>13</td>
<td>0.92</td>
<td>0.92</td>
<td>56.4</td>
<td>6.0</td>
</tr>
<tr>
<td>North American models</td>
<td>Litres</td>
<td>Bosch</td>
<td>SGE60E06UC</td>
<td>USA</td>
<td>14</td>
<td>1.24</td>
<td>1.09</td>
<td>74.6</td>
<td>8.3</td>
</tr>
</tbody>
</table>

**Notes for Figure 38:**

1. There may be better products than those 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 manufacturers’/third parties’ stated levels.
2. Appliances were selected based on a normalised energy efficiency index, and verified through their declared unit energy consumptions.
3. Country: this is the country/region from whose mapping & benchmarking database the product was originally identified. Appliances from Denmark may be available in other EU countries.

On the basis of the analysis, the best performing product overall is a 14 place setting capacity model in Australia, while the best performing products by capacity are found in the Danish and Australian datasets. It is interesting to note that the survey of current TOPTEN models did not reveal any products that were better than those in the analysis, although it is possible that some may be slightly better than the Australian products listed if, as is possible, the differences in Australian regulations that could not be normalised for give those models a normalised UEC that is lower than reality. However, the December 2013 models in TOPTEN were very close to those in Figure 38 and so it can be assumed that these best performing values are close to the current market position.

In order to assess the potential for improving efficiency within the current marketplace, Figure 39 shows by country how much extra energy the average product uses compared with the best performing product (or overall how much higher their average EEI is).

**Figure 39a: Percentage extra EEI of the average model in each country in the most recent year compared with the best performing product**

*While Canada does not collect model-specific capacity data to support representation in this table, a similar suite of products is being sold in both the Canadian and U.S. markets.*

<table>
<thead>
<tr>
<th>Country/Year</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia 2009</td>
<td>37%</td>
</tr>
<tr>
<td>Austria 2012</td>
<td>44%</td>
</tr>
<tr>
<td>Canada 2012</td>
<td>116%</td>
</tr>
<tr>
<td>Denmark 2012</td>
<td>57%</td>
</tr>
<tr>
<td>Republic Of Korea 2012</td>
<td>46%</td>
</tr>
<tr>
<td>Switzerland 2011</td>
<td>54%</td>
</tr>
<tr>
<td>UK 2011</td>
<td>59%</td>
</tr>
<tr>
<td>USA 2012</td>
<td>140%</td>
</tr>
<tr>
<td>EU 2012</td>
<td>46%</td>
</tr>
</tbody>
</table>

**Figure 39b**: Percentage extra UEC of the average model in each country in the most recent year compared with the best performing product (by capacity).
As can be seen, even within the existing products available on the market there is scope for increasing the efficiency of dishwashers. Despite the limitations of the normalisation process, which means that most of these values are only indicative, they are sufficiently large to suggest that there is significant scope in all markets.

The scope is most clearly and robustly shown by looking at Australia, where the nominal best performing product and best average product were found. Here, the largest gap between best and average is for a dishwasher with a capacity of 14 places for which the average product uses 30% more energy than the current best performing product. However, if, as was postulated in Section 5.5, manufacturers develop and roll-out new technology at higher capacities, the best performing product with a capacity of 12 place settings ought to be able to match that of the 14 place setting model. Comparing the average 12 place model with the best performing 14 place model shows a 35% increase in energy consumption.

Given that these two capacities account for the majority of the market in many countries, the potential savings by moving the market towards the existing best performer are substantial both in Australia, and almost certainly in the other markets.36

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### Limits to the use of additional energy labels:

Section 5.7.1 showed the importance of retaining sufficient differentiation in energy labels at the premium end to ensure consumers can continue to select the most efficient models. This will be an important tool for policy makers when trying to deliver the potential identified in this section. However, as efficiency improves, the range of label classes necessarily reduces and there reaches a point at which the permitted tolerances (currently 10% for measurement in the EU) are greater than the label range. Policy makers therefore need to review tolerances in parallel with any revisions to MEPS and label regulations.

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36 It should be noted that this analysis does not consider price and so it is uncertain what cost impact would result from introducing more stringent MEPS to take advantage of this potential.

**Issue date: 4 April 2014:**
6.2 Mapping the Potential

Having established that there are already products in the market that could substantially improve the efficiency of new dishwashers if adopted across the whole market, there seems value in briefly investigating the potential magnitude of energy savings that could be possible from continued vigorous policy intervention.

A forward projection of energy consumption of dishwashers in Australia, Canada, the Republic of Korea, Switzerland, the USA and the 27 member states of the EU has been undertaken on behalf of the Mapping and Benchmarking Annex using a derivative of the Danish ELMODEL-bolig (domestic) model. Using information presented earlier in this report as input data, the projections examine two potential future scenarios for dishwasher energy consumption from 2010 to 2050. The two scenarios presented are as follows:

**Baseline scenario:** This scenario assumes a 'business as usual' baseline where future stock and sales numbers are driven by projected sales distribution of efficiency classes that evolve at current rates based on technology life spans, rated capacities and natural development in sales distribution (at a rate of 2% p.a. which equates to less than 1 % net average efficiency improvement p.a.). Overall stock and sales numbers are based on projected future GDP levels for each region.

**BAT/BNAT scenario:** This scenario uses the same input data but attempts to estimate the maximum theoretical potential, by coercing the markets to offer only the currently best available technology (BAT), and future best technology that is not currently available (BNAT). For dishwashers there is no technical analysis of possible future efficiency improvements at hand. Therefore, the estimates of potential future appliance efficiencies have been set as a simple assumption of 1 % p.a. improvement of the BAT at 2010 level. A simple fact to support this assumption is the historical development. In practice these improvements can come from reduced cycle times and temperatures, due to improved detergents etc.

These moderately assumed BNAT improvements imply that the potential improvements identified are mostly driven by changes in the sales distribution, towards the most efficient energy classes.

The input data on historic sales distributions are quite sparse, but for Australia and EU-27 (based on AT, CZ, DE, DK, ES, FI, FR, GB, HU, IT, NL, PL, SE, SK) some years of data have been provided. An example of this can be seen overleaf:
The information and analysis contained within this summary document is developed to inform policy makers. Whilst the information analysed was supplied by representatives of National Governments, a number of assumptions, simplifications and transformations have been made in order to present information that is easily understood by policy makers, and to enable comparisons with other countries. Therefore, information should only be used as guidance in general policy - it may not be sufficiently detailed or robust for use in setting specific performance requirements. Details of information sources and assumptions, simplifications and transformations are contained within the document or the related Mapping Documents.

In order to make the model run without too many transitional phenomena, at least one lifespan of historical data should be available. In this case this was some 10 years of data. Therefore a series of data extrapolations and transfers from region to region has been made, since not only sales distributions, but also the needed total sales, rated capacities etc. are not provided for all regions.

In Annex 7 a description and examples of this work is provided. Figure 41 is a summary table, showing the situation in 2010, 2050 and 2050 in the BAT-scenario, for central parameters:

**Figure 41: Central parameters used in the potential scenarios analysis.**

<table>
<thead>
<tr>
<th>Region</th>
<th>Household Ownership, %</th>
<th>Cycles/y</th>
<th>Average UEC, Wh/cycles/PS</th>
<th>Total Consumption, TWh/y</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2010</td>
<td>2050</td>
<td>2010</td>
<td>2050</td>
</tr>
<tr>
<td>Australia</td>
<td>56.9%</td>
<td>72.3%</td>
<td>175</td>
<td>175</td>
</tr>
<tr>
<td>Canada</td>
<td>59.4%</td>
<td>74.1%</td>
<td>215</td>
<td>215</td>
</tr>
<tr>
<td>Korea</td>
<td>10.8%</td>
<td>30.7%</td>
<td>215</td>
<td>215</td>
</tr>
<tr>
<td>USA</td>
<td>60.0%</td>
<td>75.6%</td>
<td>215</td>
<td>215</td>
</tr>
<tr>
<td>EU-27</td>
<td>28.5%</td>
<td>39.6%</td>
<td>214</td>
<td>214</td>
</tr>
<tr>
<td>Switzerland</td>
<td>68.3%</td>
<td>84.3%</td>
<td>216</td>
<td>216</td>
</tr>
<tr>
<td>Total</td>
<td>39.7%</td>
<td>54.8%</td>
<td>213.9</td>
<td>213.9</td>
</tr>
</tbody>
</table>
The resultant projections of energy consumption under both the baseline and BAT/BNAT scenarios for dishwashers are shown in Figure 42.

Figure 42: Baseline and BAT/BNAT projections of total energy consumption of dishwashers in Australia, Canada, the Republic of Korea, the USA and the EU27 countries from 2010-2050.

The total consumption in the Baseline is seen to increase slowly towards 2050, in spite of assumed improvements in energy efficiency of the bought dishwashers. This is mainly due to growing stocks. The 2010 stock of circa 145 million appliances is estimated to grow to 244 million by 2050. This is based on the development in GDP. The corresponding average household ownership rate for all regions climbs from circa 40% to 55% in 2050.

By 2010 the total consumption is around 45 TWh (including hot water machines) and by 2050 this number has climbed to 68 TWh. Considering the larger stock, per appliance for all regions together, this represents an efficiency improvement in kWh/y from 309 to 276, or circa 10%. For new appliances, the (region weighted) average annual consumption goes down from 293 to 274 kWh/y in 2050.

The BAT/BNAT scenario shows a theoretical best case consumption development, reducing the total consumption by around 25 TWh per year already in 2020, compared to Baseline. The annual consumption of an average appliance for all the regions now shows some 89 kWh/y in 2050. This is less than 1/3 of the average for the Baseline. An accumulated saving from 2013 towards 2050 of no less than 1,234 TWh can be achieved under this best case.

While this is not as significant as some other domestic appliances, it still suggests that ongoing policy intervention in the dishwasher market is very much worthwhile and will be necessary if some of the energy saving potential available under the full BAT/BNAT scenario is to be realised.
Annex 1 Definitions of terminology used in the benchmarking report

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

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>4E</td>
<td>[The IEA’s] Efficient End-Use Electrical Equipment [Implementing Agreement].</td>
</tr>
<tr>
<td>EEI</td>
<td>Energy Efficiency Index.</td>
</tr>
<tr>
<td>EU</td>
<td>European Union.</td>
</tr>
<tr>
<td>IEA</td>
<td>International Energy Agency.</td>
</tr>
<tr>
<td>Normalised</td>
<td>Indicates that a specific value or values have been ‘adjusted’ to be comparable with other values shown (refer to main report section 3.3.1 for more details).</td>
</tr>
<tr>
<td>PWA</td>
<td>Product weighted average [of a range of values].</td>
</tr>
<tr>
<td>Sales of [appliance type(s)]</td>
<td>The total sales of a single defined appliance type, or defined group of appliance types, within a particular country in a particular year.</td>
</tr>
<tr>
<td>SWA</td>
<td>Sales weighted average [of a range of values].</td>
</tr>
<tr>
<td>Tolerances</td>
<td>Encompasses both the allowances made within testing methodology to account for variations in testing conditions, testing equipment, etc; and the allowances that are made within labelling, MEPS or other regulatory requirements to allow for natural variation in the production process of the product being regulated.</td>
</tr>
<tr>
<td>UEC</td>
<td>Unit energy consumption (kWh/cycle).</td>
</tr>
<tr>
<td>UEE</td>
<td>Unit energy efficiency (kWh/cycle/place-setting).</td>
</tr>
</tbody>
</table>
1 Overview of the mapping and benchmarking outputs for dishwashers

The basic objective of the mapping and benchmarking process is to provide time series graphic and numeric information on dishwashers. The basic metrics to be presented in both the mapping and benchmarking documents are:

- The Average Unit Energy Consumption (UEC) of the appliances in kWh/cycle;
- The Average Unit Energy Efficiency (UEE) of appliances in Wh/cycle/place setting;
- A comparative Energy Efficiency Index (EEI) for the appliances (benchmarking only);
- Average capacity in place settings; and
- Average water consumption in litres.

In addition, where possible, the analysis of a number of secondary metrics is presented. As normal, this information is published in two forms:

- A Mapping document – where the information is presented based on local conditions;
- A Benchmarking document – where testing conditions will be normalised to make product testing conditions comparable.

Results are normalised to the requirements detailed in the 2008 EU regulations\(^{37}\) and the associated EN methodology. This benchmarking ‘standard’ has been selected primarily due to the number of reporting countries that test to a similar set of requirements. The standard also provides a methodology for the calculation of an Energy Efficiency Index (EEI) which has the flexibility to directly compare products of different capacities.

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2 The mapping and benchmarking process for dishwashers

There are essentially 4 stages to the mapping and benchmarking process for dishwashers as detailed in Figure 43. Each of these stages is addressed in more detail in the following subsections.

Figure 43: Summary of stages in the mapping and benchmarking of dishwashers.

2.1 Data Cleaning and Pre-processing
2.1.1 Data cleaning

Data cleaning is best described as the process of aligning all data sets to be comparable with those received from elsewhere. This is country-specific, but includes actions such as:

- Converting data values from imperial measurement to their metric equivalents;
- Sub-dividing amalgamated data sets into individual years;
- Removal of duplicate entries where appropriate;
- Adjusting reported values to be equivalent to test values.

2.1.2 Pre-processing

The pre-processing of data:

- Assigns individual models (or groupings) to the standard or compact size range and identifies table top models to be excluded from the analysis;
- Identifies models in North American datasets that have a truncated cycle option.
2.2 Production of Graphical Mapping Outputs

Where possible, the following sales weighted and product weighted mapping outputs are produced:

- The Average Unit Energy Consumption (UCE) of the appliances in kWh/year;
- The Average Unit Energy Efficiency (UEE) of appliances in Wh/adjusted litre/year;
- The average unit capacity in place settings;
- The average unit water consumption in litres.

For mappings, the UEC is the value declared locally following data cleaning.

Where information is sales weighted, this is calculated by [Sum for all models (model variable*sales of model)]/total sales of all units. For example, sales weighted UEC is calculated as:

\[ \frac{\text{Sum for all models (model UEC } \times \text{ sales of model)}}{\text{total sales of all models}}. \]

2.3 Normalisation

2.3.1 Normalisation Overview

The testing procedures to determine the UEC of dishwashers are broadly similar within reporting countries. The main differences are described in the dishwashers product definition and of those, a number of factors have an impact on Unit Energy Consumption.

Some of these differences are not adjusted for in this analysis due to either:

- their impact being considered too small to allow reliable normalisation; or
- there being neither empirical nor theoretical methods for normalisation.

However, the most significant differences in terms of their impact on energy consumption are believed to be:

- approach to truncated cycles in the North American tests;
- inlet water temperature; and
- size and content of the load.

The approach taken in the analysis for each of these test differences is described below.

2.3.2 Conversion of truncated cycle UECs to full cycle UECs

As with all defined methodologies, the ‘cycle’ is used as the functional performance unit for the machine, with energy measured based on a single cycle basis along with some or all of, depending on the test methodology, wash quality, drying effectiveness and water consumption.

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38 see http://mappingandbenchmarking.iea-4e.org/matrix
For all test methodologies, the cycle is defined broadly as a complete washing, rinsing, and drying process defined by the programme selected, consisting of a series of operations. The time for the cycle is the time taken for the unit to complete this full cycle and return to a steady state condition.

The known exception is the Canadian and US measurements of energy consumption where units with an option to truncate the programme (i.e. turn off the powered drying cycle) have an allowance made for this functionality on the assumption that some users will elect not to use the drying cycle. Models with this functionality have half of the drying energy deducted from the final declared Unit Energy Consumption.

Where available, the full cycle UEC of units with a truncated cycle function will be analysed. Where the full cycle UEC value is not available, the UEC will be adjusted to be equivalent to the full cycle consumption. The method for this adjustment is described below:

\[
\text{Full Cycle UEC} = \text{Declared UEC} + 50\% \times \text{estimated energy for powered drying element of the cycle (PDE)}
\]

where the PDE is based on data from a test-house\(^{39}\) for 38 models showing the breakdown of energy consumption by cycle stage.

**Figure 44: Proportion of energy used for powered drying in test laboratory results.**
Figure 44: Proportion of energy used for powered drying in test laboratory results. shows the percentage of energy used for powered drying in a full cycle for the 38 truncated cycle dishwashers which were tested in 2011-13. Given the small sample size, the slight inverse correlation between total UEC and the percentage used for drying is not considered significant. The average percentage of total cycle energy used for powered drying in these units (13.1%) is therefore assumed to be a reasonable approximation of the PDE for all models in order to estimate the total cycle UEC from the declared value. While this will not be a reliable approach for individual models, it is considered a reasonable estimate when used to calculate the average full cycle UEC across a full market dataset.

2.3.3 Normalisation of UEC for differences in inlet water temperature

Test methodologies vary in nominal cold water inlet temperatures, but all account for the variations in embodied energy relative to this inlet temperature (via simple calculations based on the specific heat capacity of water). Specifically, nominal water inlet temperatures are:

- Australia: 20°C
- EU Countries, Korea and Switzerland: 15°C
- Canada and the USA: 10°C

Energy embodied in water (per cycle) will be normalised to a single nominal cold water input temperature of 15°C. Normalisation of cycle energy consumption will be based on the addition of embodied water energy for the proportion of the water intake that is heated as follows:

Additional embodied energy = total water consumption from fills that are heated in the cycle (litres) \times \text{the specific heat capacity of water (0.00115 kWh/L °C)} \times (15°C - \text{nominal local water inlet temperature in °C})

Note this will be a negative value for countries where the nominal temperature is above 15°C and a positive value for those where the nominal temperature is below 15°C.

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40 This equates to an uplift of approximately 6.1% to convert the declared result to the full cycle UEC.
2.3.4 Normalisation of UEC for differences in load size and content

There are significant differences in the loads used in test procedures around the world. For example, in the test methodology used in the EU, the dishwasher is required to be tested with a load equal in size to the rated capacity of the unit. However, in the USA and Canada, the test load for a ‘standard’ dishwasher is always 8 place settings. Further, the physical make up of the load (i.e. the items included in the wash) differs, as does whether the items are soiled or clean at the initiation of the cleaning cycle. Clearly there is a potential for each of these factors to alter the UEC that is recorded for a given model tested to different test methodologies.

There is no known empirical data on the impact on energy consumption of this variation in the loading for a given machine. It is therefore necessary to use a theoretical approach to adjusting for this difference between the tests.

There are various ways in which the energy consumption of a dishwasher could change with a variation in the number of place settings loaded. These include:

1. Variation in the amount of water used: There is a possibility that units will adjust the amount of water consumed (and hence heated) in line with the size of the load in the unit. However, expert opinion suggests\(^{41}\) that the quantity of water used is a function of the water capacity of the unit and not by the load actually placed in the machine. Therefore, this aspect will not be accounted for in this analysis;

2. Variation in the soiling: the additional load will increase the overall level of soiling that requires cleaning within the cycle. However, as is the case with the type of soiling agent described in the product definition, no information appears publicly available on the ‘relative’ impact of soiling (and the related local specification of detergent, etc) on overall performance. Therefore, no normalisation will be made for this difference in the total level of load soiling.

3. Thermal capacity of the load: During a test, a certain amount of the heating energy placed in the dishwasher is absorbed by the load. Clearly, machines where larger loads are present (or more precisely, loads with higher heat capacity) will require more energy to heat the load. Further, once heated, the various loads will transfer differing amounts of energy forward into later parts of the cycle through the thermal storage of the load. Hence, to make comparisons between machines of similar rated capacity but differing test load sizes, it is necessary to account for the impact of the relative thermal capacities of the load. The proposed approach to normalising for this is therefore described below.

---

\(^{41}\) This assumption is based on the way water consumption is controlled by dishwashers. The tableware is not immersed in the water, so when filling occurs it is either metered in or filled to a level. This is enough to fill the sump and the distribution pipes plus a very small amount in order to wet the surface of each load item. Thus water consumption should not vary much with load size.
2.3.4.1 Normalising for different thermal capacities of the load

The difference in UEC for units measured in tests other than the benchmarking methodology (EU) as a result of the relative thermal capacities of the load will be estimated as follows:

\[ \text{Normalised UEC} = \text{local UEC for machine} + \text{Load Differential Energy Consumption (LDEC)}. \]

where:

LDEC is defined as the difference in energy required to raise the temperature of the local load through a typical full EU cycle compared with the energy required to raise the temperature of the EU load through a typical full EU cycle:

and LDEC is calculated as:

\[ \left( \sum (\text{Mass of each EU load component} \times \text{specific heat capacity of each EU component}) - \sum (\text{Mass of each local load component} \times \text{specific heat capacity of each local load component}) \right) \times \text{total EU test load temperature rise} \]

2.3.4.2 Assumptions made when normalising for different thermal capacities of the load

No details of the actual specific heat capacities for each component of the load are available for each of the test methodologies under consideration. The following assumptions are therefore made about the make-up of all loads in all tests:

- the crockery load is predominantly porcelain and the cutlery load is stainless steel which have respective specific heat capacities \( (C_p) \) of \( 920 \text{ J/kg K} \) and \( 510 \text{ J/kg K} \).
- \( 1 \text{ kilojoule} = 0.000277778 \text{ kWh} \)

The following assumptions are made about the make-up of the EU load:

- the full EU load weight of each capacity is shown in the table below:

<table>
<thead>
<tr>
<th>Place settings</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of crockery in EU load (kg)</td>
<td>10.81</td>
<td>13.03</td>
<td>14.61</td>
<td>16.19</td>
<td>17.77</td>
<td>19.35</td>
<td>20.93</td>
<td>22.51</td>
<td>24.09</td>
<td>25.67</td>
<td>27.25</td>
</tr>
<tr>
<td>Mass of cutlery EU load (kg)</td>
<td>1.425</td>
<td>1.62</td>
<td>1.815</td>
<td>2.01</td>
<td>2.205</td>
<td>2.4</td>
<td>2.595</td>
<td>2.79</td>
<td>2.985</td>
<td>3.18</td>
<td>3.375</td>
</tr>
</tbody>
</table>

\[ \text{specific heat capacity} \]

\[ \text{conversion.html} \]

\[ \text{http://www.diracdelta.co.uk/science/source/s/p/specific%20heat%20capacity/source.html#UWaGmZOG1z8} \]

\[ \text{http://www.unitconversion.org/energy/kilojoules-to-kilowatt-hours-conversion.html} \]

Issue date: 4 April 2014:
The final assumption that needs to be made is to estimate the total EU test load temperature rise in a cycle. This is estimated from the temperature profiles of typical EU dishwashers under test. An example of these profiles is shown in Figure 45: Temperature of the water in a typical EU dishwasher cycle. The temperature shown is the water temperature as recorded in the dishwasher sump through a test cycle.

In order to estimate the total temperature rise of the load in such a cycle the following assumptions are made:

1. There are two main heating phases in the temperature cycle: the main wash heating phase and the final rinse heating phase;
2. The load tracks the measured water temperature very closely rising to within 1°C of the peak temperature for both the main wash and final rinse.

The total EU test load temperature rise is therefore assumed to be:

\[
\text{Peak wash cycle temperature - ambient test temperature + peak rinse cycle temperature - load temp after intermediate rinse fill - 2°C}
\]

---

44 Based on actual EU cycle profiles from tests undertaken at an internationally recognised test during 2012.
45 If the load were at a significantly lower temperature than the water, the fall in water temperature at the end of each of the heating phases would be faster and more pronounced.
where the values for each of these temperatures is estimated as the sales weighted average value from measured test cycle temperature profiles of typical models\textsuperscript{46} from the four market leading brands in the UK.\textsuperscript{47} These values are shown in the table below:

```
<table>
<thead>
<tr>
<th>Brand</th>
<th>T1</th>
<th>T2</th>
<th>T3</th>
<th>T4</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>23 °C</td>
<td>55 °C</td>
<td>38 °C</td>
<td>69 °C</td>
</tr>
<tr>
<td>B</td>
<td>23 °C</td>
<td>50 °C</td>
<td>33 °C</td>
<td>61 °C</td>
</tr>
<tr>
<td>C</td>
<td>23 °C</td>
<td>50 °C</td>
<td>35 °C</td>
<td>63 °C</td>
</tr>
<tr>
<td>D</td>
<td>23 °C</td>
<td>50 °C</td>
<td>36 °C</td>
<td>63 °C</td>
</tr>
</tbody>
</table>
```

The sales weighted average total cycle temperature rise for all EU machines is therefore assumed to be 53.6 °C.

NOTE 1: It should be noted that, because these temperature profiles are from 2012, they are likely to be less robust for earlier years in the analysis. For example, it is known that water consumption of dishwashers in the EU has fallen steadily over the period of the analysis. This means that the values for T3 would probably have been lower in earlier years as more of the heat in the system would be lost with each refill of the machine. Consequently, the energy required to raise the temperature of the load through the full cycle would have been higher in earlier years and therefore the increase in UEC for e.g. North American models would have been greater. This aspect of the normalisation is therefore less robust in earlier years and favours loads with a lower total thermal capacity.

NOTE 2: It is very difficult to estimate the exact load temperature after the water is added for the final rinse because generally the heater switches on at this point and there is not enough time for the load to stabilise enough to allow an accurate measurement to be made. However, the more easily measured temperature drop for the intermediate rinse gives a benchmark against which to estimate it. The final value for T3 is therefore estimated by a representative of the test house that provided the data and is believed to be reasonable.

NOTE 3: The extent of the temperature drop during the rinses may be affected by the presence of a heat exchanger. If heat from the wash water can be used to warm the incoming rinse water this reduces the temperature drop.

\textsuperscript{46} Again based on actual EU cycle profiles from tests undertaken at an internationally recognised test during 2012.

\textsuperscript{47} No equivalent data was available for the whole of the EU but these brands cover over 70% of the UK market in 2011 and, given the limited variation in the temperature profiles, these models are believed to be a reasonable approximation for the EU market.
2.3.5 Calculation of normalised EEI

An Energy Efficiency Index (EEI) is a mechanism through which products of different types and sizes can be compared. Again the EU method for EEI calculation is being used as follows:

\[
\text{EEI} = \frac{\text{AEc}}{\text{SAEc}} \times 100
\]

where,

\[
\text{AEc} = \text{Annual Energy Consumption of the dishwasher}
\]

\[
\text{SAEc} = \text{Standard Annual Energy Consumption of the dishwasher of the same capacity}
\]

The Annual Energy Consumption (AEc) is calculated by:

\[
\text{AEc} = E_t \times 280 + \frac{P_s \times \left( \frac{525 \times 600 - (T_i \times 280)}{2} \right) + P_l \times \frac{525 \times 600 - (T_i \times 280)}{2}}{60 \times 1000}
\]

Where:

- \(E_t\) is the Unit Energy Consumption under test conditions
- 280 washes is the assumed washes/year (based on EU assumptions).
- 525,600 is the number of minutes in a year
- \(P_s\) is standby ‘left-on mode’
- \(P_l\) is standby ‘off mode’
- \(T_i\) is programme time for the standard cleaning cycle

The standard energy consumption (SAEc) is

\[
\text{SAEc} = 378 + (7 \times \text{place settings}) \ [\text{for 10 or more place settings}]
\]

\[
\text{SAEc} = 126 + (25.2 \times \text{place settings}) \ [\text{for 9 or fewer place settings}]
\]

where the factors and constants (378, 7, 126 and 25.2) are based on an analysis of all models in the EU and are used to calculate the SAEc for any given capacity.
In the majority of datasets, one or all of the values for $P_l$, $P_o$ and $T_l$ are not provided for part or all of the dataset. When these values are unknown, EU and Swiss models are assumed to have the average value from the Danish data for each variable as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>$P_o$ (W)</th>
<th>$P_l$ (W)</th>
<th>$T_l$ (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>4.69</td>
<td>2.46</td>
<td>77</td>
</tr>
<tr>
<td>1997</td>
<td>4.48</td>
<td>2.34</td>
<td>79</td>
</tr>
<tr>
<td>1998</td>
<td>4.27</td>
<td>2.21</td>
<td>85</td>
</tr>
<tr>
<td>1999</td>
<td>4.06</td>
<td>2.08</td>
<td>89</td>
</tr>
<tr>
<td>2000</td>
<td>3.86</td>
<td>1.95</td>
<td>94</td>
</tr>
<tr>
<td>2001</td>
<td>3.65</td>
<td>1.82</td>
<td>102</td>
</tr>
<tr>
<td>2002</td>
<td>3.44</td>
<td>1.70</td>
<td>107</td>
</tr>
<tr>
<td>2003</td>
<td>3.23</td>
<td>1.57</td>
<td>115</td>
</tr>
<tr>
<td>2004</td>
<td>3.02</td>
<td>1.44</td>
<td>118</td>
</tr>
<tr>
<td>2005</td>
<td>2.82</td>
<td>1.31</td>
<td>137</td>
</tr>
<tr>
<td>2006</td>
<td>2.61</td>
<td>1.18</td>
<td>137</td>
</tr>
<tr>
<td>2007</td>
<td>2.40</td>
<td>1.06</td>
<td>158</td>
</tr>
<tr>
<td>2008</td>
<td>2.19</td>
<td>0.93</td>
<td>159</td>
</tr>
<tr>
<td>2009</td>
<td>1.99</td>
<td>0.80</td>
<td>159</td>
</tr>
<tr>
<td>2010</td>
<td>1.78</td>
<td>0.67</td>
<td>159</td>
</tr>
<tr>
<td>2011</td>
<td>1.57</td>
<td>0.55</td>
<td>160</td>
</tr>
<tr>
<td>2012</td>
<td>1.36</td>
<td>0.42</td>
<td>159</td>
</tr>
</tbody>
</table>

For all other datasets, models are assumed to have the average value from the Australian data for each variable as follows:

<table>
<thead>
<tr>
<th>Year</th>
<th>$P_o$ (W)</th>
<th>$P_l$ (W)</th>
<th>$T_l$ (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>4.69</td>
<td>2.46</td>
<td>79</td>
</tr>
<tr>
<td>1997</td>
<td>4.48</td>
<td>2.34</td>
<td>79</td>
</tr>
<tr>
<td>1998</td>
<td>4.27</td>
<td>2.21</td>
<td>79</td>
</tr>
<tr>
<td>1999</td>
<td>4.06</td>
<td>2.08</td>
<td>79</td>
</tr>
<tr>
<td>2000</td>
<td>3.86</td>
<td>1.95</td>
<td>79</td>
</tr>
<tr>
<td>2001</td>
<td>3.65</td>
<td>1.82</td>
<td>79</td>
</tr>
<tr>
<td>2002</td>
<td>3.44</td>
<td>1.70</td>
<td>80</td>
</tr>
<tr>
<td>2003</td>
<td>3.23</td>
<td>1.57</td>
<td>91</td>
</tr>
<tr>
<td>2004</td>
<td>3.02</td>
<td>1.44</td>
<td>96</td>
</tr>
<tr>
<td>2005</td>
<td>2.82</td>
<td>1.31</td>
<td>102</td>
</tr>
<tr>
<td>2006</td>
<td>2.61</td>
<td>1.18</td>
<td>108</td>
</tr>
<tr>
<td>2007</td>
<td>2.40</td>
<td>1.06</td>
<td>115</td>
</tr>
<tr>
<td>2008</td>
<td>2.19</td>
<td>0.93</td>
<td>117</td>
</tr>
<tr>
<td>2009</td>
<td>1.99</td>
<td>0.80</td>
<td>123</td>
</tr>
<tr>
<td>2010</td>
<td>1.78</td>
<td>0.67</td>
<td>128</td>
</tr>
<tr>
<td>2011</td>
<td>1.57</td>
<td>0.55</td>
<td>128</td>
</tr>
<tr>
<td>2012</td>
<td>1.36</td>
<td>0.42</td>
<td>128</td>
</tr>
</tbody>
</table>

Where data was not available in the Danish or Australian datasets, the value from the nearest year in which data is available is used.
Annex 3 Framework for grading mapping and benchmarking outputs

The grading system developed by the Annex to provide a measure of the ‘reliability’ of analysis and outputs enables the allocation of a ‘robust’, ‘indicative’ or ‘illustrative’ grading to each output. The grading system is based on an appraisal of the type and quality of the initial data input, and the degree to which any consequential manipulations are likely to have degraded the reliability of the original data and/or the comparability of outputs with those of other countries. While expert opinion is used to formulate the specific grading allocated to individual datasets or outputs, this expert opinion is formed based on a consistent framework detailed below.

Grading of data/mapping outputs

Robust – where typically:
The data is largely representative of the full market and
The data includes at least a significant element of individual product data and
The data is 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 the 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 is 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 the 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 is worth reporting, but results must be treated with caution.
10  **Annex 4 Summary of source data, impact of the normalisation process and consequential grading of the resulting mapping and benchmarking outputs**

In an effort to assist readers understand the degree of confidence they may place in the outputs associated with individual datasets, and the comparability of those outputs with outputs from data sourced elsewhere, the Annex has developed a system for the ‘grading’ of outputs as detailed in Annex 3.

Based on this grading system, each output used in the individual country mapping documents and in this report has been allocated a robust, indicative or illustrative grading. The summary justification for the grading of each output is provided in Figure 46.

**Figure 46: Summary justification for grading of outputs.**

<table>
<thead>
<tr>
<th>Country</th>
<th>Data source, content and likely impact on the reliability of resulting analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Data is drawn from the national registration database (product weighted data) and combined with sales data from GfK market research company (sales weighted data). Data, which is available from 2001-2010, is at model level and fully sales weighted and is considered highly reliable for all product attributes reported. Hence all mapping data is considered robust. However, given the inaccuracies that are inherently introduced during the normalisation process, all benchmarking analysis for Unit Energy Consumption (UEC), Unit Energy Efficiency (UEE) and Energy Efficiency Index (EEI) is considered indicative.</td>
</tr>
</tbody>
</table>
| Austria | As no normalisation is required, all mapping and benchmarking data has the same grading. All data sourced from GfK market research company as averages from 2006 to 2012. The datasets submitted are reported to cover approximately 85% of sales in the Austrian market in all years and are therefore market representative. Therefore, all unit energy consumption data can be considered robust. Information on average capacity was provided as sales per capacity range (e.g. 8-9, 10-11 etc. place settings) and so Danish averages within each range were used to estimate the overall average capacity values for Austrian dishwashers. Consequently, capacity values are considered indicative. UEE results are calculated as: \( \text{average UEC} / \text{average capacity} \). This ‘average of averages’ approach using an already indicative capacity value means all UEE values should be considered illustrative. EEI values were estimated using a table of sales by energy label. Assumptions had to be made on the typical value of EEI within each energy label category (using other EU
The information and analysis contained within this summary document is developed to inform policy makers. Whilst the information analysed was supplied by representatives of National Governments, a number of assumptions, simplifications and transformations have been made in order to present information that is easily understood by policy makers, and to enable comparisons with other countries. Therefore, information should only be used as guidance in general policy - it may not be sufficiently detailed or robust for use in setting specific performance requirements. Details of information sources and assumptions, simplifications and transformations are contained within the document or the related Mapping Documents.

<table>
<thead>
<tr>
<th>Country</th>
<th>Data source, content and likely impact on the reliability of resulting analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria continued</td>
<td>datasets to estimate the typical value). All EEI values must therefore be considered indicative.</td>
</tr>
<tr>
<td></td>
<td>No data was available on water consumption.</td>
</tr>
<tr>
<td>Canada</td>
<td>Product based data is at a model level is available between 1996-2010. It is sourced from the national registration database and is considered highly reliable for all product attributes reported.</td>
</tr>
<tr>
<td></td>
<td>Sales-weighted data (technically shipment-weighted) is sourced from the Canadian Appliance Manufacturers Association (CAMA) and is believed to be market representative by the data supplier. Therefore, all UEC mapping data is considered robust, as is the product-weighted water consumption data.</td>
</tr>
<tr>
<td></td>
<td>However, given the inaccuracies that are inherently introduced during the normalisation process, all UEC data normalised to the (EU) benchmarking test methodology is considered indicative.</td>
</tr>
<tr>
<td></td>
<td>Canada had no data on capacity and so average capacity data from the USA was used to estimate both the Unit Energy Efficiency (UEE) and Energy Efficiency Index (EEI) values for Canada. This ‘average of averages’ approach using an, albeit very similar, other market’s capacity value means all UEE and EEI values should be considered illustrative.</td>
</tr>
<tr>
<td>Denmark</td>
<td>As no normalisation is required, all mapping and benchmarking data has the same grading.</td>
</tr>
<tr>
<td></td>
<td>Product- and sales-weighted data for 1996-2012 sourced by the Danish Energy Agency direct from manufacturers importing to the country. Product-weighted data is at a model level and this is combined with total market sales (broken down by energy label) using a method that is considered reliable. Consequently, all results are considered robust.</td>
</tr>
<tr>
<td>EU</td>
<td>As no normalisation is required, all mapping and benchmarking data has the same grading.</td>
</tr>
<tr>
<td></td>
<td>All data sourced from GfK market research company as averages from 2006 to 2012. The data covers 14 EU countries only, Austria, Czech Republic, Denmark, Finland, France, Germany, Hungary, Italy, Netherlands, Poland, Slovakia, Spain, Sweden, and the United Kingdom. The proportions of these markets covered by the data ranges from 76%-100% with an estimated average of 88%. Therefore, all unit energy consumption data can be considered robust, as can all capacity data.</td>
</tr>
<tr>
<td></td>
<td>Information on Unit Energy Efficiency (UEE) and Energy Efficiency Index (EEI) are based on the robust market average values for consumption and capacity. However, as market average values have been used for derivations, both are considered indicative.</td>
</tr>
<tr>
<td></td>
<td>No data was available on water consumption.</td>
</tr>
<tr>
<td>Country</td>
<td>Data source, content and likely impact on the reliability of resulting analysis</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Republic of Korea</td>
<td>Information on products in the Republic of Korea covers the period from 2006-2012 and is model based with sales data also provided. The data is drawn directly from the National Registrations System managed by the Korea Energy Management Corporation (all products are required to be registered prior to sale). All mapping data for Unit Energy Consumption (UEC) and Unit Energy Efficiency (UEE) is therefore considered robust, as is capacity data. Korean data is only subjected to the normalisation for differences in the thermal capacity of the load, and not for differences in powered drying or inlet water temperature. The differences in the thermal load are relatively small and so the uncertainty introduced by this normalisation step is likely to be minimal. However, because this uncertainty cannot be quantified, normalised UEC and UEE values and Energy Efficiency Index (EEI) values shown in the benchmarking are considered indicative. Water consumption data is only available for years 2010-2012 covering 61%-78% of sales in the dataset. As a consequence, water consumption results are considered indicative.</td>
</tr>
<tr>
<td>Switzerland</td>
<td>As no normalisation is required, all mapping and benchmarking data has the same grading. Swiss data is available for 2003-2011 and is sourced from industry reported published sources which cover 90% of sales and are therefore considered reliable and representative of the market. However, data for Unit Energy Consumption (UEC) is derived from UEC and sales figures for 5 different product categories: stand-alone, built-in 45cm, built-in 55 cm, built-in 60 cm and small devices. This use of sales weighting of average values by sub-category means that UEC values are considered indicative. Average capacity values are based on an expert assumption. However, as it is related to the size of the devices and the expert is a specialist of the organizations Electrosuisse and FEA (Swiss trade association covering domestic and industrial electrical appliances), which collected and provided the sales figures, this assumption is considered reasonable and therefore capacity data is considered indicative. Values for Unit Energy Efficiency (UEE) rely on these assumed values for the average capacity and the averages approach described for UEC data. UEE values are therefore considered illustrative. Energy Efficiency Index (EEI) values have the same assumptions as those for UEE but also require an assumption about the typical EEI of models with a given energy label category. Consequently, EEI values are also considered illustrative.</td>
</tr>
<tr>
<td>Country</td>
<td>Data source, content and likely impact on the reliability of resulting analysis</td>
</tr>
<tr>
<td>---------</td>
<td>--------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
| UK      | As no normalisation is required, all mapping and benchmarking data has the same grading.  
Information sourced on a model level basis from GfK market research company for the years 1999-2002 and 2006-2010 only. The data covers Great Britain rather than the full United Kingdom but the markets are considered to be very similar and so both sales- and product-weighted information for these years is considered representative of the market. The dataset has data for Unit Energy Consumption, Capacity and water usage for almost 100% of models in all cases and always more than 90% (except for water usage with >80% coverage for 2 years). Consequently, all metrics for the United Kingdom are considered robust. |
| USA     | Model level information was available for all years between 2007-2012 from the California Energy Commission (CEC) database. It is considered by US representatives that this dataset will most likely give a true representation of the market. This is evidenced by the close tracking of sales-weighted market averages produced by the Association of Home Appliance Manufacturers (AHAM), which is available for the years 1996-2010 and is also considered market representative. Therefore, all Unit Energy Consumption (UEC) mapping data is considered robust.  
The CEC dataset also has near-full coverage of capacity data and consequently, all product weighted capacity data is considered robust. The Unit Energy Efficiency (UEE) values, which are calculated by model using UEC and capacity data, can therefore also be considered robust for the mapping results.  
However, given the inaccuracies that are inherently introduced during normalisation, which are exacerbated for the USA results by limited data on water consumption which is a core part of the normalisation process, all benchmarking UEC, UEE and EEI data is considered illustrative.  
Data on water consumption was limited to around 30% in the years for which it was available. As the skew of this sample is unknown, USA water data should be considered illustrative. |
11 Annex 5 Summary of policy interventions by country

Section 4 gives an overview of the development of the main policy interventions across the participating countries and summarises these in table form. Figure 47 gives a more detailed overview of these policies. 48

Figure 47: A description of the key policy interventions by country.

<table>
<thead>
<tr>
<th>Country</th>
<th>Description of key policy interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>The European Union</td>
<td>The European Union has two primary EU-wide regulations related to dishwashers:</td>
</tr>
<tr>
<td></td>
<td>• <strong>Minimum Efficiency Performance Standards (MEPS):</strong> the Commission Regulation (EU) No 1016/2010 of 10 November 2010 defined a two-tier minimum Energy Efficiency Index (EEI) requirement of 71 for ‘large’ units and 80 for ‘small’ units. These minimum requirements are strengthened from 1 December 2013 to 63 and 71 respectively, with an EEI of 63 applying to all units from 1 December 2016. A two-tier minimum requirement for drying efficiency also comes into force on 1 December 2013.</td>
</tr>
<tr>
<td></td>
<td>• <strong>Mandatory Labelling:</strong> current EU labelling requirements were established by Commission Delegated Regulation (EU) No 1059/2010 of 28 September 2010. They show Energy Efficiency Index (EEI) by label categories A+++ through to a lowest level of D. The EEI boundaries do not align with the previously used method of measured energy consumption for a full cycle corrected for water usage.</td>
</tr>
<tr>
<td></td>
<td>In November 1999, the European Committee of Domestic Equipment Manufacturers (CECED) entered into a voluntary agreement49 with the Commission with an overall target to reduce the specific energy consumption of household dishwashers by 20% by 31 December 2002 related to the base case figures of 1996. This included a two-stage programme to phase out less efficient units by stopping the import and production of ‘large’ E and all F-G rated units by the end of 2000 and all D-E units by the end of 2003. The voluntary agreement with CECED was not continued due to the introduction of the EU Ecodesign measures for dishwashers.</td>
</tr>
<tr>
<td></td>
<td>In addition there are a large number of regional, national and local policy interventions used within the European Union.</td>
</tr>
<tr>
<td>Australia</td>
<td>Minimum Performance Standards and mandatory labelling are the primary policy interventions for improving the energy efficiency of domestic appliances in Australia. These are currently implemented as follows for dishwashers:</td>
</tr>
<tr>
<td></td>
<td>• <strong>Minimum Efficiency Performance Standards (MEPS):</strong> There are no MEPS in place for dishwashers in Australia. There are minimum mandatory performance standards in place for cleaning and drying performance.</td>
</tr>
<tr>
<td></td>
<td>• <strong>Mandatory Labelling:</strong> Energy labelling was introduced in 1988 with the label itself being updated in 2000. The current label includes the star rating (coloured stars), annual energy consumption (CEC), energy consumption per cycle, rated capacity (plus other information such as energy consumption if an auxiliary water heating supply is used – so called supplementary energy consumption). A separate declaration on the water consumption of the unit is made but, although measured during the test in order to meet a minimum requirement, cleaning performance and drying performance</td>
</tr>
</tbody>
</table>

48 Full descriptions are available in the country mapping reports available from http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=11
The information and analysis contained within this summary document is developed to inform policy makers. Whilst the information analysed was supplied by representatives of National Governments, a number of assumptions, simplifications and transformations have been made in order to present information that is easily understood by policy makers, and to enable comparisons with other countries. Therefore, information should only be used as guidance in general policy - it may not be sufficiently detailed or robust for use in setting specific performance requirements. Details of information sources and assumptions, simplifications and transformations are contained within the document or the related Mapping Documents.

### Issue date: 4 April 2014:

<table>
<thead>
<tr>
<th>Country</th>
<th>Description of key policy interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Continued</td>
</tr>
</tbody>
</table>
| Austria | | As a member of the European Union, all policies listed in the EU section above apply to Austria. Some of the additional local polices in Austria are described below.  

There are programs in Austria which aim to improve energy efficiency by granting subsidies for suitable measures for the household sector. These subsidies have usually been designed as a contribution towards investment costs or as a loan with reduced interest rates. For purchasing energy efficient electrical appliances, subsidies can be obtained from some regional electrical utilities. These subsidies are granted to all customers of the respective utility, regardless of whether the customer is the owner of a private household, an enterprise or a public institution.

The most innovative and popular measure in Austria is the long-term programme for active climate protection (klima: aktiv - [www.klimaaktiv.at](http://www.klimaaktiv.at)), that was launched in 2004 by the Environmental Ministry (Lebensministerium). The program’s main focus lies on increasing the market share of energy efficient products and services. The overall goal is to reduce greenhouse gas emissions. As part of the initiative klima: aktiv, the ‘Top products’ program – a platform for energy efficient appliances - provides information on best and worst available products in the market ([www.topprodukte.at](http://www.topprodukte.at)), for household and commercial users.


| Canada | Canada has three primary federal policy interventions related to energy efficiency for dishwashers:  

• **Minimum Energy Performance Standards (MEPS)**: The *Energy Efficiency Act*, enacted in 1992, gives the Government of Canada the authority to make and enforce regulations on performance standards and labelling requirements for energy-using products that are imported into Canada or shipped across provincial and/or territorial borders for the purpose of sale or lease.

MEPS for dishwashers were first introduced in February 1995, with the registration of the *Energy Efficiency Regulations*. Since then, two amendments have been made to the *Regulations* concerning dishwashers. Amendment 8, published in September 2004, updated the reference for the test procedure for determining the minimum Energy Factor (EF) for dishwashers as well as introduced lower number of loads per year. Amendment 10, published in December 2008, increased the MEPS for dishwashers, replacing EF as a measure of energy performance with a total annual energy consumption which includes the calculation of a standby power. An amendment to further increase the stringency of MEPS for dishwashers has been announced in the regulatory plan for 2013-2015.

Generally, regulations and MEPS serve in transforming the Canadian marketplace by eliminating products with poor energy efficiency performance, while fostering a commitment to improving efficiency for energy-using equipment. |
### Country | Description of key policy interventions
--- | ---
**Canada** continued. | • **Mandatory Labelling:** The EnerGuide label was introduced in 1978 under the Consumer Packaging and Labelling Act (1971), giving Canadians the opportunity to compare the energy consumption of major electrical household appliances, including dishwashers. With the enactment of the Energy Efficiency Regulations, placement of the EnerGuide label on major electrical household appliances and room/window air conditioners became mandatory. In addition to providing the average annual energy consumption of appliances, the EnerGuide label also includes a scale showing how the given appliance compares with other similar products in terms of annual energy consumption.

Voluntary Labelling: In 2001, Canada officially introduced ENERGY STAR, the international symbol for energy efficiency. As of January 20, 2012, in order to be eligible for the ENERGY STAR label:
- standard dishwashers must exceed the regulated performance standards by at least 17% and have a water factor of less than 16.09 L/cycle, and
- compact dishwashers must exceed the regulated performance standards by at least 14% and have a water factor of less than 13.25 L/cycle.

ENERGY STAR has also been integrated with the EnerGuide label to further enable consumers to identify the most energy efficient products.

In addition the ENERGY STAR for new homes initiative encourages the use of energy efficient appliances, including dishwashers.

• **Conformity Assessment:** Various monitoring activities are utilized to achieve a high level of compliance: self-monitoring by manufacturers and dealers; monitoring by regulatory authorities including NRCan designated inspectors, provincial partners, and Canada Customs and Border Services (CBSA); market surveys, product testing and electronic monitoring of energy efficiency reports and imports information to determine compliance; third-party verification mark issued by independent certification bodies accredited by the Standards Council of Canada; and finally complaints and tips from dealers, manufacturers and consumers. Compliant product models are listed on Natural Resources Canada’s website and in product directories for consumers, utilities, dealers, and the public.

In addition to these major policy interventions, federal, provincial and territorial governments have also introduced programs to encourage the purchase and use of energy efficient equipment, including grants, and rebate and incentives programs.

**Denmark** | As a member of the European Union, all policies listed in the EU section above apply to Denmark.

**Republic of Korea** | Korea has two primary policies targeting dishwashers:
- • **Mandatory Energy Labelling:** Introduced in 1992, the Korean energy label requires an indication of efficiency on a 1-5 grade scale. The dishwashers label was introduced in 2002 and shows an energy efficiency index which is derived from both energy and water use with grade 1 being the best energy efficiency (with an index > 70 for full size models) and 5 being the least efficient (with an index ≤ 30 for full size models).
<table>
<thead>
<tr>
<th>Country</th>
<th>Description of key policy interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Republic of Korea continued</td>
<td>The labelling requirement was defined by a special standard ‘Regulation on Energy Efficiency Labelling and Standards’(^{50}) which applies to many domestic appliances. This standard has been updated and strengthened many times since 1993 (see the standard for full details).</td>
</tr>
<tr>
<td></td>
<td>- <strong>Mandatory Energy Performance Standards (MEPS)</strong> since 2002: Production and sales of products that fall below the 5th energy label grade is prohibited thereby setting the MEPS. For dishwashers, the MEPS are currently set at:</td>
</tr>
<tr>
<td></td>
<td>o Rated capacity ≤ 6 place settings: MEPS = 5.00</td>
</tr>
<tr>
<td></td>
<td>o Rated capacity &gt; 6 place settings: MEPS = 10.00</td>
</tr>
<tr>
<td></td>
<td>Both these policies sit within an overall framework of the Korean Energy Efficiency Program that targeted over 30 products in 2011, and 35 products in 2012. In this program, every manufacturer and importer of target product must report their products with test results, and they have to attach efficiency grade labels on their products.</td>
</tr>
<tr>
<td></td>
<td>In addition, Korea has a range of policies that affect the energy consumption of appliances either directly or indirectly. In particular:</td>
</tr>
<tr>
<td></td>
<td>+ Korea has standards for ‘energy frontier’. Energy frontier is designed to highlight products that achieve energy consumption/efficiency levels that are 30-50% better than the current 1* grade thresholds.</td>
</tr>
<tr>
<td></td>
<td>+ Korea has introduced a carbon pricing and annual energy cost information program since 2009 (requiring display of this information on many products).</td>
</tr>
<tr>
<td>Switzerland</td>
<td>The following policy interventions are the primary Swiss actions on dishwashers:</td>
</tr>
<tr>
<td></td>
<td>+ <strong>Minimum Efficiency Performance Standards (MEPS):</strong> Switzerland will regulate dishwashers from August 2014. At that time the regulation will be in line with the EU regulation.</td>
</tr>
<tr>
<td></td>
<td>+ <strong>Mandatory Labelling:</strong> The current Swiss labelling of dishwashers is in line with the EU labelling. It was introduced 1 January, 2012, with the allowed transition time until 30 June, 2012.</td>
</tr>
<tr>
<td></td>
<td>The European Union has two primary EU-wide regulations related to dishwashers that impact on the Swiss market:</td>
</tr>
<tr>
<td></td>
<td>+ <strong>Minimum Efficiency Performance Standards (MEPS):</strong> the Commission Regulation (EU) No 1016/2010 of 10 November 2010 defined a two-tier minimum Energy Efficiency Index (EEI) requirement of 71 for ‘large’ units and 80 for ‘small’ units. These minimum requirements are strengthened from 1 December 2013 to 63 and 71 respectively with an EEI of 63 applying to all units from 1 December 2016. A two-tier minimum requirement for drying efficiency also comes into force on 1 December 2013.</td>
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</tr>
</tbody>
</table>

\(^{50}\) [http://www.kemco.or.kr/nd_file/kemco_eng/MKE_Notice_2010-124.pdf](http://www.kemco.or.kr/nd_file/kemco_eng/MKE_Notice_2010-124.pdf)
The information and analysis contained within this summary document is developed to inform policy makers. Whilst the information analysed was supplied by representatives of National Governments, a number of assumptions, simplifications and transformations have been made in order to present information that is easily understood by policy makers, and to enable comparisons with other countries. Therefore, information should only be used as guidance in general policy and may not be sufficiently detailed or robust for use in setting specific performance requirements. Details of information sources and assumptions, simplifications and transformations are contained within the document or the related Mapping Documents.

<table>
<thead>
<tr>
<th>Country</th>
<th>Description of key policy interventions</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td>As a member of the European Union, all policies listed in the EU section above apply to the UK.</td>
</tr>
</tbody>
</table>
| USA     | The USA has three primary federal policy interventions related to dishwashers:  
- **Minimum Energy Performance Standards**: Based on the 1987 National Appliance Energy Conservation Act, which established the first uniform national efficiency standard for residential dishwashers and gives the Department of Energy the ability to place establish or amend energy standards on various consumer products. The current standards for dishwashers are defined in the Code of Federal Regulations (CFR) at 10 CFR Part 430.32(f)(3).  
  MEPS for dishwashers first took effect in 1994 with a revision in 2010. Strengthened standards were announced in May 2012 with an effective date 30 May 2013.  
- **Mandatory Labelling**: EnergyGuide, which provides an indication of comparative energy consumption and an estimate of costs to the consumer. First introduced in 1980, with a redesigned label (featuring more prominently displayed cost estimates) being announced in 2007.  
- **Voluntary Labelling**: ENERGY STAR which seeks to help consumers identify higher performing products that meet a range of performance standards. In the case of dishwashers, at the time of this report, the ENERGY STAR criteria were approximately 4% below federal standards for energy consumption and 15% below federal standards for water consumption. Dishwashers with the ENERGY STAR label were on average 10% more efficient than those without it.  
  ENERGY STAR was introduced for dishwashers in 1996. The most recent addition of the ENERGY STAR criteria came into effect on 20-1-2012. In 2009, it was estimated that at least 68% of US dishwashers carried the ENERGY STAR label.  
  In addition there are a large number of regional, state and local policy interventions by a large number of bodies. Such interventions range from state based MEPS through major procurement activities (e.g. utility DSM programmes), often driven by requirements in states such as California and/or based on ENERGY STAR qualified products. |

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51 The majority of policy information sourced from US DOE  
52 http://www.energystar.gov/index.cfm?c=manuf_res.pt_appliances#asd

Issue date: 4 April 2014.
Annex 6 Review of the possible causes of the higher dishwasher unit energy consumptions in North America

Figure 48 shows Unit Energy Consumption (UEC) with all results normalised to the benchmarking test methodology. It clearly indicates that dishwashers in North America use significantly more energy in a single wash cycle than dishwashers in all of the other markets covered in the analysis. Before progressing onto the review of the remaining metrics in this study, it is worth reviewing the possible causes of this apparent discrepancy in UECs. The analysis undertaken for this review is described below.

There are a number of differences between markets in product design and/or use that may contribute to this additional energy consumption. The aim of this section is simply to assess the order of magnitude of the main candidate factors in order to establish whether or not these apparent differences are realistic. The results presented in the next sections are not meant to show exact estimates of the causes of the differences in North America, but simply to establish whether the overall scale of difference can be accounted for.

![Figure 48: Normalised average unit energy consumption for new dishwashers 1996-2012 (refer to Annex 8 for data table).](image-url)
The use of powered drying.
The first primary difference in the way that dishwashers are both tested and used in North America is that a powered drying option is very common. This appears not to be the case in any of the other markets analysed. The extent of the use of powered drying in North America is shown in Figure 49:

![Figure 49: The percentage of all dishwashers with a powered drying (truncated cycle) option in North America over time.](image)

In both the USA and particularly Canada, powered drying is very prominent and becoming more so in recent years. There is a clear energy penalty associated with using powered drying as described in the summary of the approach to the analysis, 2.3.2. In the main analysis, the declared value for UEC is converted to a full cycle value, i.e. the energy used for a cycle that included the powered drying element. This is done using test data from an internationally recognised test house detailing the amount of total cycle energy that is used for powered drying. The same approach can be used in reverse to estimate the UEC of the
dishwashers for the truncated cycle, i.e. switching off the cycle before the powered drying phase commences.

Selecting the United Kingdom and Canada as representative markets (because both have detailed data on water use - see next section) allows us to see what impact this has on the comparative UECs as shown in Figure 50.

As can be seen, the impact of removing the powered drying energy reduces Canadian UECs by around 13% but they are still significantly higher than those in the United Kingdom in all years.

**The use of larger volumes of heated water.**
The second major factor to consider is the difference in the volume of water used in North American dishwashers compared with those in the rest of the world. Figure 51 shows how water use compares across all countries in the study and it can clearly be seen that in both USA and Canada water use is significantly higher. Of course, additional water use only incurs a significant energy penalty if that water is heated and this is the case for most machines in North America which typically use hot feed systems with inlet temperatures of most commonly 49°C.
The information and analysis contained within this summary document is developed to inform policy makers. Whilst the information analysed was supplied by representatives of National Governments, a number of assumptions, simplifications and transformations have been made in order to present information that is easily understood by policy makers, and to enable comparisons with other countries. Therefore, information should only be used as guidance in general policy – it may not be sufficiently detailed or robust for use in setting specific performance requirements. Details of information sources and assumptions, simplifications and transformations are contained within the document or the related Mapping Documents.

In order to estimate the energy penalty of this additional heated water, it is necessary to estimate how much water goes into each part of the cycle. To do this properly would require both water filling and temperature profiles of each dishwasher to be analysed but this level of detail is not available to the annex. However, given this exercise is simply to estimate the order of magnitude of the different factors contributing to increased UEC in North America it is reasonable to make some assumptions.

**Total amount of water used:**
The total amount of water used is calculated from the formula of a linear trend line for both the Canadian and UK water use. This is shown in Figure 52.

![Figure 52: Regression analysis of water use in dishwashers in the United Kingdom and Canada.](image)

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**Water use at each stage of the dishwasher’s cycle:**
The amount of water assumed at each stage of the cycle is based on two assumptions:

- Firstly, it is assumed that water is either metered in or filled to a level, typically enough to fill the sump and the distribution pipes plus a very small amount in order to wet the load.
- Secondly, it is assumed the typical dishwasher cycle has three fill stages;
  
  Fill 1. the pre-wash fill that is retained for the main wash;
  Fill 2. the intermediate rinse fill; and
  Fill 3. a final rinse fill.

Therefore it is assumed that a third of the total water consumption is used in each of the three fill stages.

**Peak temperatures at each stage of the dishwasher’s cycle:**
The peak temperatures of each of the fill stages in North America are unknown because no temperature profiles are available to the annex. However, it is known that the hot feed water has a temperature of 49°C and that a minimum wash temperature of 49°C must be reached. Most machines have the functionality to reheat water that has reduced in temperature back to or potentially above, this 49°C level. However, by looking at the typical EU cycle as described in section 2.3.4.2 of the *Summary of the approach to the analysis*, temperatures above 49°C are only likely in the final rinse stage as a means of raising the temperature of the load for evaporative drying. This may not be necessary in North American tests in which the powered drying function is switched on.

Therefore, in the absence of any evidence to the contrary, it is conservatively assumed that the peak temperature in all stages of the North American wash is 49°C. If peak temperatures are higher than this at any point in the North American cycle, then the energy penalty for North American dishwashers would be higher than estimated here.

**Calculating the additional energy in each fill:**
The final assumption is necessary due to use of hot feed dishwashers in North America as opposed to cold feed in the EU. In the EU, the intermediate rinse is typically cold whereas, because of the hot feed, North American intermediate rinses are by necessity hot.

This leads to the following assumptions:

- Fills 1 and 3: the energy cost of heating extra water is only estimated for the additional water used in North American dishwashers;
- Fill 2: the energy cost of heating extra water is estimated for all the water used in North American dishwashers.
The information and analysis contained within this summary document is developed to inform policy makers. Whilst the information analysed was supplied by representatives of National Governments, a number of assumptions, simplifications and transformations have been made in order to present information that is easily understood by policy makers, and to enable comparisons with other countries. Therefore, information should only be used as guidance in general policy—it may not be sufficiently detailed or robust for use in setting specific performance requirements. Details of information sources and assumptions, simplifications and transformations are contained within the document or the related Mapping Documents.

Combining all of the assumptions above gives us the following equations for calculating the additional energy used by the additional water in North American dishwashers:

Fills 1 and 3:

\[ \Delta UEC = \Delta W_a \cdot C_p \cdot \Delta T \]

Fill 2:

\[ \Delta UEC = \Delta W_t \cdot C_p \cdot \Delta T \]

Where:

\( \Delta W_a \): additional water used for fills 1 and 3 in Canada compared with the UK by year.

\( C_p \): specific heat capacity of water.

\( \Delta T \): temperature rise from benchmarking fill temp of 15°C.

\( \Delta W_t \): total water used for fill 2 in Canada by year.

Figure 53 summarises the analysis of the additional water use in North American dishwashers. Removing the estimated extra energy input in the additional water used in each of the three fills brings the Canadian UEC down to levels that are very similar to those for dishwashers in the UK.

This is very much a high level analysis, and the relative positions of the UK data compared with the adjusted Canadian data must be considered as illustrative. There is some uncertainty as a result of the normalisation process and there maybe some uncertainty due to errors in the underlying data or other unknown factors. However, as a first order approximation, this analysis very much implies that the higher North American UECs are real and most likely caused by the use of powered drying and larger volumes of hot water.
Annex 7 Assumptions, data, extrapolations and inter-region data transfers for the potential savings modelling

Ideally the model inputs consist of the following: appliance data from 2000 to 2010 for sales and sales distributions on energy classes, rated capacities, annual number of cycles and lifespans (if dynamic). Data for GDP (or another growth indicator) for the same years is needed, and not least a forecast till 2050. Additionally the housing stock development should be known as this is useful when wanting to relate and validate the results.

In practice the received material for the different regions is somewhat less. Typically the sales and sales distribution is lacking, or is just specified for a few years - or only the stock is specified. Rated capacities and annual cycles are also missing, but can in some cases be found in other material. Lifespans are assumed to be $10^{53}$ years for all regions. GDP and housing stock data is readily available through national and regional data websites.

For simplicity, the GDP growth forecast to 2050 is assumed to be an absolute increase every year that amounts to 2% the first year, and then gradually declines relatively. This obtains what is considered a conservative scenario for GDP growth. The same approach is used to create a housing stock forecast, with historical developments supporting the figure of 2% p.a. in this case.

General assumptions in the analysis:

Some general model assumptions that are applied across the analysis are:

- The 'normal' development can be described as the sales distribution undergoing a (small) percentual change per year, towards efficiency-improved sales.
- The total sales follow a predetermined development, normally inspired by the general GDP development, but also third party forecasts.
- The total stock can be calculated as the result of sales of the appliance with a normal-distributed lifespan.

Assumptions around some central input parameters are shown in Figure 54:

**Figure 54: Used annual cycles and rated capacities 2010, according to the submitted input data.**

<table>
<thead>
<tr>
<th>Region</th>
<th>Annual</th>
<th>Rated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia*</td>
<td>175</td>
<td>12.5</td>
</tr>
<tr>
<td>Canada**</td>
<td>215</td>
<td>11.7</td>
</tr>
<tr>
<td>Korea</td>
<td>215</td>
<td>11.7</td>
</tr>
<tr>
<td>USA</td>
<td>215</td>
<td>11.7</td>
</tr>
<tr>
<td>EU-27</td>
<td>214</td>
<td>12</td>
</tr>
<tr>
<td>Switzerland</td>
<td>216</td>
<td>11.6</td>
</tr>
</tbody>
</table>

Notes:
* = assumed average used for Australia.
** = transferred from USA.

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53 This figure is supported by the 20+ years of data in the Danish ELMODEL although it is known that other EU markets use longer lifespans.
Especially for Australia the annual cycles showed a big difference, as the number was reported to be 175, compared to all the other regions (with Korea set to an average). It was therefore chosen to use an average of 215 for Australia as well.

Standby is generally neglected in the calculations, but is for simplicity included for Australia and EU-27, since it is a part of the energy class definitions.

_General amendments in the analysis:_

Sales data missing in the historic period are estimated through simple linear extrapolation. Sales distributions are transferred from Australia and/or EU-27. Sales not specified are, when a stock is specified, calculated as:

\[
Sales_{y+1} = Stock_{y+1} - Stock_y + 0.1 \times Stock_y
\]

where \( y \) is any given year. The factor 0.1 comes from the assumed 10 year lifespan, which on average leads to a replacement rate of 10% of the stock every year. In the long run the derived stock from this equation fits the specified stock. _Note that this approximation is only for establishing an input time series for the sales. After that, i.e. in the model, the stock calculations are based on a normal distribution assumption for the lifespan._

If not even the stock is specified, the sales are estimated through transfer from similar regions (e.g. Canada and USA are considered similar) with a housing stock scaling.

_Country-specific actions in the analysis:_

A number of country/region-specific actions were required to undertake the analysis. Below is a detailed explanation of these for Australia followed by the key actions for the other regions included.

_Case study of assumptions and actions for Australian data:_

The data processing for Australia provides a typical example of the work done. First the energy class (midpoint) values (Wh/cycle/place setting) had to be established, since this is only specified as a formula for the Star Rating Index (SRI):

\[
SRI = 1 + \log(\text{CEC}/\text{BEC}) / \log (1 - 0.3)
\]

where:

<table>
<thead>
<tr>
<th>Metric</th>
<th>Assumption</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>CEC: average Projects Annual Energy Consumption (PAEC) of the typical unit in a given SRI rating</td>
<td>4</td>
<td>W (off mode 5 years avg)</td>
</tr>
<tr>
<td>Standby (used in PAEC calculation)</td>
<td>600</td>
<td>kWh/y (i.e. RC x 8)</td>
</tr>
<tr>
<td>BEC is the Base Energy Consumption</td>
<td>12.5</td>
<td>Average size over last 10 years</td>
</tr>
</tbody>
</table>

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A table for the SRI going from 1 to 6 can then be established, isolating the BEC, and applying 365 cycles per year:

<table>
<thead>
<tr>
<th>SRI</th>
<th>Cycle consumption Limit</th>
<th>Avg for class kWh/Cycle</th>
<th>Avg for Class Wh/Cycle/RC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>1.433324</td>
<td>10th</td>
<td>1.4</td>
</tr>
<tr>
<td>2</td>
<td>1.319944</td>
<td>9th</td>
<td>1.3</td>
</tr>
<tr>
<td>2.5</td>
<td>1.215013</td>
<td>8th</td>
<td>1.2</td>
</tr>
<tr>
<td>3</td>
<td>1.117903</td>
<td>7th</td>
<td>1.1</td>
</tr>
<tr>
<td>3.5</td>
<td>1.02803</td>
<td>6th</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>0.944855</td>
<td>5th</td>
<td>0.93</td>
</tr>
<tr>
<td>4.5</td>
<td>0.867878</td>
<td>4th</td>
<td>0.85</td>
</tr>
<tr>
<td>5</td>
<td>0.796639</td>
<td>3rd</td>
<td>0.78</td>
</tr>
<tr>
<td>5.5</td>
<td>0.730709</td>
<td>2nd</td>
<td>0.72</td>
</tr>
<tr>
<td>6</td>
<td>0.669693</td>
<td>1st</td>
<td>0.65</td>
</tr>
</tbody>
</table>

i.e. the most efficient group uses 52 Wh/Cycle/Rated capacity, the 6th 80 Wh and the 10th 112 Wh/Cycle/RC. We assume sales weighted class midpoint close to limits, according to general Mapping and Benchmarking finding for how the manufacturers design their products.

The sales where specified through the stock, using the above mentioned method (blue figures are estimates):

The sales distribution was actually specified for most years, the rest is extrapolated. Using the absolute sales figures, this distribution was found:

GDP: static increase corresponding to circa 2% in 2012. This is close to the development in household stock.
Key assumptions for Canada:

There is no data on the distribution of sales by energy efficiency class in Canada. An average percentage distribution across the six efficiency classes is calculated from EU-27 and Australian distributions. The efficiency averages in Wh/ps/cycle for the six classes are set so that the weighted average corresponds to Product Weighted Average from the input data.

Rated Capacity is not specified, US data is used.

<table>
<thead>
<tr>
<th></th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>A+++ % of sales</td>
<td>10.9</td>
<td>11.1</td>
<td>11.4</td>
<td>11.7</td>
</tr>
</tbody>
</table>

The number of annual wash cycles is taken from the USA Technical Support Document54.

Key assumptions for the Republic of Korea:

Some sales distribution data is specified and also total sales from KEMCO (Korean Energy Management Corporation). Number of households is given, and the rest is transferred from Australia. Annual washes is a population weighted average of other markets.

Key assumptions for Switzerland:

Most data given, including the sales distribution. This has been modified though, since more energy label classes have emerged in the meantime, i.e. the A++, A+ and A categories. Therefore the top three energy classes are assumed to have no sales:

<table>
<thead>
<tr>
<th></th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>A+++ % of sales</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>A++ % of sales</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>A+ % of sales</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>A % of sales</td>
<td>88.6%</td>
<td>88.8%</td>
<td>93.3%</td>
<td>95.3%</td>
<td>97.0%</td>
<td>98.7%</td>
<td>98.9%</td>
<td>99.7%</td>
<td>99.7%</td>
</tr>
<tr>
<td>A Typical energy performance (UEE)</td>
<td>8.9%</td>
<td>8.9%</td>
<td>8.9%</td>
<td>8.9%</td>
<td>8.8%</td>
<td>8.8%</td>
<td>8.7%</td>
<td>8.6%</td>
<td></td>
</tr>
<tr>
<td>B % of sales</td>
<td>7.0%</td>
<td>5.1%</td>
<td>2.3%</td>
<td>1.9%</td>
<td>1.3%</td>
<td>0.9%</td>
<td>1.1%</td>
<td>0.3%</td>
<td>0.3%</td>
</tr>
<tr>
<td>B Typical energy performance (UEE)</td>
<td>10.5%</td>
<td>10.6%</td>
<td>11.2%</td>
<td>11.2%</td>
<td>11.2%</td>
<td>12.0%</td>
<td>9.8%</td>
<td>9.8%</td>
<td></td>
</tr>
<tr>
<td>C % of sales</td>
<td>3.8%</td>
<td>3.8%</td>
<td>3.4%</td>
<td>2.0%</td>
<td>0.8%</td>
<td>0.5%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>C Typical energy performance (UEE)</td>
<td>13.2%</td>
<td>13.1%</td>
<td>13.0%</td>
<td>14.2%</td>
<td>15.5%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Key assumptions for the USA:

No sales or distributions are specified – here we transfer from the assumed sales distribution for Canada (described above), scaling with housing stock. As with Canada, the number of annual wash cycles is taken from the USA Technical Support Document 54.

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54 http://www.regulations.gov/#/documentDetail;D=EERE-2011-BT-STD-0060-0007
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Annex 8 Results graphs with data tables

Figure 1/Figure 17:
Normalised average unit energy consumption for new dishwashers 1996-2012.

Figure 2/Figure 20: Comparing the UEC of the average product available to that of the average product purchased in Australia.
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Figure 3/Figure 22: Average capacity of dishwashers 1996-2012.

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

Figure 4/Figure 28b: Energy performance of UK dishwashers by capacity.

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**Figure 5/Figure 32: The impact of MEPS and labelling regulations on the average EEI of standard size dishwashers in the EU.**

**Figure 16: Declared average unit energy consumption for new dishwashers 1996-2012.**
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Figure 18: Estimate of the factors contributing to larger UEC values in Canada compared with the UK.

Figure 19: Declared Product Weighted Average unit energy consumption for new Australian dishwashers by capacity 2001 and 2008-2010.

<table>
<thead>
<tr>
<th>Year</th>
<th>2001</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-7</td>
<td>0.52</td>
<td>0.45</td>
<td>0.46</td>
<td>0.43</td>
</tr>
<tr>
<td>8-9</td>
<td>1.02</td>
<td>0.97</td>
<td>0.96</td>
<td>0.83</td>
</tr>
<tr>
<td>10-11</td>
<td>1.05</td>
<td>0.95</td>
<td>0.91</td>
<td>0.91</td>
</tr>
<tr>
<td>12-13</td>
<td>0.71</td>
<td>0.81</td>
<td>0.98</td>
<td>0.92</td>
</tr>
<tr>
<td>14-15</td>
<td>1.26</td>
<td>1.02</td>
<td>0.92</td>
<td>0.89</td>
</tr>
</tbody>
</table>
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Figure 21: Normalised Product Weighted Average Unit Energy Consumption.

Figure 26: Normalised average Unit Energy Efficiency of new dishwashers.
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**Figure 27:** Normalised average Unit Energy Efficiency Index of new dishwashers 1996-2012.

**Figure 28a:** Energy performance of UK dishwashers by capacity.

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**Figure 29: Declared Unit Energy Consumption of USA dishwashers by capacity.**

**Figure 30: Average water consumption for new dishwashers 1996-2012.**
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Figure 31: Average programme cycle time;

![Image of graph showing average programme cycle time for countries over time]

Figure 34: Percentage of models on sale in the UK by label class.

![Image of bar chart showing percentage of products by label category over years]