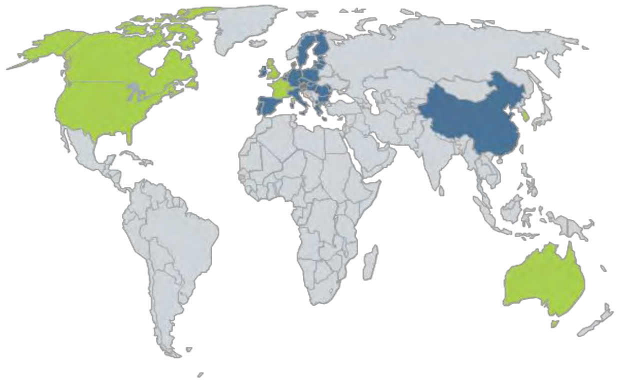
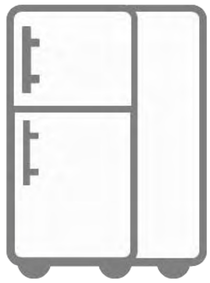
Technology: Domestic Cold Appliances
Freezers and Refrigerator/ Freezers Combinations





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

Other Regions covered:
China, EU

Other Funding countries:
Netherlands

Benchmarking of Domestic Cold Appliances

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

Summary For Policy Makers

This benchmarking has been undertaken as part of the IEA's Mapping and Benchmarking Annex of the Efficient End-Use Electrical Equipment Implementing Agreement. It has been undertaken to provide policy makers with comparisons of the performance of new and installed Domestic Cold Appliances over time and is designed to provide policy makers with a broad analysis of:

- Key differences between countries
- Key areas of concern for policy makers, including areas where policy intervention may be required
- Key outcomes of policy interventions to date

This Benchmarking addresses Domestic Cold Appliances. Refrigerator-Freezer combinations and Freezer only units have been selected by participant countries as representative sub-categories of the Domestic Cold Appliance market and it is these products that have been investigated.

Analysis is based on the best information that could be obtained and consequently, the majority of the Benchmarking is based on information supplied by Australia, Canada, China, the EU, Republic of Korea, the UK and the USA, with limited additional information included on Austria, Denmark and Switzerland. Insufficient or no data was available from other countries at the time this analysis was undertaken.

Considerable efforts have been taken to ensure the integrity of the data supplied and the subsequent data manipulation and analysis. However, the data collection, processing and analysis has required a number of compromises to be made and these should be borne in mind when interpreting the following analysis. The specific approaches adopted are detailed in the overall Mapping and Benchmarking Framework[1], the Cold Appliance Product Definition[2,] in the individual Country Mapping Sheets[3] and, where necessary, within this Benchmarking document.

Observations

- Differences in refrigerator/freezer combination unit energy consumption between individual products in various countries are relatively small with all countries appearing to move toward a plateau of normalised new product energy consumption of 350-400kWh/year (with the exception of China where unit consumptions are significantly lower). However, this difference is smaller than expected given the large variations in product volumes between countries (up to 70% difference in average sizes in 2007). The consumption of freezer only units continues to fall albeit more slowly with units within a band of 270–370kWh/year. Canada is a unique outlier with

[1] See to Annex framework at http://mappingandbenchmarking.iea-4e.org/
[2] See to detailed product definition at http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=1
[3] See individual country mappings at http://mappingandbenchmarking.iea-4e.org/matrix

freezer consumption 25% greater than the lowest consumption elsewhere, although Canadian volumes average twice that of other areas.

- Energy efficiency has been improving in almost all regions over the periods data is available (for both combination and freezer only units). Although rates of improvement vary significantly between countries, as is to be expected, those with the worst initial efficiencies are improving most rapidly.

- For refrigerator/freezer combination units it appears a significant proportion of the improvement in efficiency may be due to the rapid increase in volume of products (efficiency improves with greater volume), although this is less so for freezer only units. As a consequence, actual refrigerator/freezer product performance may be improving more slowly than it appears. However, there is still considerable opportunity for improvement (reduction in consumption) in those countries where product volumes are smaller than average simply to align with the performance efficiencies achieved by similar smaller products already on the market in other countries. Further, significant opportunities appear to exist in all markets through the re-examination of the Energy Efficiency indices (used to institute policy measures, particularly MEPS and Labelling) to capitalise on differences in efficiencies of units at various volumes in the differing global markets.

- It is not possible to differentiate the impact of mandatory labelling from that of Minimum Energy Performance Standards (MEPS) as all countries reporting sufficient data for analysis have both policy measures.

- The markets where mandatory labelling and/or MEPS were introduced earlier and/or are revised regularly (Canada, Korea and the USA) tend to be those markets with the better performing products. However, as similar measures have been introduced in the remaining countries (Australia and the UK), efficiencies are rapidly improving and are beginning to approach the better performers (Australia's efficiencies are approaching the "norm" more quickly, possibly because their policies appear to be reviewed more regularly).

- Even immediately after the implementation of MEPS, some new products on the market are typically 50% more efficient than the *average* product for sale and even more so than the least efficient. This appears to offer the potential for the imposition of much more aggressive MEPS to overcome the apparent plateauing of improvement in new product energy consumption at a time when the total number of products installed is increasing in all markets.

- The change in total consumption of stock (products already installed in households) is variable between countries with reported changes in consumption ranging from continual increase through to rapid decrease. However, in a number of cases, there are apparent contradictions between the product consumption of new products and those in the stock, i.e. the products in the stock appear to have consumptions that are lower than may have been expected based on available knowledge of new product sales over an extended period[4].

- The explosive growth in ownership levels in China is more than outweighing any overall energy/efficiency gains made elsewhere (despite rapid improvement in the performance of Chinese products).For refrigerator/freezer combination units in 2006, Chinese consumption was already at 60% of the combined consumption of Canada, Denmark, France, Korea and the UK. However, since that point, Chinese consumption has risen by over 35% and is likely to have surpassed the combined consumption of these nations. However, Chinese ownership levels are still less than one appliance in every 4 households so consumption will almost certainly continue to grow rapidly and for an extended period even with strong policy intervention.

Policy Recommendations

- As new product consumptions are beginning to plateau after a long period of reducing in most countries, without strong policy intervention to drive down new product consumption the overall energy consumption of stock will begin to rise more rapidly if marginal improvements in consumption are outweighed by growth in households and/or second appliance ownership.

- The combination of MEPS and Mandatory Labelling appear to have maximum market impact provided they are reviewed frequently.

  In general, product efficiency is inherently improved as volumes increase. Thus, the use of energy efficiency as the sole metric for policy development and evaluation may be misleading and may actually lead to perverse outcomes if products are increased in volume (and potentially consumption) simply to improve apparent efficiency. As the control of volume growth is likely not to be possible, policy makers should consider the development of policy based on consumption caps (and consequently efficiency caps).

- If current stock models are correct, then for some countries programmes designed to accelerate replacement of older products (which have traditionally been assumed to have much higher consumption) may not be appropriate as they will yield marginal improvement in efficiency/lower consumption.

- There appears to be value in investigating the robustness of current modelling information on the efficiency and consumption of products within the stock to confirm their robustness as a basis for policy making and evaluation.

[4] Note that such apparent contradictions may be accounted for through local modelling assumptions on usage patterns, operational conditions, etc.

- Given the explosive growth in product ownership in China, and the huge ongoing potential for continued growth before the market begins to approach saturation, any technical or policy support that can be offered in managing this growth in demand would yield very high returns. Therefore, policy makers outside of China may wish to consider the value of redirecting some of their resources which are currently focusing on their domestic markets towards supporting the China government in actions being undertaken to manage demand.
- Readers should be aware that alternative correction factors have been proposed for the normalisation of testing temperatures between countries/regions. While the vast majority of the analysis presented is applicable to both the conversion factors used and the alternative conversion factors, the alternative correction factors lead to results that differ from those presented in this report.

Section 1: Introductions and Cautions

1.1 Introduction

This benchmarking has been undertaken as part of the IEA's Mapping and Benchmarking Annex of the Efficient End-Use Electrical Equipment Implementing Agreement. It has been undertaken to provide policy makers with comparisons of the performance of new and installed cold appliances over time and is designed to provide policy makers with a broad analysis of:

- Key differences between countries
- Key outcomes of policy interventions to date
- Key areas of concern for policy makers, including areas where policy intervention may be required in the future

This Benchmarking addresses Domestic Cold Appliances. Refrigerator-Freezer combinations and Freezer only units have been selected by participant countries as representative sub-categories of the cold appliance market and it is these products that have been investigated[5].

Data was sought from all countries participating in the Annex and a number of additional countries/geographical areas. Information was sought for the periods 1996-2009 relating to product efficiency, product consumption, product sizes, etc[5]. For individual countries and regions, information obtained was mapped in a consistent format and presented to show:

- The energy efficiency and energy consumption of new products sold within individual markets
- Changes in products within the stock (products in use in households) over the period
- Policies that are thought to have influenced the performance of new products and stock
- Cultural issues that may have influenced product selection within individual countries

Please refer to the Mapping and Benchmarking Annex website to review individual country/region mappings[6].

Significant efforts have been made by all participating parties to obtain and process data from a range of sources. However, inevitably there have been some difficulties sourcing information for all countries/regions, and indeed in sourcing all information from individual countries/regions even where this information exists. Thus, this benchmarking analysis is based on the best information that could be obtained and included in the individual country/region mapping sheets as outlined above. Consequently, the majority of the Benchmarking is based on information supplied by Australia, Canada, China, the EU, the Republic of Korea, the UK and the USA, with limited additional information included on

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[5] See detailed product definition and data request at http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=1
[6] See individual country mappings at http://mappingandbenchmarking.iea-4e.org/matrix

Austria, Denmark, France and Switzerland. Insufficient data was available from Japan at the time this analysis was undertaken.

1.2 Important Cautions for Interpreting and Using Mapping and Benchmarking Information

(Editing note to readers – the categorisation of data and transformations into robust, indicative and illustrative "quality" remains unchanged since the previous issue pending the outcome of the Mapping and Benchmarking Management Committee's decision on revised proposals)

Considerable efforts have been taken to ensure the integrity of the data supplied and the subsequent data manipulation and analysis. However, the aim of the Mapping and Benchmarking Annex is, within a limited set of resources, to provide policy makers with high level information to facilitate strategic decision making and/or to enable them to target further resources to investigate specific areas of interest. As such the data collection, processing and analysis has required a number of compromises to be made and these should be borne in mind when interpreting the following analysis. The specific approaches adopted are detailed in the overall Mapping and Benchmarking Framework[7], the Cold Appliance Product Definition[8,] in the individual Country Mapping Sheets[9] and, where necessary, within this Benchmarking document.

However, it has not proved possible to provide a statistical analysis of the impact of variations in specific data sets and the associated outcomes. Therefore any inference made from the original data and associated analysis should be treated with caution. In order to provide as much transparency as possible, the analysis (and especially graphics) presented within this benchmarking are divided into three categories:

> ***Robust* – comparisons where it is believed the data sources and transformations are robust and the comparisons are as reliable as possible within boundaries outlined above**
>
> ***Indicative* – where data sets are not strictly comparable, or where the data manipulation used is less reliable, or where data has been supplied as market averages rather than on a product level basis, but where there is a degree of confidence that the data is sufficiently comparable to derive useful lessons**
>
> ***Illustrative* – where data sets are not comparable (and/or where it has not been possible to derive the methodologies used prior to provision of data and thus form an opinion on the comparability with other data), but where the provision of the data may give at least limited insight into the comparable functionings of the various markets.**

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[7] See to Annex framework at http://mappingandbenchmarking.iea-4e.org/
[8] See to detailed product definition at http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=1
[9] See individual country mappings at http://mappingandbenchmarking.iea-4e.org/matrix

In general, readers should be aware of the following:

1) Data and other information has been supplied by participating countries and obtained from other secondary sources. In the majority of cases it appears this data is of high quality. However, in a few cases it has not been possible to verify with certainty the complete accuracy of the material supplied (all sources of data are included in the original country Mappings[5] or are noted here in the analysis). Particular caution should be taken when considering:

- Product consumption, efficiency and volume data (plus a number of other criteria) have been supplied on an individual product level basis by Australia, Canada, the Republic of Korea, the UK and the USA (for EnergyStar qualified products). Information from China and the EU is supplied only on market averages. There are inherent statistical differences in comparing product level and market level averages, particularly where normalisation is required. As such, the market level averages are considered to be indicative at best.
- Chinese data is based on declared data submitted to and recorded on the Chinese Government's Labelling Data base and is considered robust. However, it has not been possible to access this data at a product level and therefore all data reported is based on averages supplied for each information category. That said, as all reported data is based on the same testing methodology as the EU (to which normalisation is taking place), it has not been necessary to normalise this data and therefore most supplied information is considered at least indicative in nature[10].
- EU data is reported as market averages only and for a selected number of countries (Austria, Belgium, Germany, Spain, France, UK, Italy, Netherlands, Portugal, Sweden, Czech Republic, Hungary, Poland, Slovakia. Data earlier in the time series (2000-2004) is based on smaller proportions of the market and has been treated as less reliable. Further, for freezers only, data before 2005 excludes "eastern" European countries (ie excluding, Czech Republic, Hungary, Poland and Slovakia). Thus, data before 2004 is treated as illustrative only, and data from 2004 (2005 for freezer only units) is considered indicative and representative of the majority of the EU[11].
- Almost all Austrian data is sourced via the ODYSSEE project. However, as the *originating* source and associated transformations are not entirely transparent, all Austrian data is presented as illustrative only.
- French product based data is only for "TOPTEN" and thus presents only the best ten products and the single worst product in the market for a particular year. As this is

[10] The source of Chinese data is the national registration database for labelled products (labelling of cold appliances has been mandatory for all years reported). However, this data was reported as market averages only rather than at the individual product level. Therefore, local adjustments for products (eg corrections for auto defrost units) could not be removed from the data, hence the categorisation of data reliability at indicative. The *maximum* impact of the correct factors could be upto a 20% improvement in reported consumption and associated efficiency figures, but the actual value is expected to be well below 10% across the market.
[11] Similar to the Chinese data above, EU data has only been reported as market averages and has therefore been treated at indicative from 2004 onward, and illustrative for the preceding period.

not representative of the market, or a specific market subset, no French data is included in this benchmarking.

- Information on products in the Republic of Korea between 1997-2005 is based only on new product registrations in the year reported (ie excludes previous years). As a consequence, it is likely not to be representative of the overall market (information before 2001 is also based on very small data sets and should be treated with additional caution). Information on 2006 and later is believed to be reflective of the market.
- With the exception of shipment weighted new product energy consumption, information from the USA is based on products which have achieved Energy Star registration. Such products represent only selected products on the market that perform significantly better than the minimum standard in place in the USA. On average they are thought to represent no more than 30% of the market at any one time. The sales weighted data supplied is “shipped” and may not include import/export balances. Therefore all data from the USA is treated as illustrative.
- The conversions necessary to adjust for temperatures differences under test conditions will tend to have the effect of underreporting energy consumption and over-reporting efficiencies for the USA and Canada[12].
- Information on stock (products already in use) is almost always drawn from modelling data used within the country concerned. However, such models contain differing assumptions on usage patterns and product ages, sometimes from surveyed data and sometimes assumed. It has been impossible to disaggregate these stock models and therefore information is presented as supplied.

Further, *as a general statement*, information in more recent years is considered to be of higher integrity.

2) Products have been considered based on functionality, ie they perform the same basic function of cooling or freezing the relevant compartment contents. Thus:

- Refrigerator/freezer combination products with freezers above, below and to the side of the refrigerator units have been considered together.
- Freezer units that are upright and chest have been considered together.

However, the various configurations of units have some inherent differences in energy consumption/efficiency and the relative and absolute volumes of the various compartments vary considerably. As the proportion of the individual product configurations vary by country, this has an effect on the apparent relative performance of products between countries. As a general statement, markets with average larger net compartment volumes should typically report lower average consumptions per unit volume than those with comparably smaller net compartment volumes.

[12] In both Canada and the USA products may be tested to two alternative compartment temperatures. As the specific test temperatures used are not required to be reported, the most extreme alternative of both tests is assumed in benchmarking which will tend to lead to underreporting of the average consumptions/efficiencies of units from these markets.

3) The appliances being Mapped and Benchmarked are tested differently in various parts of the world and they are grouped/recorded differently depending on local regulations and practices. In many cases this has required one or more of the following to occur:

- Product groups have been aggregated where their performance is not identical, eg fridge/freezer combination units with the freezer above, below and to the side of the refrigerator unit
- Some supplied data has been excluded from the analysis as it does not contain sufficient information to be processed at all or in a way that aligns with data supplied from other sources
- Efficiencies are based on energy consumption per year divided by adjusted volumes only[13]. Energy Efficiency Indices (EEIs) have not been used due to the complexity in aligning the various product groupings used in different markets (see section 2.1.1).
- Correction factors have been applied to allow comparison of products sold in different markets with differing test regimes (e.g. a correction factor is applied to allow benchmarking of products tested with different internal and external temperatures). Where such correction factors have been applied, the resulting data is referred to as “normalised” in this document. Where “normalised” is not used, the data referred to is the original data *as declared* under each country’s local regulations.

Terminology and Correction Factors used in this benchmarking document are provided in Annex 1.

Readers should be aware that alternative correction factors have been proposed for the normalisation of testing temperatures between countries/regions. These alternative correction factors lead to results that differ from those presented in this report. While the vast majority of the analysis presented is applicable to both the conversion factors used and the alternative conversion factors, to ensure transparency, graphics demonstrating the comparative impact of the alternative conversions factors are included in Annex 4.

[13] See to detailed product definition at http://mappingandbenchmarking.iea-4e.org/matrix?type=product&id=1

Section 2: New Product Consumptions and Efficiencies

2.1 Observations

2.1.1 Energy Consumption – Refrigerator/Freezer Combinations

Initially examining the most robust data available, normalised product weighted[14] energy consumption of individual new products is falling in all markets[15] (see Figure 1a). Over the range of periods in which robust data/analysis is available, the average improvement in unit consumption has been 3.6% per annum. Even given the various starting dates for available data[16] and the wide variations in consumption in the first year reported[17], the net effect of these improvements is that normalised consumptions per product appear to be converging towards the 350-400kWh/year range in almost all countries. This trend is reflected even more strongly with the addition of the slightly less reliable indicative data (see Figure 1b). However, caution must be exercised. Such a convergence of consumptions **does not** equate to new products being equally efficient because there are significant differences in the average

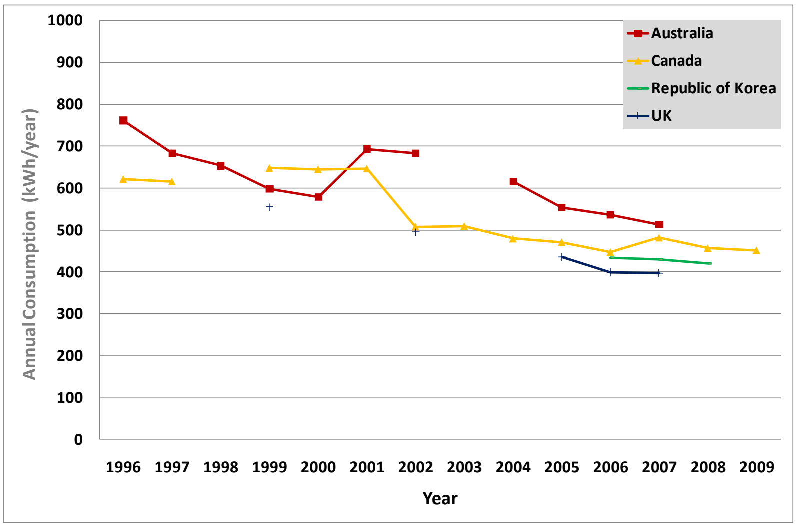

Figure 1a: Robust Normalised New Product Weighted Energy Consumption (kWh/year - See Annex 2 Figure 1a)

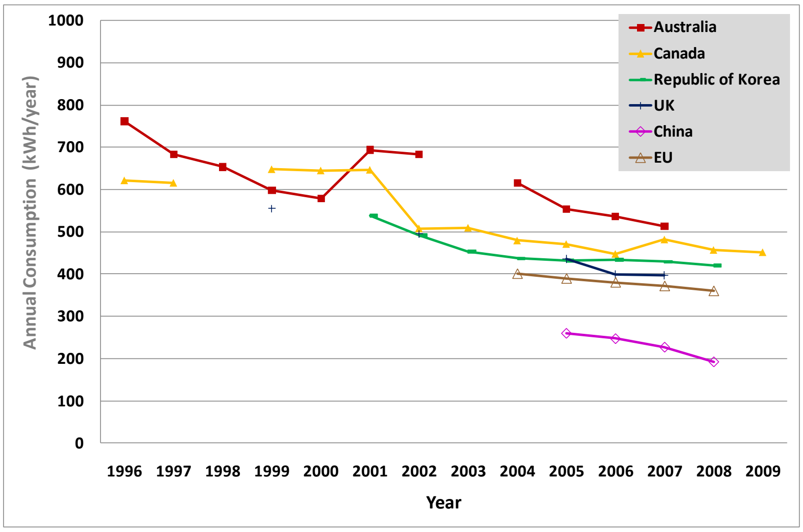

Figure 1b: Indicative Normalised New Product Weighted Energy Consumption (kWh/year - See Annex 2 Figure 1b)

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[14] Product weighted average consumptions are used as these are reported by the majority of countries and could be normalised.

[15] The major anomaly to this statement is the Australia rise in consumption in 2001. However, this sudden increase in apparent consumption is almost entirely due to a realignment in the local regulations that caused in the inclusion of a number of product types not previously addressed.

[16] The range of dates where robust data becomes available is best illustrated by example. Robust Australian and Canadian data is available from 1996 onwards, while robust data for Korea spans only the 2006-8 period)

[17] Earliest robust consumption data ranges from 762kWh/year in Australia in 1996, to 401kWh/year in the EU in 2004)

product volumes (see section 2.1.3).

The stark exception to the above analysis is the product performance report by China. Rather than tending towards the 350-400kWh normalised annual consumption range, products in China have normalised annual consumption that has fallen from 260-193kWh in the limited period that data is available (2005-2008). This low comparative unit consumption is despite China introducing MEPS for cold appliances in 1999 (with an effective data of 2004) and mandatory labelling of cold appliances in 2005, both later than most other countries reported. At the time of analysis, the reason for this remarkable difference in performance of Chinese units compared with other countries is not clear. Although at least part of the disparity may be caused by correction factors in the Chinese energy consumption algorithm[18], this is believed to have a relatively minimal impact in the context of the almost halving of comparative annual energy consumption (the impact is an absolute *maximum of 20%* but is thought to be less than 10% under reporting of consumption).

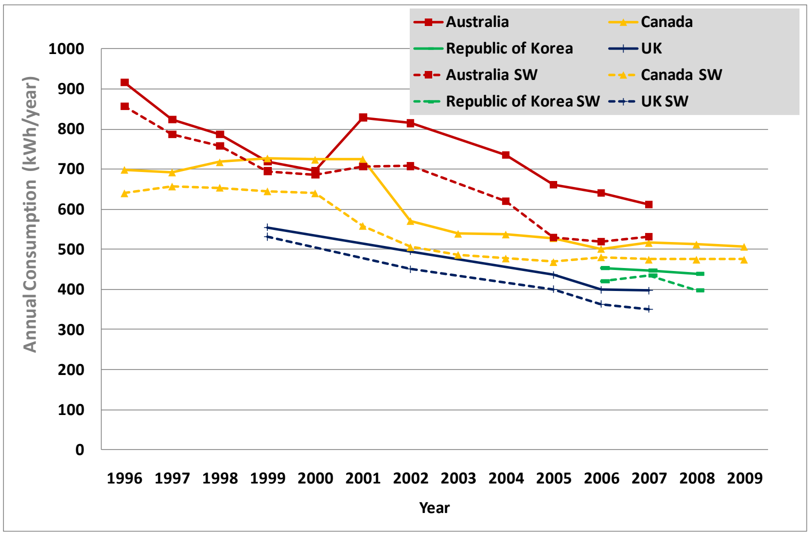

Figure 2: Indicative Declared New Product Sales Weighted (SW) and Product Weighted Energy Consumption (kWh/year - See Annex 2 Figure 2)

It is worth noting that for the majority of countries/regions where data is available (Australia, Canada, Korea and the UK) declared sales weighted average energy consumptions are 10% below their product weighted equivalents, ie consumers are purchasing products that consume 10% less energy than the energy consumption of the average product on the market[19] (see Figure 2). This general apparent consumer preference for units of higher efficiency relative to the average of those on sale may be due to:

- Active purchase of higher efficiency units, or
- Selecting products of smaller units than average size unit on sale (and hence lower consumption)

Unfortunately, from the data available it is not possible to establish which is the cause, although it is likely to be a combination of the two factors.

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[18] Chinese data was reported as market averages only rather than at the individual product level. Therefore, local adjustments for products (eg corrections for auto defrost units) could not be removed from the data. The *maximum* impact of the correct factors could be upto a 20% improvement in reported consumption and associated efficiency figures, but the actual value is expected to be well below 10% across the market.

[19] The exception is the EU as a whole where the sales weighted average consumption is typically 3% worse than the product weighted average

Relatedly, it is interesting to note that premium product endorsement labels are present in Canada and the UK (Energy Star and EST Recommended respectively), but not in Australia, Korea or the EU (all countries have information labels). Thus, at first sight, endorsement labels *appear* to have little impact on the overall consumer selection. However, such impact may be present but masked by a preference for smaller units in markets without endorsement labels compared with markets where an endorsement label is present. This hypothesis is somewhat supported by the data with Canadian *declared* sales weighted average efficiencies are 16% more efficient than product weighted averages while in Korea (for the three years where data is available), *declared* sales weighted average efficiencies are 35% less efficient than *declared* product weighted averages. However, in the UK the sales weighted and product weighted efficiencies are similar *while* sales weighted consumption is significantly lower that product weighted consumption. This implies the effect in the UK is mainly a preference purchase of larger, rather than more efficient, units.

2.1.2 Energy Consumption –Freezer only

Initially examining the most robust data available, normalised product weighted[20] energy consumption of freezer only units is falling in all markets (see Figure 3a). This trend is reflected with the addition of the slightly less reliable indicative data (see Figure 3b)[21] with average overall consumptions falling at around 3.4% per year (China and Korea significantly exceed this Figure with average annual unit consumption falling by 6.0% and 4.4% respectively, while Canada's average annual unit consumption falls by only 0.2% per year)[22].

However, in slight contrast to the refrigerator/ freezer combination units, the overall unit energy consumptions between countries is still converging, but more slowly and towards a

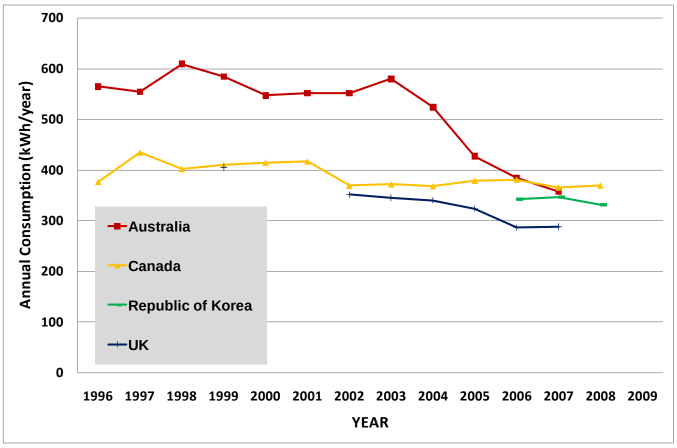

Figure 3a: Robust Normalised New Product Weighted Energy Consumption (kWh/year - See Annex 3 Figure 3a)

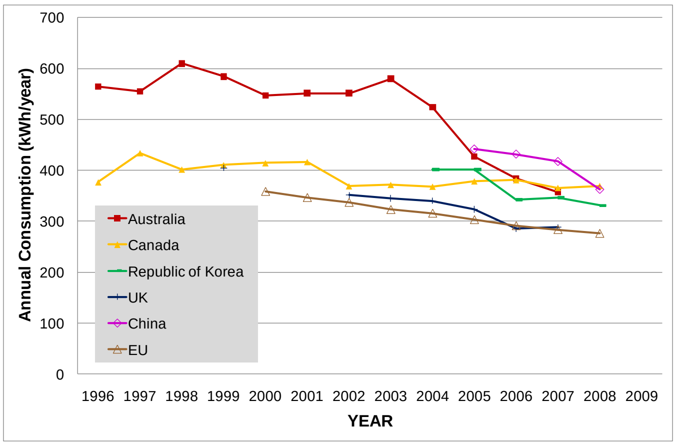

Figure 3b: Indicative Normalised New Product Weighted Energy Consumption (kWh/year - See Annex 3 Figure 3b)

[20] Product weighted average consumptions are used as these are reported by the majority of countries and could be normalised.
[21] Note that the exceptions to this statement are Canada and the USA. In Canada, for the period 1996-2008, normalised unit energy consumption falls by only 1.9% over the entire period (an average of only 0.15% per year). In the USA, Illustrative Energy Star data shows a marked increase in normalised product weighted unit energy consumption of over 15% between 2004 and 2009. Normalised full market data for the USA implies a broadly fixed unit energy consumption throughout the period reported (1996-2008). However, this USA full market data is shipment weighted (broadly equivalent to sales weighted) where other data referenced in this section is product weighted.
[22] It is worth noting that in absolute terms, the fall in annual unit consumption in Australia has been remarkable, from 549kWh/year in 1996, to 358kWh/year in 2007)

wider band (currently 270–370kWh/year). Again, such a convergence of consumptions **does not** equate to new products being equally efficient. Whilst freezer volumes in most reporting countries are broadly similar, volumes in Canada[23] in 2008 are almost twice that of the average elsewhere (see section 2.1.4) whilst normalised unit energy consumption is only 25% more than the lowest unit energy consumption elsewhere (the EU). This marked difference in unit performance relative to volume is despite unit energy consumption in Canada having remained broadly stable over the entire reporting period while consumptions have been falling elsewhere.

Once again, it is worth noting that for the countries/regions where data is available (Australia, Canada, Korea and the UK) declared sales weighted average energy consumptions are typically 5-10% below their product weighted equivalents, ie consumers are purchasing products that consume 10% less energy than the average product on the market (see Figure 4). However, this general apparent consumer preference for units of higher efficiency relative to the average of those on sale on sale may be due to:

- Active purchase of higher efficiency units, or
- Selecting products of smaller units than average size unit on sale (and hence lower consumption)

Unfortunately, from the data available it is not possible to establish which is the cause, although it is likely to be a combination of the two factors.

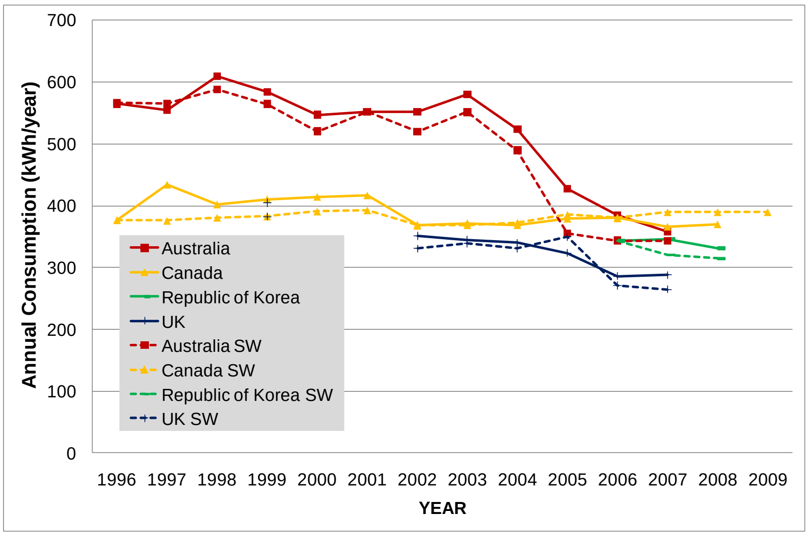

Figure 4: Indicative Normalised New Product Sales Weighted (SW) and Product Weighted Energy Consumption (kWh/year - See Annex 3 Figure 4)

[23] USA Energy Star product volumes are higher still, but as Energy Star represents only a small proportion of the market and are based on unit *efficiency*, it is unclear whether these volumes are representative.

2.1.3 Product Volumes – Refrigerator/Freezer Combinations

The (product weighted) volumes of new products in each country are shown in Figure 5 and Figure 6[24]. As can be seen across all markets (with the exception of China[25]), the total unadjusted combined fridge freezer volume has risen considerably during the periods data is available. In 1999, combined (unadjusted) fresh and frozen volumes in Canada and Korea were more than twice that in the UK, yet in the worst case, the normalised unit energy consumption in Canada is only 16.8% higher than the UK (see above). Similarly, but to a lesser extent, the combined volume in Australia (in 1999) was approximately 29% less than Canada, yet consumption is only marginally better (8.3%), although this may partially be due to the probably under-estimate of normalised Canadian consumption (see above).

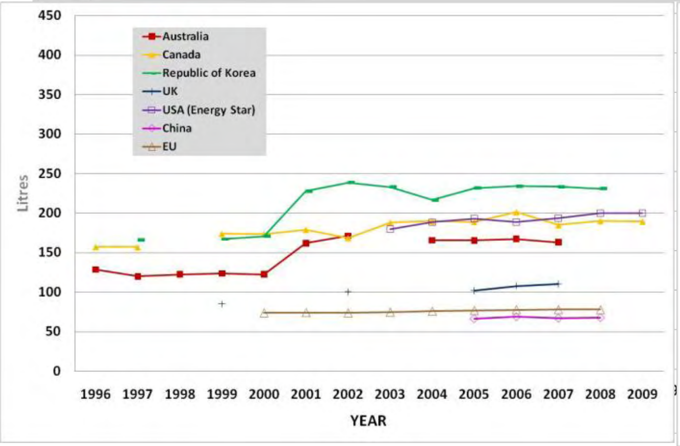

Figure 5: Illustrative Average Unadjusted Frozen Compartment Volume (litres - see Annex 2 Figure 5)

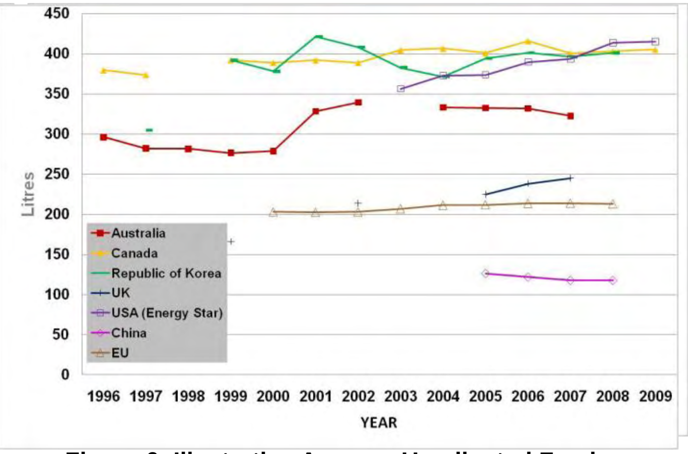

Figure 6: Illustrative Average Unadjusted Fresh Compartment Volume (litres - see Annex 2 Figure 6)

More recently this differential in volumes has decreased, and volumes in all countries other than the UK are appearing to plateau (or even fall in the case of Australia and China). However, the volume differences between countries/regions are still marked given the convergence of product consumptions. This general improvement in consumptions, but disparity in volumes is demonstrated visually in Figure 7 using only Republic of Korea, Australia and the UK as examples.

24 Note that illustrative values are used in these graphics as volume data submitted by the various contributing countries/regions is more reliable in general, and requires less manipulation, and the trends are reflected across robust and indicative data sets.

25 It is speculated that the decrease in total product volumes in China may be due to the rapid penetration of these products in lower income groups. These groups typically have smaller homes and thus volumes may be constrained by available space for installation. However, it must be stressed that it is not possible to confirm this hypothesis with available data.

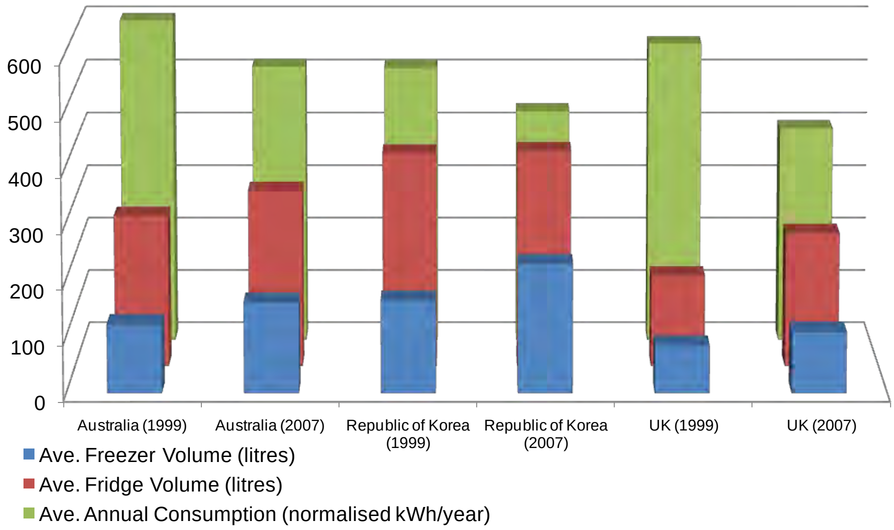

Figure 7: Illustrative Visual Representation of Comparative Volumes and Normalised Energy Consumptions for 1999 and 2007

2.1.4 Product Volumes – Freezers Only

The (product weighted) volumes of freezer products in each country are shown in Figure 8[26]. In significant contrast to the Refrigerator/Freezer combination units, Freezer volumes have remained remarkably stable over the period reported by countries. In fact the average change over all markets (using indicative data) was less than 0.1%. There are variations around this Figure with freezer volumes in the UK and China falling at 1.8% per year (volumes in Australia have fallen 1.2% per year) and Korea where volumes have been rising at an average of 4.1% (volumes in Canada have risen by 0.4% per year). However, as noted in section 2.1.3 (Product Consumption – Freezers only), by 2008 Canadian freezer volumes are approximately twice the average volume elsewhere (excluding the USA), yet normalised unit consumption is only 25% greater than the lowest

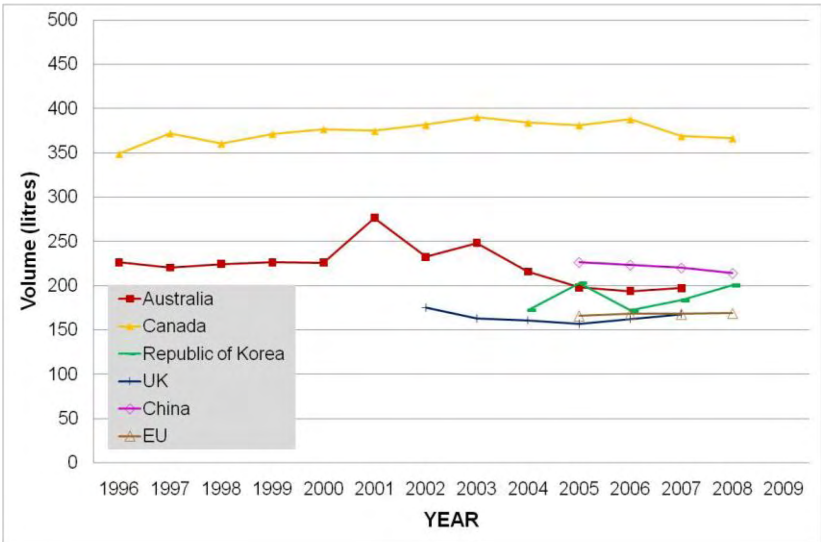

Figure 8: Illustrative Average Unadjusted Frozen Compartment Volume (litres - see Annex 3 Figure 8)

[26] Note that illustrative values are used in this graphics as volume data submitted by the various contributing countries/regions is more reliable in general, and requires less manipulation, and the trends are reflected across robust and indicative data sets.

consumer (the EU). The relative variation in unit consumption and volumes is demonstrated visually in Figure 9 using only Canada, Australia and the UK as examples.

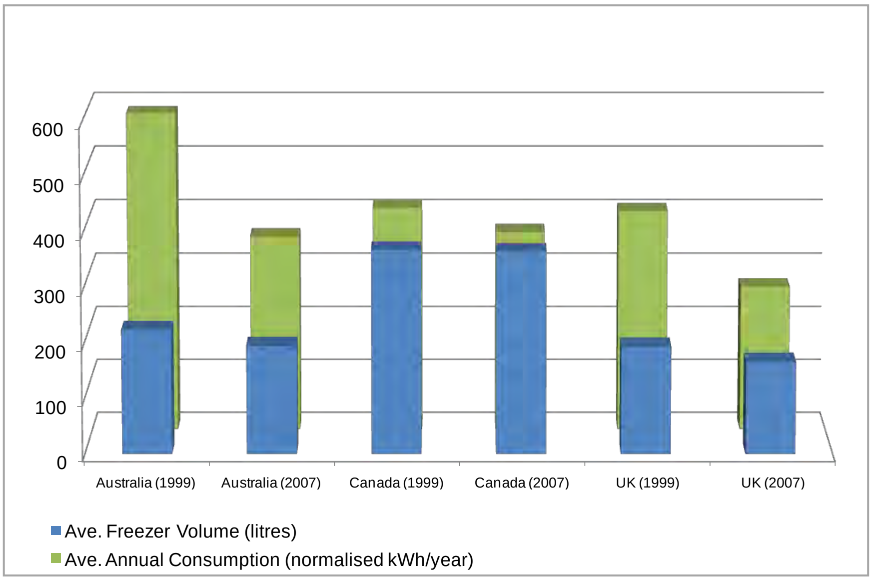

Figure 9: Illustrative Visual Representation of Comparative Volumes and Normalised Energy Consumptions for 1999 and 2007

2.1.5 Energy Efficiency – Refrigerator/Freezer Combination Units

Figure10a shows the country breakdown of (product weighted[27]) new product normalised efficiency, as defined by annual energy consumption per litre of adjusted volume. The graph shows a falling trend with all countries having improvements in energy efficiency as should be expected with falling unit energy consumption. This trend is exacerbated by the rapid increase in volumes in some countries. The UK is a particularly strong example where normalised (product weighted) energy consumption has fallen by 29%, while efficiency has improved by 47% between the years 1999 and 2007. This trend is repeated when indicative data is used to enable the inclusion of more countries/regions (see Figure 10b).

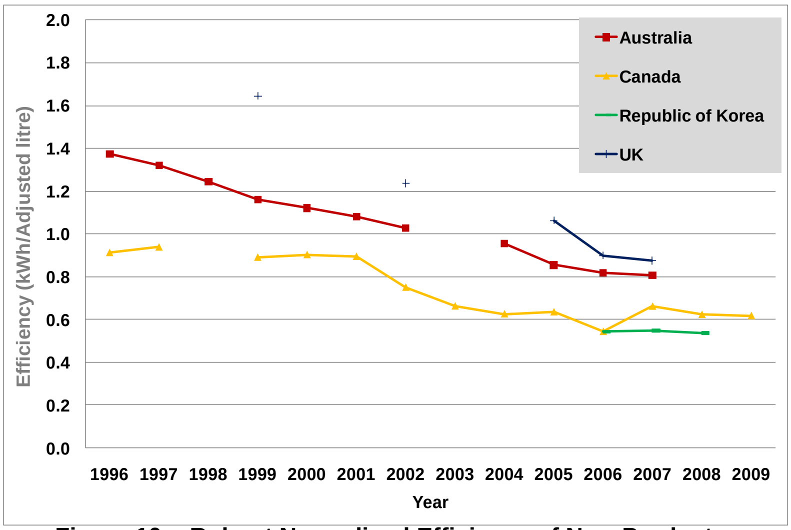

Figure 10a: Robust Normalised Efficiency of New Products (kWh/adjusted volume/year) (See Annex 2 Figure 10a)

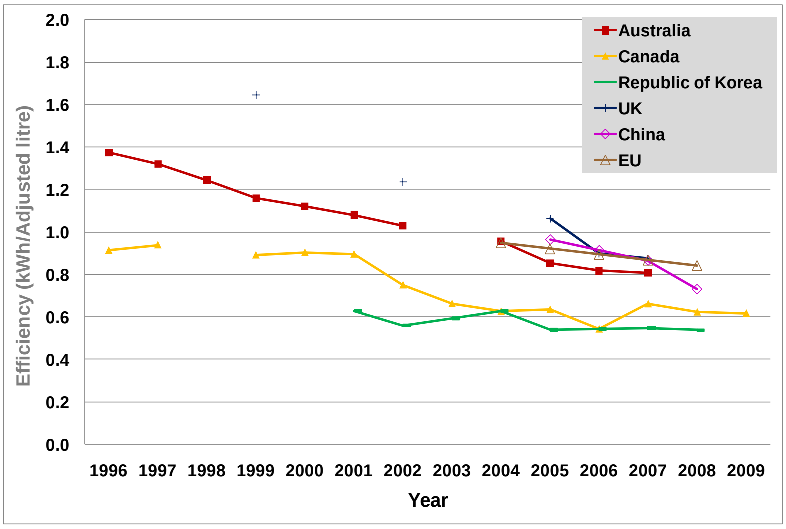

Figure 10b: Indicative Normalised Efficiency of New Products (kWh/adjusted volume/year) (See Annex 2 Figure 10b)

Unfortunately, this analysis has two short comings:

1) **Increasing Volumes:** As is clear from the UK example above, at least some of the efficiency improvement can be attributed to increasing volumes as larger units (typically) have a lower volume to surface area ratio which inherently makes the units more efficient per litre per kWh energy input.

[27] Note that the graphic refers to *normalised* product weighted efficiencies as data available from most countries allowed for normalisation of product weighted efficiencies but not sales weighted efficiencies. However, in Canada *declared* sales weighted average efficiencies are 16% more efficient than product weighted averages while in Korea (for the three years where data is available), *declared* sales weighted average efficiencies are 35% less efficient than *declared* product weighted averages. Therefore, the efficiency of the average product on sale is not necessarily representative of the typical product purchased. See the discussion on sales weighted and product weighted energy consumptions and associated consumer preferences in the Section 2.1.1 above.

2) **Differing Volumes Masking Efficiency Similarities/Differences between Countries/Regions:** The comparisons between countries are average efficiencies at all volumes within the market and thus those countries with larger average volumes *should* give better efficiencies simply due to the larger volumes. However, this does not provide any indication of comparable efficiencies within market subsectors where products are of a similar size.

Attempt to address these issues separately:

1) Unfortunately it is not possible to create a true comparison between countries of improvements in efficiency excluding improvements that are solely due to the increase in volumes[28]. However, it is possible to gain an *indication* of the increased efficiency in each country due to improved product performance *excluding changes in volume* by considering efficiency levels of products over the full time frame, but fixing volumes for each country at their level in 2007 (see Figure 11).

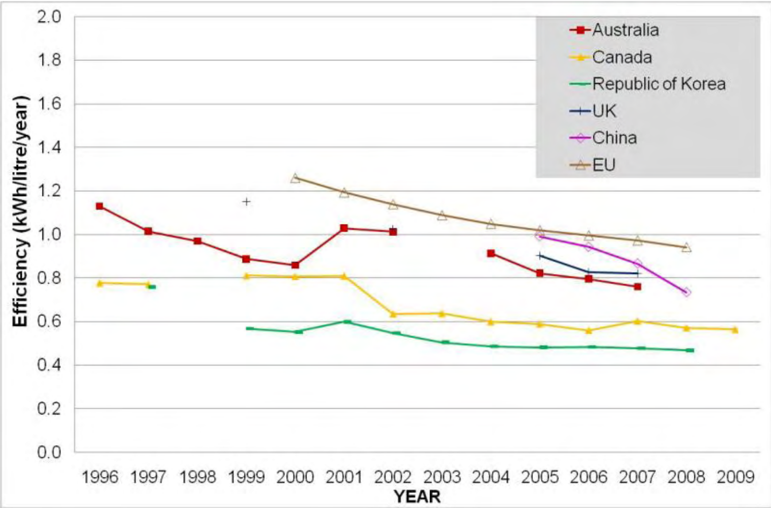

Figure 11: Illustrative Normalised New Product Efficiency (kWh/litre/year) Calculated with 2007 volume for all years (see Annex 2 Figure 11)

Comparing Figure 11[29] with Figure 10b, the speed of improvement in efficiencies is significantly slower (in almost all cases) which *indicates* efficiency gains due to improvements in the product performance are significantly less dramatic than appears solely from viewing product efficiency over time. Hence, using energy efficiency as the sole metric for measuring improvement in the energy performance of products:

a. *May* be misleading if market demand is causing rapid change in product compartment volumes (although in very recent years this is less significant as growth in product volumes in most countries other than the UK appears to be reaching a plateau).

[28] Such a comparison is difficult as the proportions of improvement related to increasing volumes and improved product performance (eg improved insulation, more efficient compressor, etc) vary significantly between different product models and configurations and, as such cannot be disassociated in the data available.

[29] Efficiencies in Figure 12 are based on average product weighted volumes and consumptions for the entire market for each country. Hence they are not 100% comparable with Figure 11 which is produced using a combination of product level data and market averages. However, net results are believed to be comparable with little error. Further, as Figure 12 (on next page) is based on annual averages for both volumes and consumptions and thus does not give absolute comparisons with data reported elsewhere for all years/regions.

b. *May* have the perverse effect of encouraging the supply of larger products to the market to improve apparent efficiency while actually increasing (or at the very least, slowing the decrease) in product consumption.

2) The problem of differing volumes masking efficiency similarities/ differences between countries/regions is normally addressed through the application and comparison of Energy Efficiency Indices (EEIs) for products within each market. To explain simply, an EEI for cold appliances introduces a factor to the energy consumption based on the adjusted volumes of the units. This factor attempts to remove the inherent variations in efficiency related to volume (and often other factors) to allow effective and fair comparison/regulation of all models in the market. Figure 12 gives a graphical illustration of how, as volumes increase linearly, comparable unit energy consumption increases incrementally less to account for inherent improvements in efficiency as the units become larger.

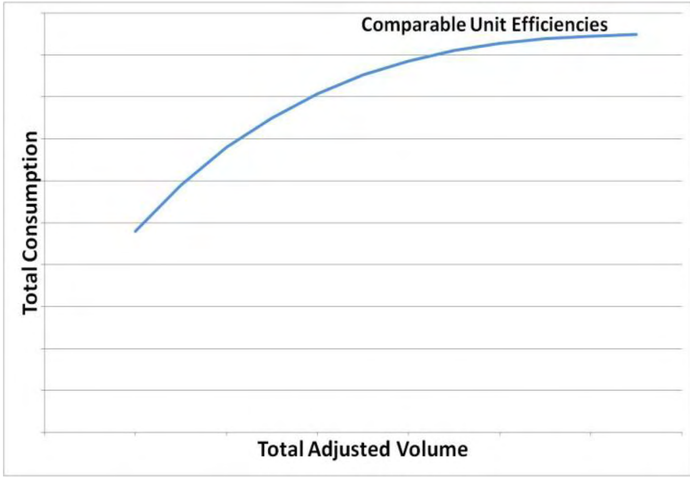

Figure 12: Illustration of Comparable Unit Energy Consumptions across a range of Volumes through the Application of Energy Efficiency Indices

Unfortunately, given the variations in EEIs applied in the various regulatory regimes in countries/regions supplying data, and the variations in categorisation of products within these markets, it has not been possible to generate a generic EEI that would provide comparable results between markets over time. However, to at least provide a comparison of product efficiencies between markets at various volumes, it is possible to plot all products available within individual markets for a particular year[30] (see Figure 13). The spread of products at each adjusted volume provides an indication of comparable efficiency at those volumes. The addition of a best fit line[31] for products in each market (a proxy indication of an EEI for that market), shows:

a. The marked difference in consumptions (and hence efficiencies) in models in various markets for each volume range. For example, the UK clearly has the most efficient smaller units, but UK units perform significantly less well in larger size ranges. The reverse is true for Korean products.

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[30] This is only possible for markets where individual product data is available (not aggregated market data), ie Australia, Canada, Korea and the UK - the USA has this product level data but is excluded as it is based on Energy Star only and as such does not represent the market.
[31] Created using a simple “power” best fit in Microsoft Excel.

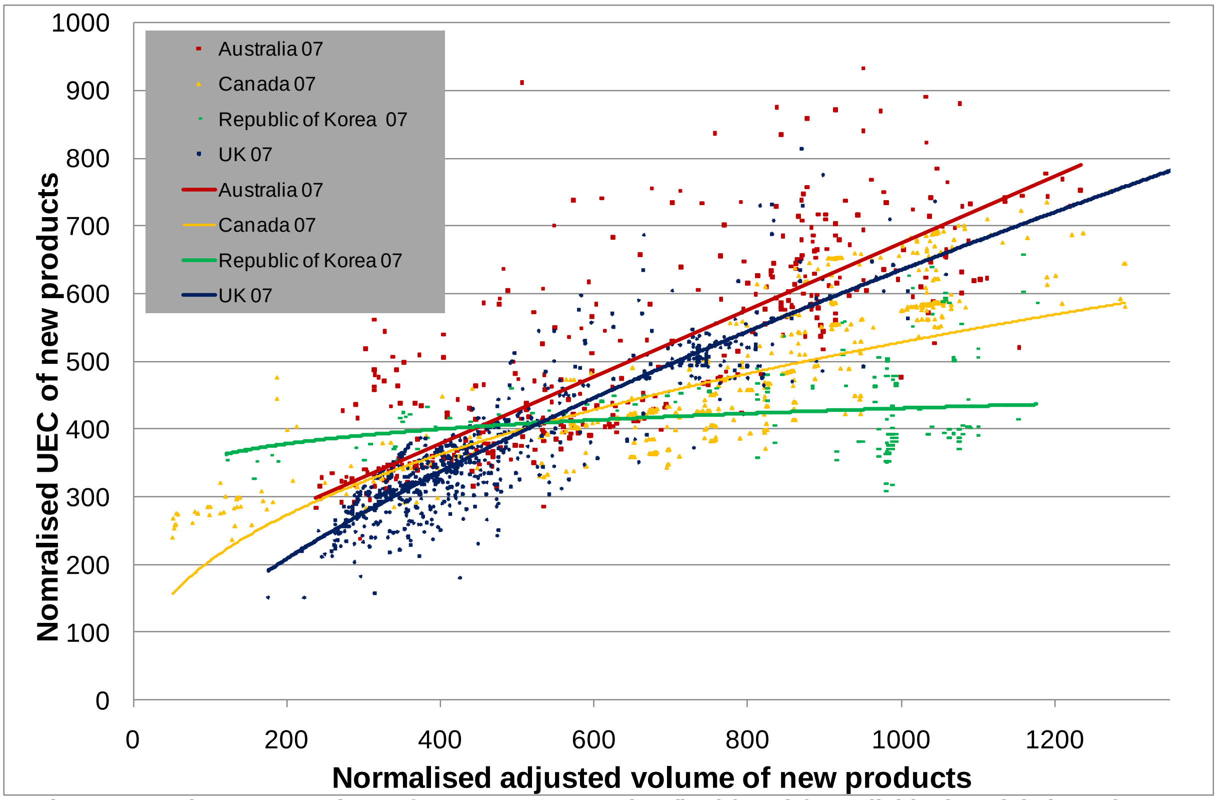

Figure 13: Robust Comparison of Energy Consumption (kWh/year) for Individual Models by Volume (litres), with a best fit (power) line added (See Annex 2 Figure 13)

b. There is also a marked difference in the spread of consumptions (and hence efficiencies) at each volume in the different markets. The UK appears to have very limited spreads while Australia appears to have products that cover a very wide range of consumptions (and efficiencies) in each volume range[32].

It is not possible to draw *firm* conclusions from this analysis. However, it appears clear that:

- Looking at overall efficiencies of products within countries does mask some quite stark differences in efficiencies at specific product volumes
- These differences are not constant for all volumes
- The regulatory regimes in each country (all have mandatory labelling and MEPS) are leading to very different outcomes in efficiencies of products at various volume levels.

During the development of their regulatory regimes, most policy makers use EEIs whose development is based on the products currently in their market. It is clear that this may lead to significant missed opportunities for driving down consumptions (and improving

[32] *At least* part of the Australian product spread is due to the local regulatory regime which allows sale of products imported prior to regulation. Hence, some apparently none-compliant products (ie high consumers) may still be being sold many years after regulations come into force, although typically in very low volumes as stock is depleted over time.

efficiencies). *For a simplified example*[33], if policy makers created a MEPS line based on the UK best fit line at low volumes, and the Korean best fit line at higher volumes, there would be large potential benefits in all markets while policy makers could be assured that products could be produced to these consumptions/efficiencies due to their current availability in other markets. Hence, when developing EEIs seeking to maximise energy saving within their market, policy makers may wish to look beyond their own borders at product performance elsewhere.

2.1.6 Energy Efficiency – Freezers Only

Figure 14a shows the country breakdown of (product weighted[34]) new product normalised efficiency, as defined by annual energy consumption per litre of adjusted volume. The graph shows a falling trend (with the obvious exception of Canada) with all countries having improvements in energy efficiency as should be expected with falling unit energy consumption. However the falling trend is not as rapid as refrigerator/freezers combinations, primarily because volumes have remained relative static when compared to the volume increases seen in the refrigerator/freezer combinations. This trend is repeated when indicative data is used to enable the inclusion of more countries/regions (see Figure 14b).

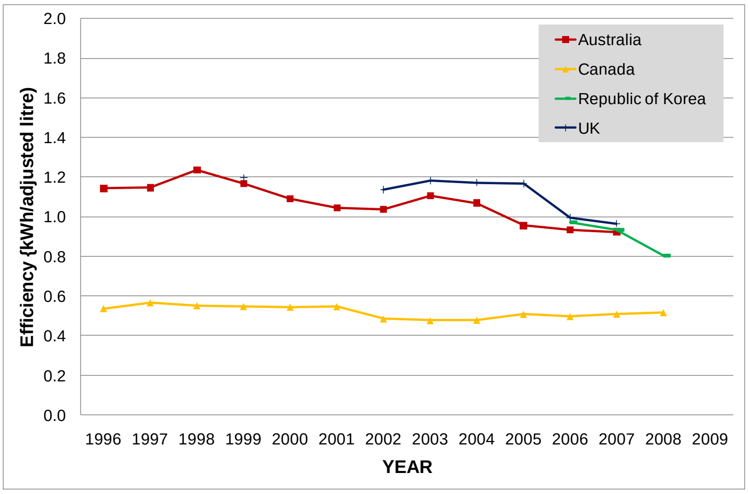

Figure 14a: Robust Normalised Efficiency of New Products (kWh/adjusted volume/year) (See Annex 3 Figure 14a)

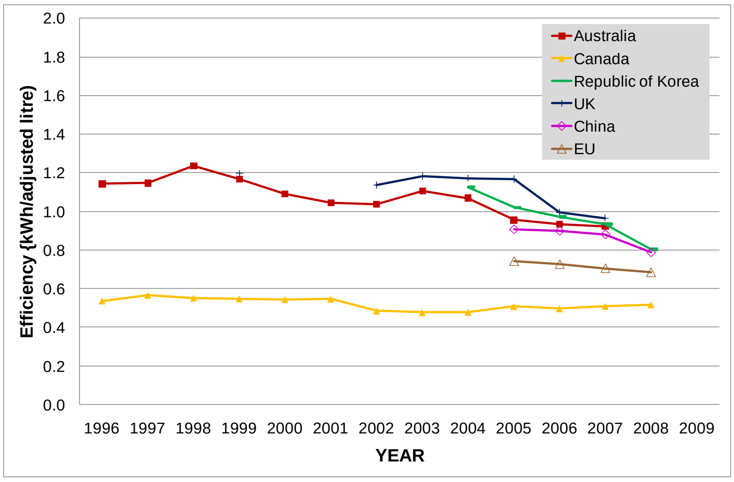

Figure 14b: Indicative Normalised Efficiency of New Products (kWh/adjusted volume/year) (See Annex 2 Figure 14b)

Unfortunately, once again this analysis has an issue that potentially differing volumes are masking efficiency similarities/ differences between countries/

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[33] There are a number of complicating factors, eg range of products types, functionality, etc that make this example extremely simplified. However, given the range of consumption/efficiency differences at the same volumes between countries, even allowing for these complicating factors, there are clearly opportunities for enhanced MEPS levels in almost all markets.

[34] Again that the graphic refers to *normalised* product weighted efficiencies as data available from most countries allowed for normalisation of product weighted efficiencies but not sales weighted efficiencies.

regions (see section 2.1.5 for an explanation). However, once more it is possible to provide a comparison of product efficiencies between markets at various volumes by plotting all products available within individual markets for a particular year[35] (see Figure 15). The spread of products at each adjusted volume provides an indication of comparable efficiency at those volumes. The addition of a best fit line[36] for products in each market provides a proxy indication of an EEI for that market. Again the data shows:

a. The marked difference in consumptions (and hence efficiencies) in models in various markets for each volume range. In this case, Canada has more efficient smaller products with the UK have more efficient larger units (although the UK *may* be distorted by limited products at the larger volume covering a wide spread of consumptions).
b. There is also a marked difference in the spread of consumptions (and hence efficiencies) at each volume in the different markets. In this case the UK appears to have significant product spreads while Canada and Australia appear to have products that cover a tighter range of consumptions (and efficiencies) in each volume range.

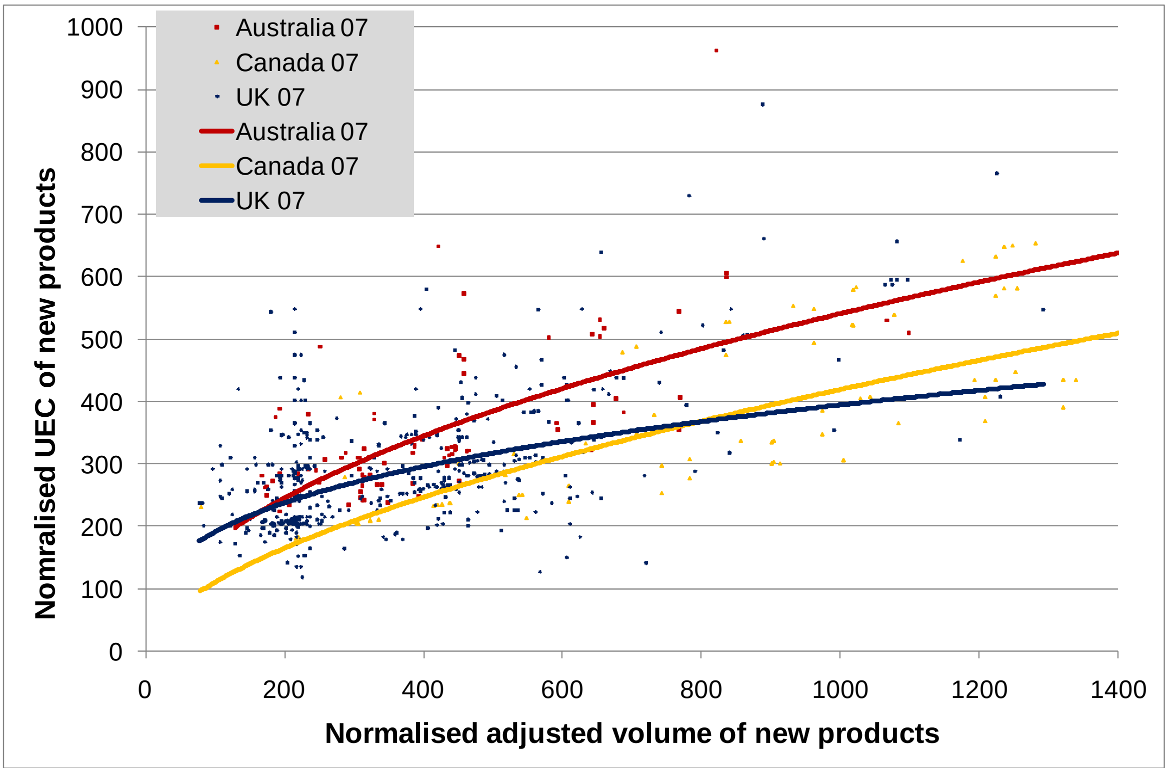

Figure 15: Robust Comparison of Energy Consumption (kWh/year) for Individual Models by Volume (litres), with a best fit (power) line added (See Annex 3 Figure 15)

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[35] This is only possible for markets where individual product data is available (not aggregated market data), ie Australia, Canada, Korea and the UK - the USA has this product level data but is excluded as it is based on EnergyStar only and as such does not represent the market).
[36] Created using a simple "power" best fit in Microsoft Excel.

Again it is not possible to draw *firm* conclusions from this analysis. However, once more it appears clear that:

- Looking at overall efficiencies of products within countries does mask some quite stark differences in efficiencies at specific product volumes
- These differences are not constant for all volumes
- The regulatory regimes in each country (all have mandatory labelling and MEPS) are leading to very different outcomes in efficiencies of products at various volume levels.

The same conclusion is drawn that when developing EEIs seeking to maximise energy saving within their market, policy makers may wish to look beyond their own borders at product performance elsewhere.

2.2 Key issues for policy makers: new products

The following issues are identified as potentially being of interest to policy makers:

- For refrigerator/freezer combination units, differences in energy consumption between individual products in various countries are relatively small with almost all countries appearing to move toward a normalised new product energy consumption of 350-400kWh/year. However, this difference is smaller than expected given the large variations in product volumes between countries (over 70% difference in average sizes in 2007). The exception to this is China where product consumptions appear to be typically half the level reported elsewhere. The convergence of consumptions for freezer is less pronounced and is moving more slowly and towards a wider band (currently 270–370kWh/year), although in general consumption continues to fall. Again there is an exception with Canadian freezer consumption 25% greater than the lowest consumption elsewhere, although Canadian volumes average twice that of other areas.

- For the majority of countries/regions where data is available, declared sales weighted average energy consumptions of refrigerator/freezer combination units are 10% (5-10% for freezer only units) below their product weighted equivalents, ie consumers are purchasing products that consume 10% less energy than the energy consumption of the average product on the market. However, it is not possible to be sure whether this is due to consumers actively seeking more efficient units, or that consumers are purchasing units of larger than average volumes (which would create the same apparent outcome).

- Energy efficiency has been improving in all regions over the periods data is available. Although rates of improvement vary significantly between countries, as is to be expected, those with the worst initial efficiencies are improving most rapidly. However, it appears a significant proportion of this improvement may be due to the rapid increase in volume and actual product performance may be improving significantly more slowly than it may appear (this issue is more significant for refrigerator/freezer combinations, but to a lesser extent also applies to freezer only units).

- There is still considerable opportunity for improvement in efficiencies in almost all countries. However, to realise the full potential, when creating regulatory/supporting policy regimes, policy makers should be aware that:

    - Energy Efficiency Indices (EEIs) based only on products available within the policy makers own region may not reflect the true correlation of efficiency to volume and so may distort associated policy/miss potential saving opportunities. Therefore policy makers may wish to consider looking at data from a range of markets to assess what is a reasonable efficiency/volume algorithm on which to base policy in order to maximise opportunities within the local market.

- The use of energy efficiency as the sole metric for policy development and evaluation may be misleading and *may* actually lead to perverse outcomes if products are increased in volume simply to improve apparent efficiency. Thus policy makers may wish to consider differential policies to encourage the use of smaller cold appliances or the development of policies based on consumption caps (and consequently efficiency caps).

Section 3: Stock Consumption

3.1 Observations

As noted in the “cautions” at the beginning of this document, information on stock consumptions should be interpreted with care as source information is almost entirely based on modelling information supplied by individual countries. Hence, assumptions such as usage patterns, corrections for climate, etc are likely to differ significantly and in the majority of cases are unknown. Further, as the models of stock are based on local regulations and practice, the “normalised” new product consumptions and efficiencies used in previous sections of this report are non-comparable. However, there is value in presenting the information in conjunction with the new product consumptions as declared under local regulations as there are some interesting items to note.

3.1.1 Stock Product Consumption – Refrigerator/Freezer Combinations

The average product energy consumption of refrigerator/freezer combination units in stock is shown in Figure 16. This stock consumption is derived from overall stock consumption divided by total products in stock, both as reported. However, this simple analysis seems at odds with the energy consumption information supplied for new refrigerator/freezer products as declared (see Figure 17). Where stock and new product performance are both reported (Canada, Korea, the UK and China), there is a huge difference in consumption of products in stock, for example 993kWh/year in Canada (1999) compared with 619kWh for the UK in the same year (Denmark was as low as 460kWh in the same year). This would mean new product performance appears to be over 28% better than the stock level by 2005 while only 18% better in the UK in the same year. Given the long product lives[37] and the general rapid improvement in efficiency and falling consumptions over the period reported here, such an outcome is surprising. While it is very possible the outcome may be explained by the difference in modelling (eg assumptions on use of secondary units, operational consumption

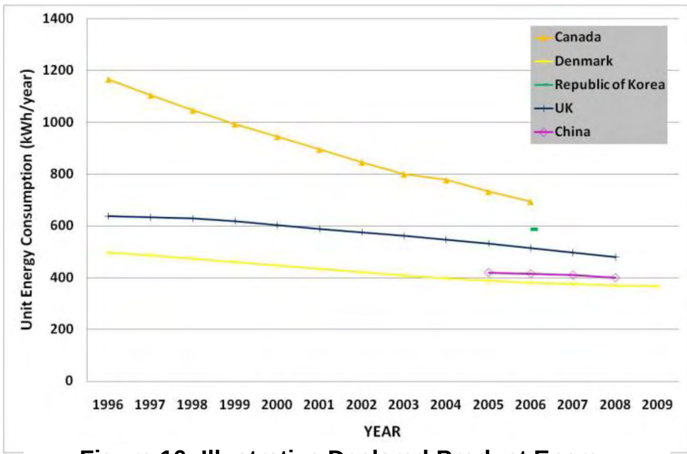


Figure 16: Illustrative Declared Product Energy Consumption of Stock (kWh/year See Annex 2 Figure 16)

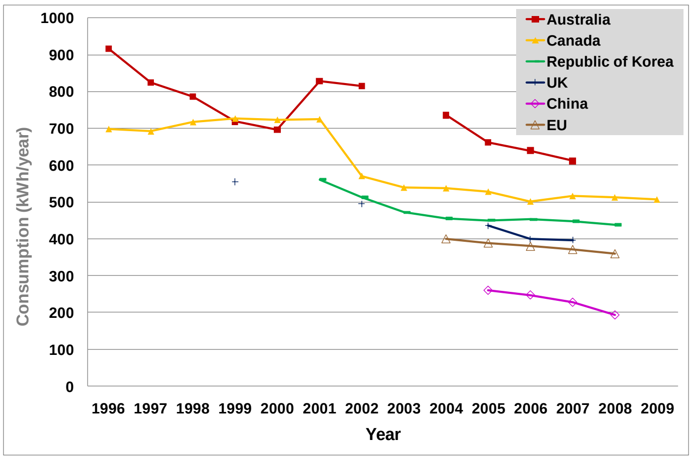


Figure 17 (reproduced): Indicative Declared Product Weighted New Product Energy Consumption (See Annex 2 Figure 17)

[37] Reported lifetimes are Australia 17 years, Canada 20 years, France 10.5 years, Korea 6.8 years and the USA 14 years

compared with that under test, etc), or less likely products purchased before 1996 are significantly smaller and/or have lower consumption than their more recent counterparts, there appears merit in investigating stock models to establish their robustness for policy making and evaluation purposes. This is particularly the case if policy makers are considering the impact of policies designed to accelerate the replacement of old stock, which is normally assumed to have significantly higher consumption than newer products.

3.1.2 Stock Product Consumption – Freezers Only

The average product energy consumption of freezer units in stock is shown in Figure 18. As for refrigerator/freezer units, this stock consumption is derived from overall stock consumption divided by total products in stock, both as declared. However, once more this simple analysis seems at odds with the energy consumption information supplied for new products as declared (see Figure 19). Where stock and new product performance are both reported (Australia, Canada, and the UK), the difference in unit consumption of freezer products in stock compares well with the consumption of declared new units in Canada and the UK. Even given the precipitous fall in stock consumption in Canada, the steady state of (relatively low) Canadian new product performance over a long period compared with initial stock consumption levels, this would be expected despite the long product lives. However, in the case of Australia, new product consumption is actually higher than stock unit consumption in a number of years. While there are possible explanations for this (eg differences in modelling assumptions on use of secondary units, operational consumption compared with that under test, etc), the outcome is surprising. Although an effective comparison of stock and new unit consumption is not possible for other countries, there again seems value in investigating stock models to establish their robustness for policy making and evaluation purposes. This is particularly the case if policy makers are considering the impact of policies designed to accelerate the replacement of old stock, which is normally assumed to have significantly higher consumption than newer products.

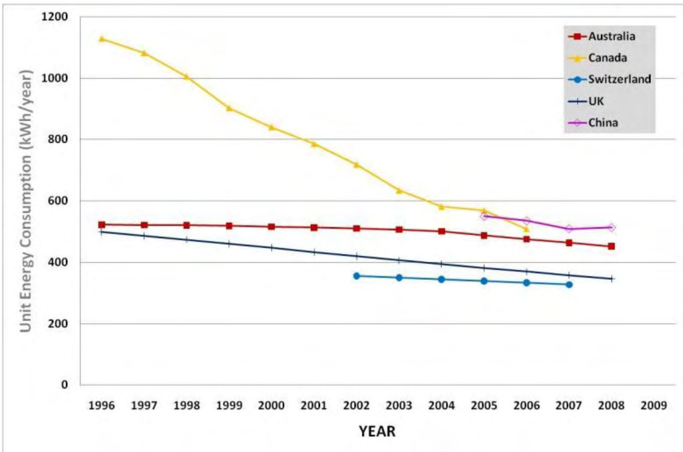


Figure 18: Illustrative Declared Product Energy Consumption of Stock (kWh/year See Annex 3 Figure 18)

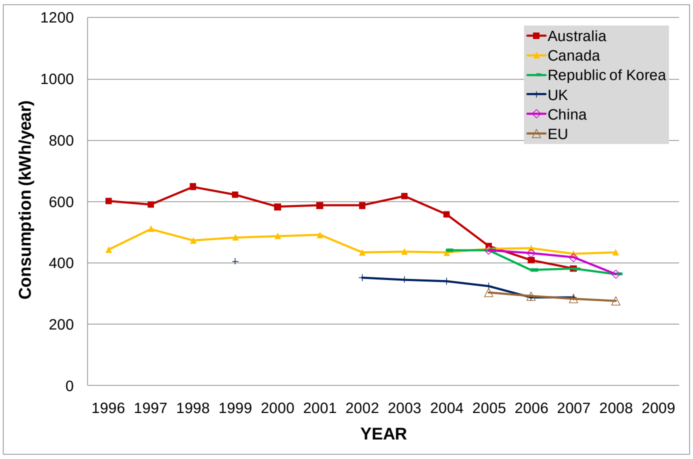


Figure 19: Indicative Declared Product Weighted New Product Energy Consumption (See Annex 3 Figure 19)

3.1.3 Total Stock Energy Consumption – Refrigerator/Freezer Combinations

Total refrigerator/freezer combination stock energy consumption is variable between countries who have reported. Consumption in France and Denmark is rising slowly over the full period; in the UK consumption peaked in 2001 and has been falling slightly since; in Canada there is a continuing sharp fall from a high starting consumption; and Korea has relatively stable consumption (see Figure 20). However, the startling major observation is the near exponential growth in overall consumption in China (driven by the growth in ownership levels – see Figure 21) which makes all "slight" increases or decreases elsewhere seem almost insignificant. In 2006 (the last year where Canada, Denmark, France, Korea, the UK and China all report data), Chinese consumption was already at 60% of all the other countries combined. Since that point, Chinese consumption has risen by over 35% and in likely to have surpassed consumption by all other nations reported in Figures 20 and 21. However, Chinese ownership levels are still less than one appliance in every 4 households so consumption will continue to grow rapidly for an extended period.

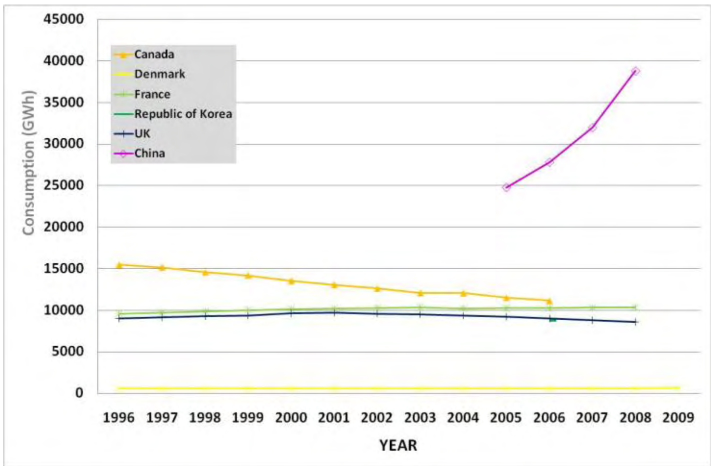


Figure 20: Illustrative Total Stock Energy Consumption (GWh/year)
(see Annex 2 Figure 20)

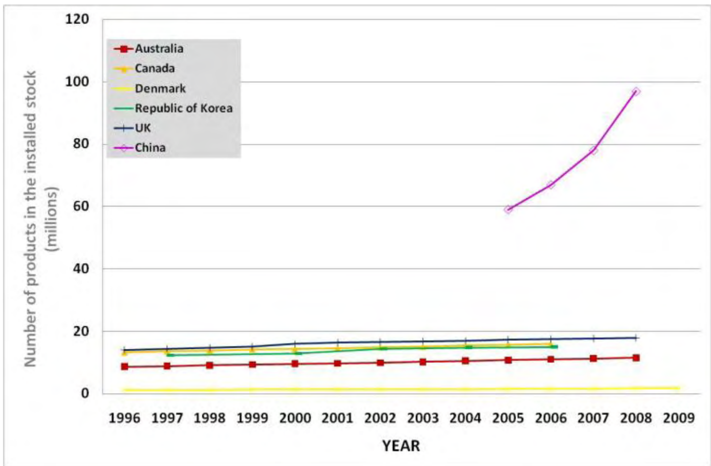
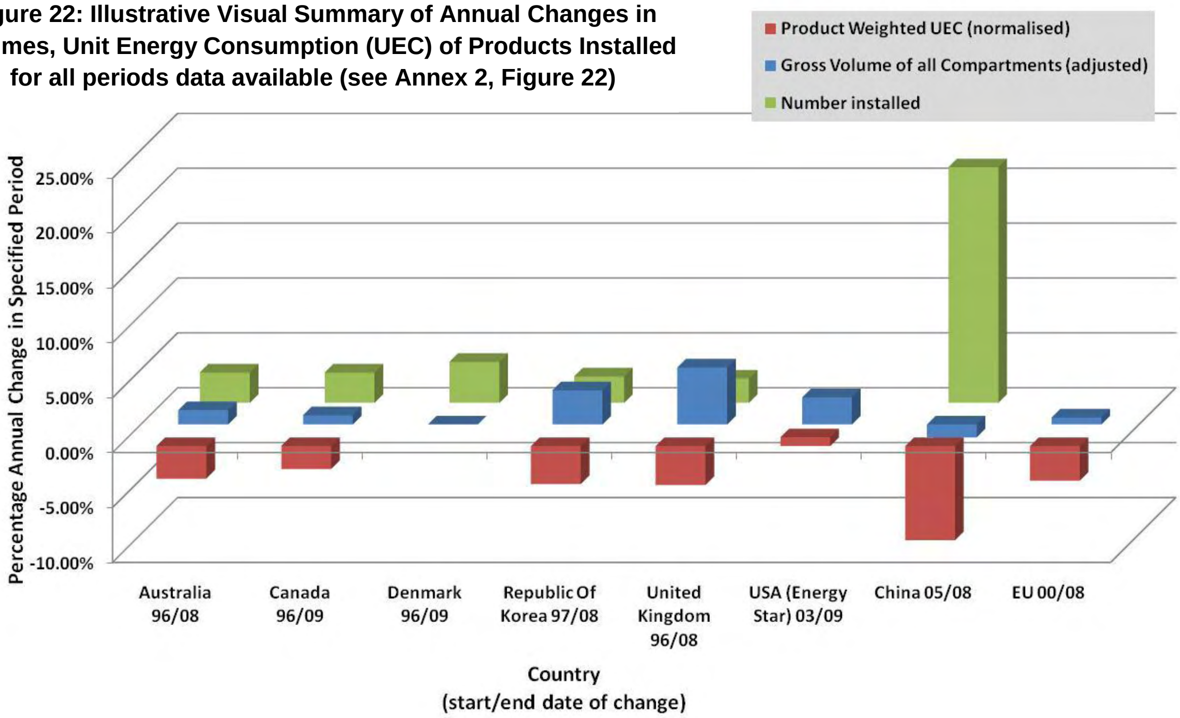


Figure 21: Total Number of Products Installed (millions)
(see Annex 2 Figure 21)

Other than the unique Chinese growth in consumption, it is difficult to form any conclusions based on this stock information as again it is subject to the modelling differences. However, it is useful to note that stock consumption in general is not falling anywhere near as quickly as new product consumption (with the exception of Canada). Partly this is due to the long product lives as noted in the previous sub-section, and the consequential time lag for the new (assumed to be lower consumption) products to enter the market. However, partly the growth in consumption (or reduced speed in improvement) is due to in typically increasing product volumes and growth in the total number of products installed (either due to increasing numbers of households and/or the increase in ownership of second products)[38]. All countries are reporting an annual growth in number of installed products ranging from 1.37% in Switzerland to 2.5% in Australia[39] - see Figure 21.

Figure 22 provides a visual summary of the changes in refrigerator/freezer combination volumes, number of products installed and the average consumption of individual products for each country where data is available.

Figure 22: Illustrative Visual Summary of Annual Changes in Volumes, Unit Energy Consumption (UEC) of Products Installed for all periods data available (see Annex 2, Figure 22)



Thus, it is important for policy makers to be aware of both the lag in products entering the market compared with improvements in overall energy consumption, *and* the growth of total numbers and volume of products in the market, when considering the impact of policies on overall consumption levels. Further, policy makers should also note that, in a number of countries, new product consumptions are beginning to plateau following a long period of reducing consumptions (see above). Thus, in the medium term, without strong policy intervention to drive down product consumption, it appears overall consumption of stock will begin to rise more rapidly as marginal improvements in consumption are outweighed by growth in households and/or second appliances (assuming growth in households/second appliances continues roughly in line with present trends).

[38] Note that in some countries this growth is also due to a switch from refrigerator only units to refrigerator/freezers. However, the impact of this switch is not known.
[39] Australia's data includes both refrigerator and refrigerator/freezer numbers. It is believed that refrigerators constitute approximately 20% of the total product numbers for the entire period.

3.1.4 Total Stock Energy Consumption – Freezers Only

In line with refrigerator/freezer combination units, total freezer stock energy consumption is variable between the countries who have reported data. Consumption in France has risen by over 10%, with Australia, Denmark, Switzerland and the UK all falling by approximately the same percentage. Canadian consumption has fallen precipitously (see Figure 23). However, as with refrigerator/freezer combination units, the startling major observation is the near exponential growth in overall consumption in China driven by the growt

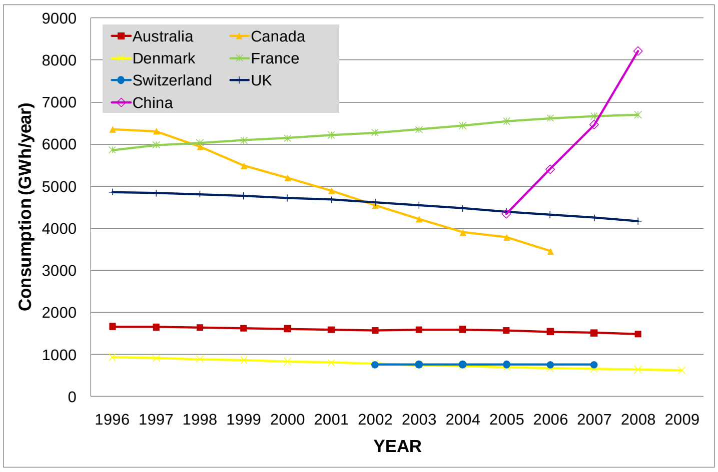


Figure 23: Illustrative Total Stock Energy Consumption (GWh/year) (see Annex 3 Figure 23)

Other than the rapidity of the growth in co given low product penetration rate), it is again difficult to form any conclusions based on this stock information as it is once more subject to the modelling differences. However, it is possible to provide a visual summary of some of the underlying changes in volumes, products installed and the product UECs for each country were data is available (Figure 25).

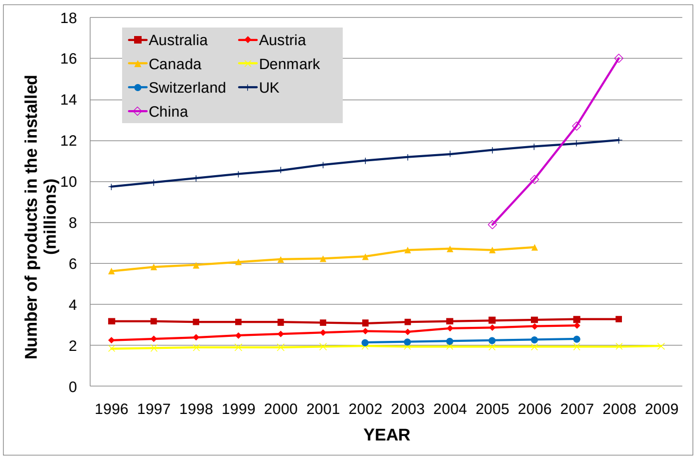


Figure 24: Total Number of Products Installed (millions) (see Annex 3 Figure 24)

Thus, it is important for policy makers once more to note the lag in products entering the market compared with improvements in overall energy consumption, *and* the growth of total numbers of products in the market, when considering the impact of policies on overall consumption levels.

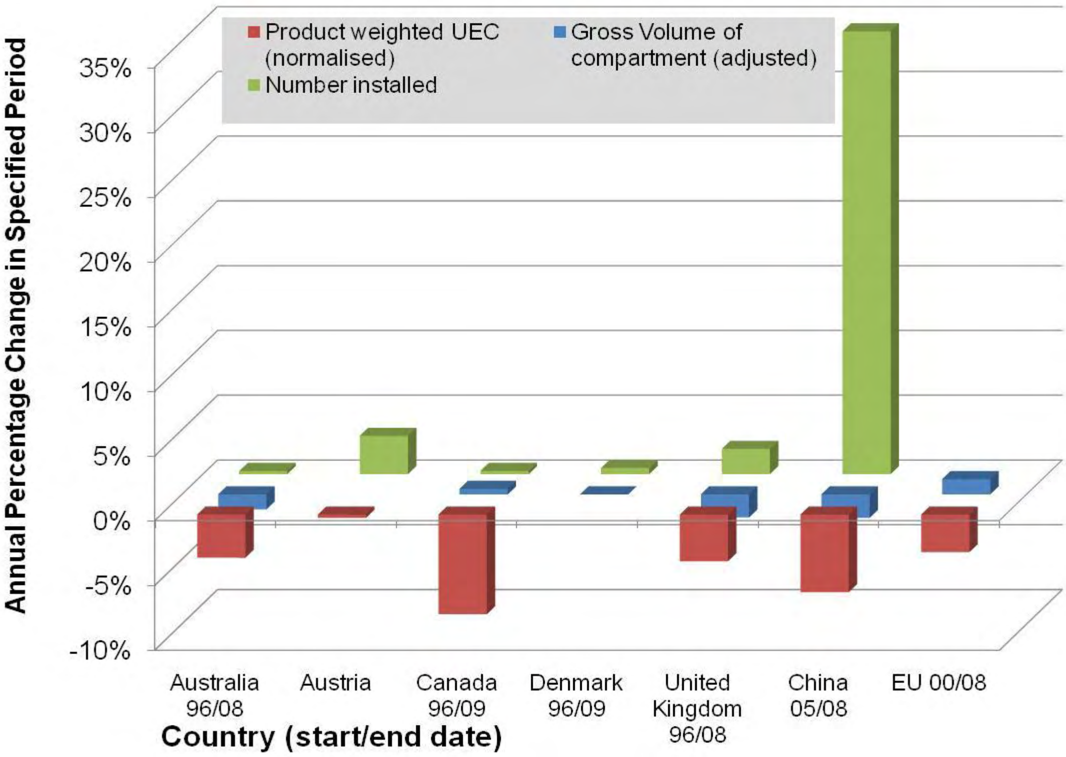


Figure 25: Illustrative Visual Summary of Average Annual changes in Volumes, Unit Energy Consumption (UEC) of products installed for all periods data available (see Annex 2, Figure 25)

3.2 Key issues for policy makers: installed stock

The following issues are identified as potentially being of interest to policy makers:

- The change in total consumption of stock for both refrigerators/freezer combinations and freezers is variable between countries with reports ranging from continual increase in consumption through to rapidly decreasing consumption. However, in a number of cases, there are apparent contradictions between the product consumption of new products and those in the stock, ie the products in the stock appear to have consumptions that are lower than may have been expected. Thus, there appears to be value in investigating current models of products within the stock to confirm their robustness as a basis for policy making and evaluation.

- If current stock models are correct, then for some countries' programmes designed to accelerate replacement of older products (which have traditionally been assumed to have much higher consumption) may not be appropriate as they will yield marginal improvement in efficiency/lower consumption.

- As new product consumptions are falling slowly or reaching a plateau (for refrigerator/freezer combinations) after a long period of reducing in most countries, without strong policy intervention to drive down new product consumption the overall energy consumption of stock may begin to rise more rapidly as marginal improvements in consumption are outweighed by growth volumes, in households and/or second appliance ownership.

- The explosive growth in ownership levels in China is more than outweighing any gains made elsewhere. For refrigerator/freezers in 2006, Chinese consumption was already at 60% of the combined consumption of Canada, Denmark, France, Korea and the UK. However, since that point, Chinese consumption has risen by over 35% and in likely to have surpassed the combined consumption of these nations. However, Chinese ownership levels are still less than one appliance in every 4 households so consumption will continue to grow rapidly for an extended period even with strong policy action. A similar though slightly less extreme situation applies to freezer only units.

Section 4: Policy Measures

4.1 Observations

A summary of policy actions drawn from individual country mapping sheets is provided in Figure 26.

As can be seen, all countries reporting policy interventions have compulsory labelling and some level of Minimum Energy Performance Standards (MEPS), most having revised both at least once. Further, in all cases with the exception of China, labelling (either mandatory or voluntary) was introduced prior to the earliest year for which data was collected (1996) with MEPS already in place in Canada, Korea and the USA (soon after) this date. Voluntary labelling of premium products is also in place in Canada (Energy Star), the USA (Energy Star) the UK (Energy Saving Recommended) and China (China Energy Certification Label). Given the complementary nature of these policy actions, and the typically early awareness and response of the suppliers to their impending arrival (even where no formal announcement has been made), it is impossible to make specific statements about the effectiveness of individual policies, or the comparative effectiveness of one policy over another. The two exceptions to this statement are:

- The 2001 revision of MEPS in Canada seems to have caused a step change improvement in the efficiency and consumption of new products with product weighted average efficiency improving by 29% and consumption improving by 26% between 2001 and 2003[40]
- In Australia, the 2005 revision of MEPS seems to have brought an improvement of 17% in both consumption and efficiency between 2004 and 2006.

Other than this, only **broad generalisations** can be made on policy effectiveness as follows:

- The markets where mandatory labelling and/or MEPS were introduced earlier and/or are revised regularly (Canada, Korea and the USA) tend to be those markets with the better performing products. However, as similar measures have been introduced in the remaining countries (Australia and the UK), efficiencies are rapidly improving and are beginning to approach the better performers (Australia's efficiencies are approaching the "norm" more quickly as their policies appear to be reviewed more regularly).

- Even immediately after the implementation of MEPS, some new products on the market are typically 50% more efficient[41] than the *average* product for sale and even more so than the least efficient. This appears to offer the potential for the imposition

[40] The improvement in sales weighted averages in each case is lower (efficiency 16% and consumption 14%) which is in line with the expectation that a product weighted average will improve significantly as the worse products are removed, but sales weighted averages will more less quickly except where original sales are comprised heavily of the lower performing products.
[41] Note that this potential improvement may be slightly misleading in some markets as a range of products have been grouped and the most efficient product may be of a type with inherent higher efficiencies but may have low penetration in the market. However, the broad implication of the observation *appears* to be true in all markets and almost all product sectors.

of much more aggressive MEPS to overcome the apparent plateauing of improvement in new product energy consumption at a time when the total number of products installed is increasing in all markets. The traditional restriction on such action is the cost to the consumer whom it is expected will have to pay a higher price for the more efficient products which must be recouped rapidly in reduced energy costs. However, recent research[42] suggests that such price rises have rarely materialised in the market post implementation of the MEPS and thus, when cost benefits are conducted, the increases in performance could have been much higher than previously considered at the same marginal costs to the consumer.

[42] "Experience with Energy Efficiency Regulations for Electrical Equipment", Mark Ellis, IEA 2007

Figure 26: Summary of Policy Major Policy Interventions Reported for Refrigerator Freezer Combinations

	Australia	Austria	Canada	EU	France	Korea	UK	USA	China
Voluntary Labelling (non-premium products)	1986-1994 incremental introduction to all States		1978 EnerGuide Label introduced						
Mandatory Labelling	2000 Mandatory labelling based on revised algorithm and 1-6 star system	1995 Mandatory Labelling based on A-G scale 2004 A+ A++ categories introduced to label July 2010 New performance requirements	1995 Mandatory use of EnerGuide label transferred from Consumer Package and Labelling Act to the Energy Efficiency Act and Regulations	1995 Mandatory Labelling based on A-G scale 2004 A+ A++ categories introduced to label July 2010 New performance requirements	1995 Mandatory Labelling based on A-G scale 2004 A+ A++ categories introduced to label July 2010 New performance requirements	1992 Mandatory Labelling introduced based on 1-5 system 2008 Label redesigned and algorithm changed	1992 Mandatory Labelling based on A-G scale 2004 A+ A++ categories introduced to label July 2010 New performance requirements	1980 Mandatory use of EnerGuide 2007 EnerGuide revision announced	2005 Mandatory labelling based on a 1-5 scale
Voluntary Premium Product Labelling			2001 Energy Star Introduction 2004 Energy Star revised15% better 2008 Energy Star revised 20% better					1998 Energy Star Introduction 2003 Energy Star Scope Expanded 2008 Most recent revision	1999 Certification label introduced
Minimum Energy Performance Standards	1999 MEPS introduced 2005 MEPS revision	1999 MEPS introduced to remove D-G labelled products (2002 Voluntary industry commitment to supply B or better by 2004) July 2010 New performance requirements	1995 MEPS introduced 2001 MEPS revision 2010/11 Proposed MEPS revision	1999 MEPS introduced to remove D-G labelled products (2002 Voluntary industry commitment to supply B or better by 2004) July 2010 New performance requirements	1999 MEPS introduced to remove D-G labelled products (2002 Voluntary industry commitment to supply B or better by 2004) July 2010 New performance requirements	1994 MEPS removes anything below label level 5 2002 MEPS revised 2004 MEPS revised 2008 MEPS revised	1999 MEPS introduced to remove D-G labelled products (2002 Voluntary industry commitment to supply B or better by 2004) July 2010 New performance requirements	1990 MEPS introduced 1993 MEPS revision 2001 MEPS revision Possible MEPS revision in 2010 for introduction in 2014	1999 MEPS announced and revised in 2003 (in force 2004) Revised 2009

	Australia	Austria	Canada	EU	France	Korea	UK	USA	China
Other Policy			Compliance: 3rd party verification mark Mandatory reporting requirements State and- provincial and federal monitoring Marketplace surveillance (testing)			Mandatory reporting requirements (from 1992) Mandatory indication of efficiency grade label (from 1992	CERT (and predecessors) support domestic initiatives through energy suppliers (often based on Energy Saving Recommended Label ACT on CO2 Campaign to support behaviour change EcoHomes/Sustainable Homes create “whole home” rating for efficiency		Various promotional policies particularly at the local level. Normally promotional policies subsidy based with government providing incentives for the purchase of more efficient appliances. In 2009, central government instituted support of energy efficient appliances including cold appliances. The support offered was scaled, but provided subsidy for cold appliances carrying level 1 and 2 labels, with level 1 products receiving the highest subsidy (typically around $90/product). Recent strong efforts to improve enforcement of energy label regulations

Annex 1: Terminology and Correction Factors Used in Data Transformations

Terminology

The following terminology is used within this benchmarking:

Volume: based on fresh food and frozen food volume declarations (as defined in local regulations in litres) with freezer compartment volume multiplied by a correction factor (derived locally for *declared* and below for *normalised* values) to get equivalent net *adjusted* volume.

Product Energy Consumption: *declared* values based on total annual energy consumption (kWh/year) under local test conditions with *normalised* values calculated based on correction factors outlined below.

Product Energy Efficiency: Derived from Product Energy Consumption divided by Total Product Volume (using declared or normalised values as necessary).

Sales Weighted Energy Consumption (or Efficiency) of Products: Average of product consumption (or efficiency) weighted by sales of individual units (using declared or normalised values as necessary).

Product Weighted Energy Efficiency of New Models: Average of product consumption (or efficiency) weighted by products available in the market (using declared or normalised values as necessary).

Declared and Normalised: Correction factors (see below) have been applied to allow comparison of products sold in different markets with differing test regimes (e.g. a correction factor is applied to allow benchmarking of products tested with different internal and external temperatures). Where such correction factors have been applied, the resulting data is referred to as “normalised” in this document. Where “normalised” is not used, the data referred to is the original data *as declared* under each country’s local regulations.

Correction Factors Used in Data Transformations

Correction factors have been applied to allow comparison of products with different functionality and sold in different markets with differing test regimes. These correction factors are detailed below.

Corrections for Ice Makers

Units with ice makers have extra functionality over units that do not have ice-making facilities. Although ice-makers are turned off during testing in all known methodologies, units with ice-makers use more energy under test conditions as typically the area where the ice maker is installed allow greater heat transmission from the interior to the exterior of the unit. Expert opinion indicates this extra energy is approximately 5% of total energy input. To include units with ice-makers on a comparable basis the energy penalty of the additional functionality is removed by reducing declared energy input for such units by 5%.

Adjustments for Voltage/Frequency of Supply

No adjustment has been made for voltage or frequency of supply. Units are designed for one voltage/frequency and optimised to this. Expert opinion suggests small variations (eg between 220V and 240V will have a minor impact, but this cannot be predicted as sometimes energy consumption rises and sometimes it falls).

Adjustments for Volume

Internal volumes of units are measured differently in different test methodologies. However, only net internal volumes are declared and, given the differing geometries of units, it has not been possible to normalise to one methodology. Therefore, internal net volumes used throughout the analysis are net declared values without adjustment.

Adjusted volumes are used to allow comparison of units with large refrigerators and smaller freezers with the units with the opposite configurations. In effect such adjustments try to account for the extra energy used to cool the freezer compartment compared with the fresh compartment by, in effect, converting the freezer cabinet to a refrigerator of a size that would consume the equivalent amount of energy. However, again the method for adjusting volumes varies. When normalising data, all net declared values are adjusted using:

Total Adjusted volumes = Declared Volume Fresh + (2.15 x Declared Volume Frozen)

Adjustment for Temperature

The various test methodologies use different internal and external temperatures. Under the stable conditions created during cold appliance testing, the energy used by the appliance is directly related to the difference between internal compartment temperatures and external (ambient) temperature. Expert opinion indicates the change in energy required to cool the appliance is approximately 3% for every 1^{o}C change in the differential between internal and external test temperatures, ie if the differential temperature is 1^{o}C greater in test methodology A compared with test methodology B, then to be comparable, the energy consumed in test methodology A must be reduced by 3%. However, the differential in temperature between tests may be different in the refrigerator compartment and ambient, and the freezer compartment and ambient, therefore, the energy used within each compartment has to be divided appropriately. Given the various product configurations, there is no known mechanism for this energy allocation. However, to allow comparison in this benchmarking, the energy used by each compartment was allocated on the basis of *adjusted volume using local adjustment factor.* Thus, for countries within the EU, the declared volume of the freezer compartment was multiplied by 2.15 to give an adjusted freezer volume. This adjusted freezer volume is added to the fresh compartment volume to give a total adjusted volume. The declared energy consumed under test was then allocated to each compartment based on:

Allocated Fresh Energy = Declared Energy Consumption x (Declared Fresh Volume/Adjusted Total Volume)

and

Allocated Freezer Energy = Declared Energy Consumption x (Adjusted Freezer Volume/Adjusted Total Volume).

Total Normalised Energy Consumption was then established by:

Total Normalised Energy Consumption =
[Allocated Fresh Energy + (Differential in Test Temperature x 1.03 Allocated Fresh Energy)]
+ [Allocated Freezer Energy + (Differential in Test Temperature x 1.03 Allocated Freezer Energy)]

Given the proportionately higher numbers of EU countries that would potentially supply data, normalisation was based on conversion of test energy consumptions to the EU differential test temperatures as detailed in the following table:

	EU countries and China	Canada/US	Korea	Australia
Internal Fridge	5	7.2	3	3
External	25	32.2	30	32
Difference	20	28.9	27	29
Difference to EU (Fresh)	**0**	**-5**	**-7**	**-9**
Internal Freezer	-20	-15	-18	-15
External	25	32.2	30	32
Difference	45	47.2	48	47
Difference to EU (Frozen)	**0**	**-2.2**	**-3**	**-2**
		(All values in ^{o}C)		

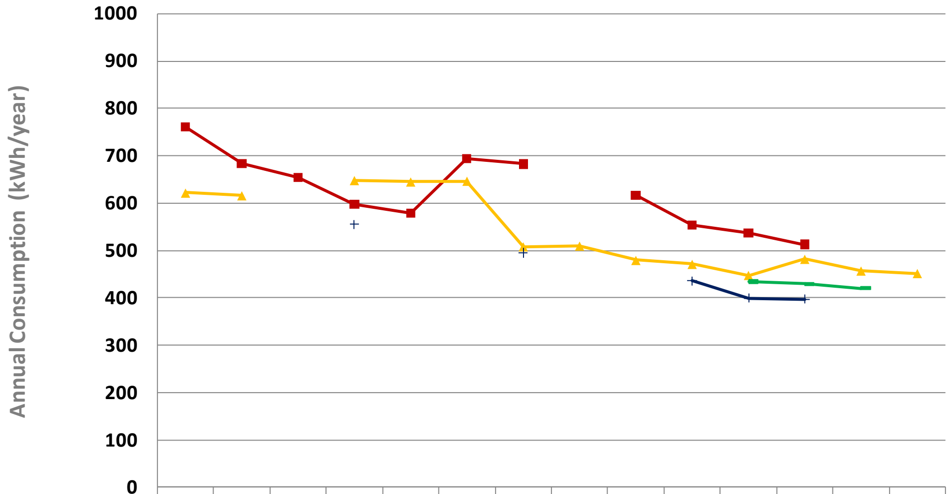
Notes on Table

1) *EU and China Internal Fresh Compartment Test temperature is 4^{o}C for all tests except the energy consumption test referred to here.*
2) *EU and China Internal Frozen Compartment Test temperature is -18^{o}C. However, this is the temperature of the warmest test pack (load). All other test methodologies measure air temperature which is believed to be equivalent to approximately 2^{o}C temperature differential, hence the EU frozen test temperature has been lowered by 2^{o}C.*
3) *The US and Canadian Energy Tests temperatures (during the energy test) are:*
   a. *basic refrigerator-freezer compartment temperature: –9.4 °C (15°F) in the freezer compartment or 7.2 °C (45°F) in the fresh food compartment, whichever yields the higher energy consumption; and*
   b. *refrigerator-freezer compartment temperature: –15.0 °C (5°F) in the freezer compartment or 7.2 °C (45°F) in the fresh food compartment, whichever yields the higher energy consumption.*

   However, the specific test used in not declared in the data received, therefore the two extreme temperatures are used. This is likely to have the effect of underreporting energy consumption and over-reporting efficiencies for the USA and Canada.

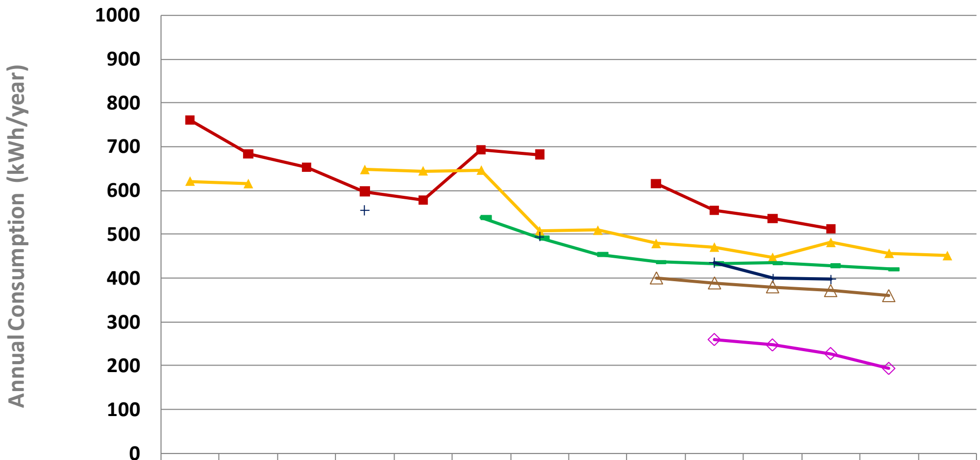
Annex 2: Graphics and Data Tables for Refrigerator/ Freezer Combinations

Figure 1a: Robust Normalised New Product Weighted Energy Consumption (kWh/year)



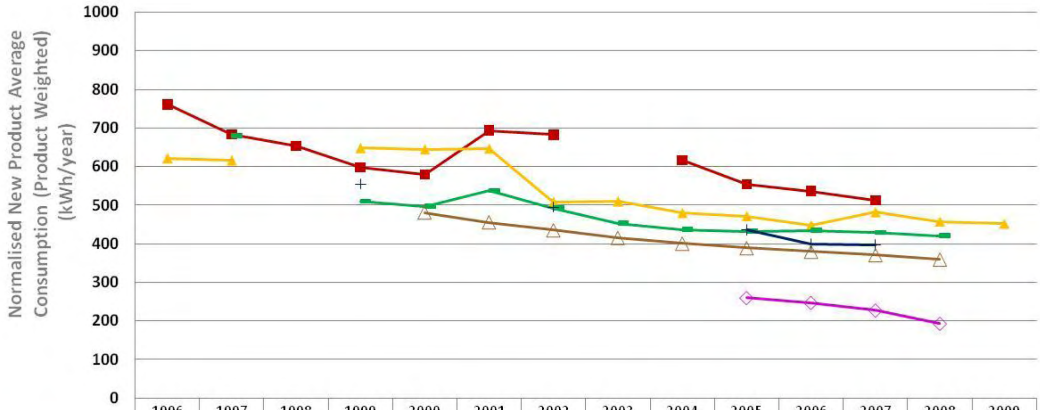
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	762	684	654	598	579	694	683		616	554	537	513		
Canada	622	616		648	645	647	508	510	479	471	448	482	457	451.6
Republic of Korea											434	429	420	
UK				555			495			436	399	397		

Figure 1b: Indicative Normalised New Product Weighted Energy Consumption (kWh/year)



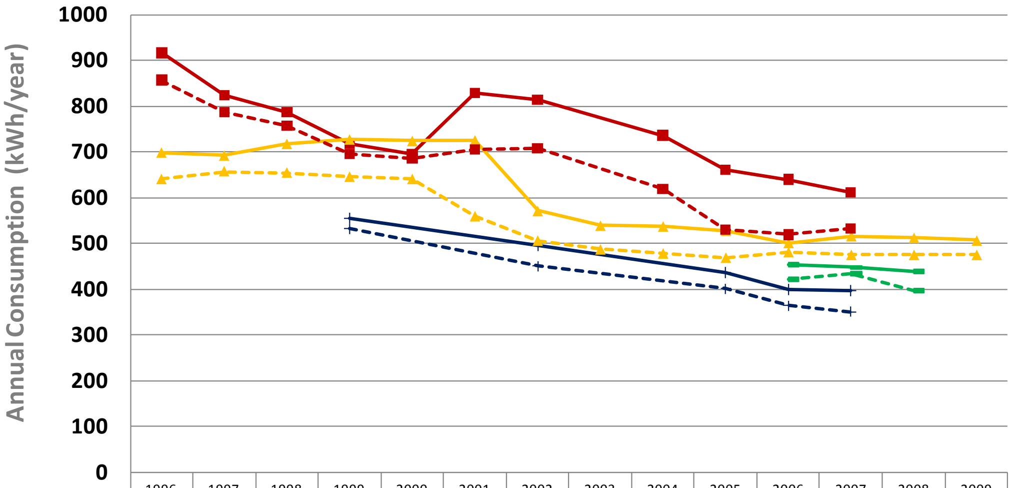
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	762	684	654	598	579	694	683		616	554	537	513		
Canada	622	616		648	645	647	508	510	479	471	448	482	457	451.6
Republic of Korea						538	492	453	437	432	434	429	420	
UK				555			495			436	399	397		
China										260	247	227	193	
EU									401	389	380	371	360	

Figure 1c: Illustrative normalised new product weighted energy consumption (kWh/year)



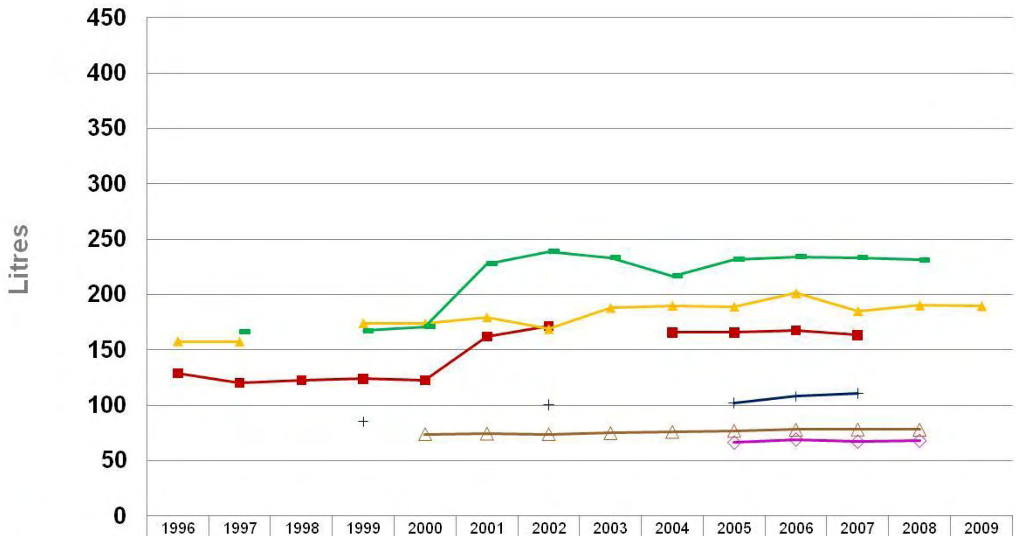
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	762	684	654	598	579	694	683		616	554	537	513		
Austria														
Canada	622	616		648	645	647	508	510	479	471	448	482	457	451.6
Denmark														
France														
Republic of Korea		681		510	497	538	492	453	437	432	434	429	420	
Switzerland														
UK				555			495			436	399	397		
China										260	247	227	193	
EU					481	456	435	416	401	389	380	371	360	
Japan														

Figure 2: Indicative Declared New Product Sales Weighted (SW) and Product Weighted Energy Consumption (kWh/year)



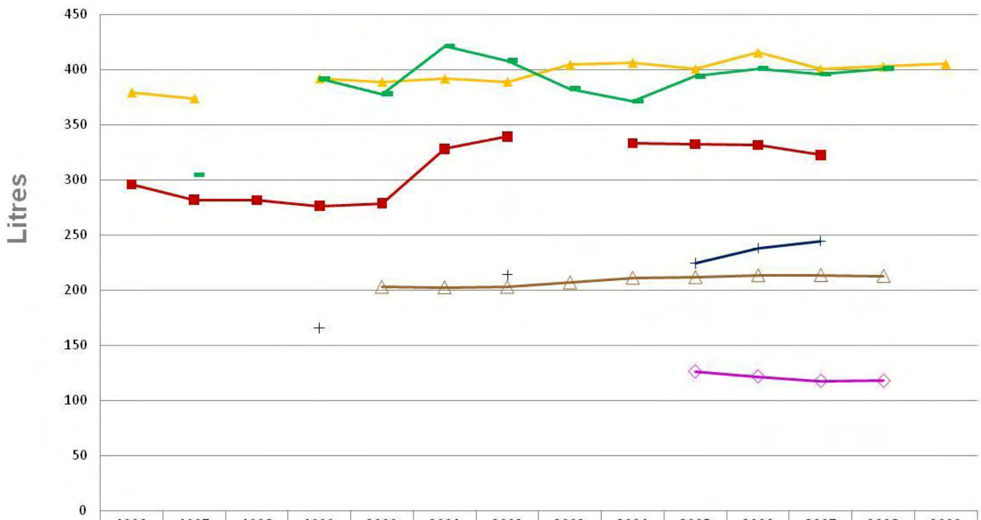
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	917	824	787	719	696	829	815		736	662	640	612		
Canada	699	693	718	728	724	726	571	539	537	528	501	516	512	506.6
Republic of Korea											453	447	439	
UK				555			495			436	399	397		
Australia SW	857	787	757	695	686	706	708		619	530	519	532		
Canada SW	640	657	654	645	640	559	506	487	478	469	481	475	475	475.0
Republic of Korea SW											421	434	397	
UK SW				532			450			400	363	351		

Figure 5: Illustrative Average Unadjusted Frozen Compartment Volume (litres)



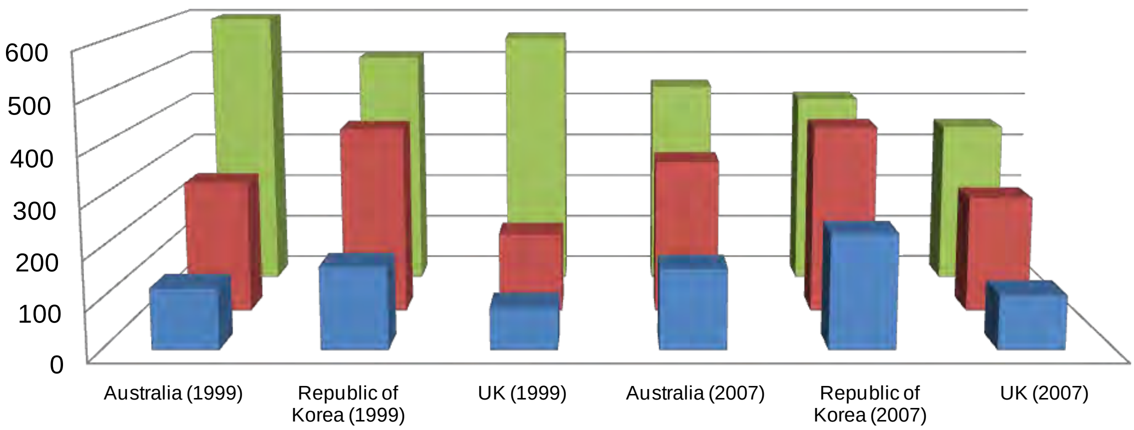
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	129	120	123	124	123	162	172		166	166	168	163		
Canada	158	157		174	174	179	169	188	190	189	202	185	190	190
Republic of Korea		167		167	171	228	239	233	217	232	234	233	231	
UK				85			101			102	108	111		
China										67	69	67	68	
EU					74	75	74	75	76	77	78	78	78	

Figure 6: Illustrative Average Unadjusted Fresh Compartment Volume (litres)



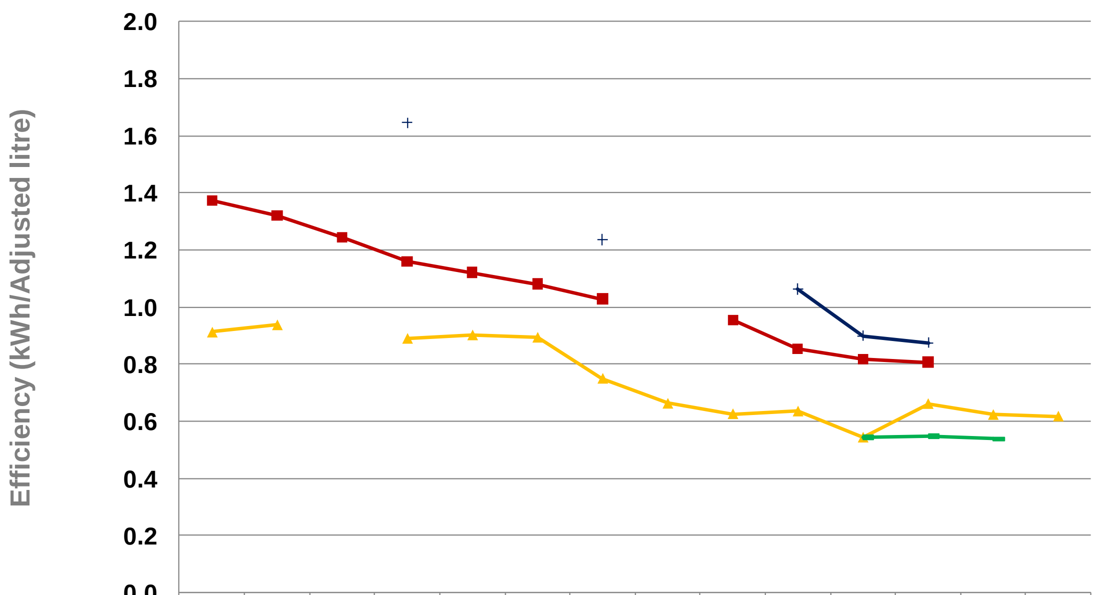
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	296	282	282	276	279	328	339		333	332	332	323		
Canada	379	374		392	389	392	389	405	406	401	416	401	403	405
Republic of Korea		305		392	378	421	408	383	371	394	401	396	401	
UK				166			214			225	238	245		
China										126	122	118	118	
EU					203	202	203	207	211	212	213	214	213	

Figure 7: Illustrative Visual Representation of Comparative Volumes and Normalised Energy Consumptions for 1999 and 2007



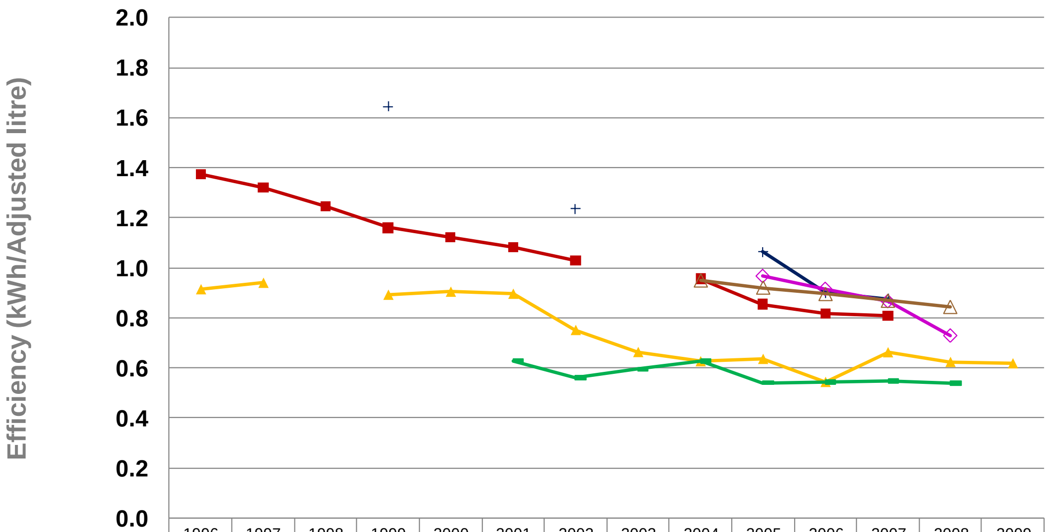
	Australia (1999)	Republic of Korea (1999)	UK (1999)	Australia (2007)	Republic of Korea (2007)	UK (2007)
Ave. Freezer Volume (litres)	124	167	85	163	233	111
Ave. Fridge Volume (litres)	276	392	166	323	396	245
Ave. Annual Consumption (normalised kWh/year)	598	510	555	444	415	351

Figure 10a: Robust Normalised Efficiency of New Products (kWh/yr/adjusted volume)



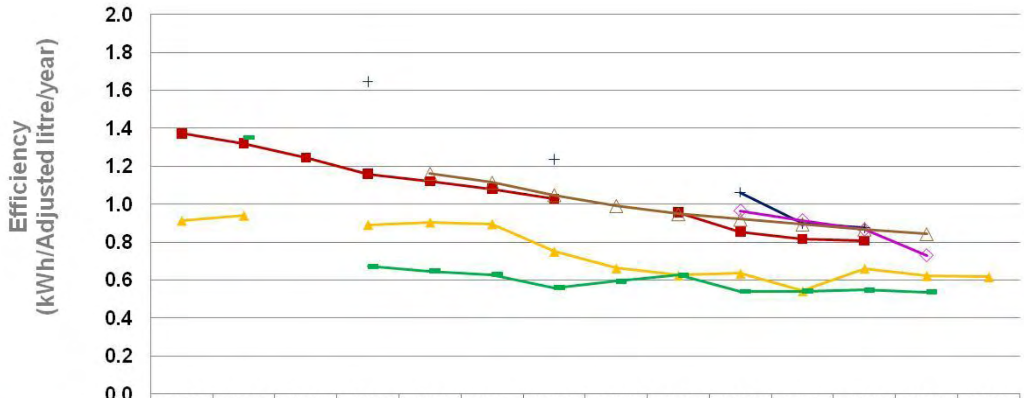
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	1.37	1.32	1.25	1.16	1.12	1.08	1.03		0.96	0.85	0.82	0.81		
Canada	0.91	0.94		0.89	0.90	0.90	0.75	0.7	0.63	0.64	0.54	0.66	0.62	0.62
Republic of Korea											0.54	0.55	0.54	
UK				1.65			1.24			1.06	0.90	0.88		

Figure 10b: Indicative Normalised Efficiency of New Products (kWh/yr/adjusted volume)



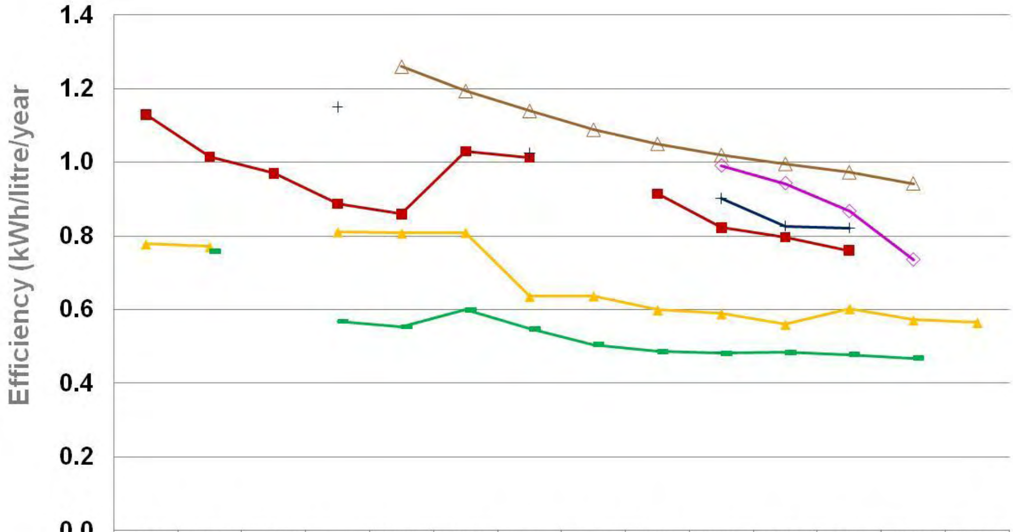
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	1.37	1.32	1.25	1.16	1.12	1.08	1.03		0.96	0.85	0.82	0.81		
Canada	0.91	0.94		0.89	0.90	0.90	0.75	0.7	0.63	0.64	0.54	0.66	0.62	0.62
Republic of Korea						0.63	0.56	0.6	0.63	0.54	0.54	0.55	0.54	
UK				1.65			1.24			1.06	0.90	0.88		
China										0.97	0.91	0.87	0.73	
EU									0.95	0.92	0.90	0.87	0.84	

Figure 10c: Illustrative Normalised Efficiency of New Products (kWh/yr/adjusted volume)



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	1.37	1.32	1.25	1.16	1.12	1.08	1.03		0.96	0.85	0.82	0.81		
Austria														
Canada	0.91	0.94		0.89	0.90	0.90	0.75	0.7	0.63	0.64	0.54	0.66	0.62	0.62
Denmark														
France														
Republic of Korea		1.35		0.67	0.65	0.63	0.56	0.6	0.63	0.54	0.54	0.55	0.54	
Switzerland														
UK				1.65			1.24			1.06	0.90	0.88		
China										0.97	0.91	0.87	0.73	
EU					1.16	1.12	1.05	1.0	0.95	0.92	0.90	0.87	0.84	
Japan														

Figure 11: Illustrative Normalised New Product Efficiency (kWh/litre/year) Calculated with 2007 volume for all years



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	1.13	1.01	0.97	0.89	0.86	1.03	1.01		0.91	0.82	0.80	0.76		
Canada	0.78	0.77		0.81	0.81	0.81	0.64	0.64	0.60	0.59	0.56	0.60	0.57	0.57
Republic of Korea		0.76		0.57	0.55	0.60	0.55	0.50	0.49	0.48	0.48	0.48	0.47	
UK				1.15			1.03			0.90	0.83	0.82		
China										0.99	0.94	0.87	0.74	
EU					1.26	1.19	1.14	1.09	1.05	1.02	1.00	0.97	0.94	

Figure 13: Robust Comparison of Energy Consumption (kWh/year) for Individual Models by Volume (litres), with a best fit (power) line added

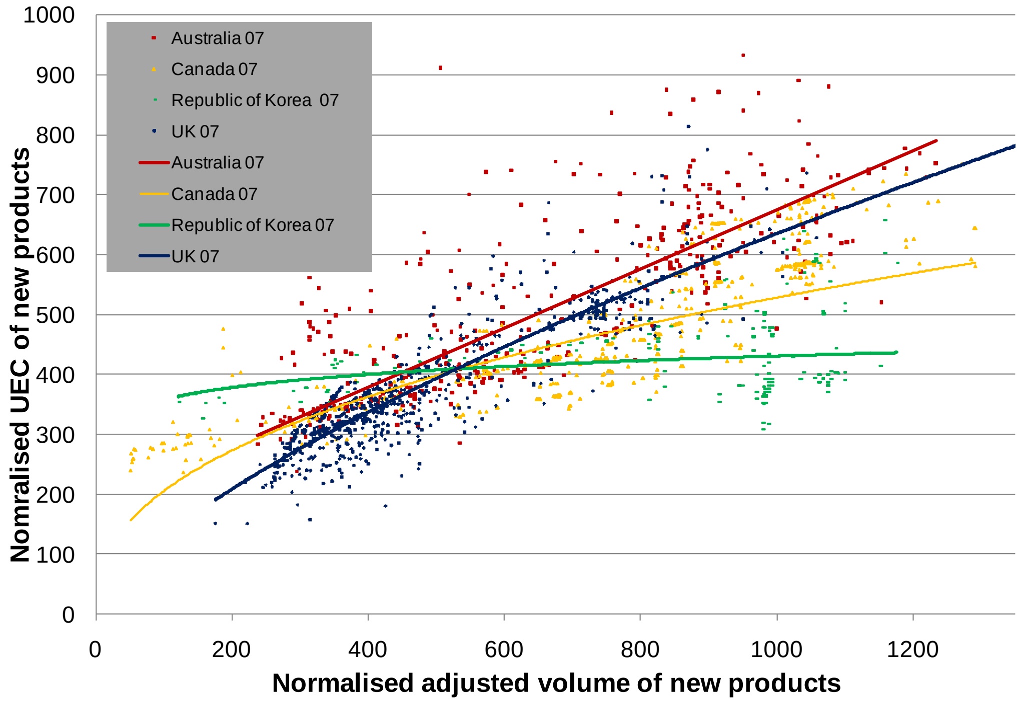
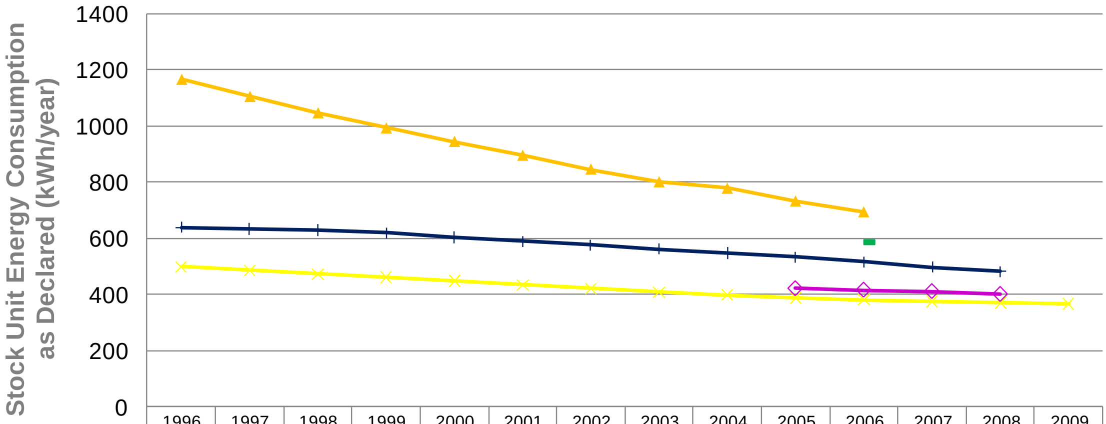
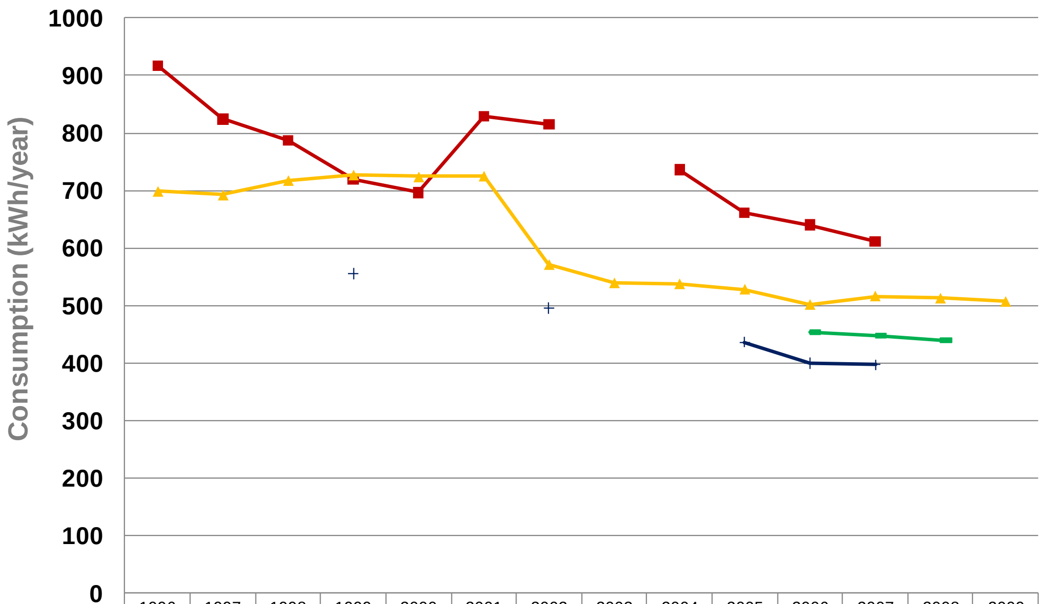


Figure 16: Illustrative Declared Product Energy Consumption of Stock



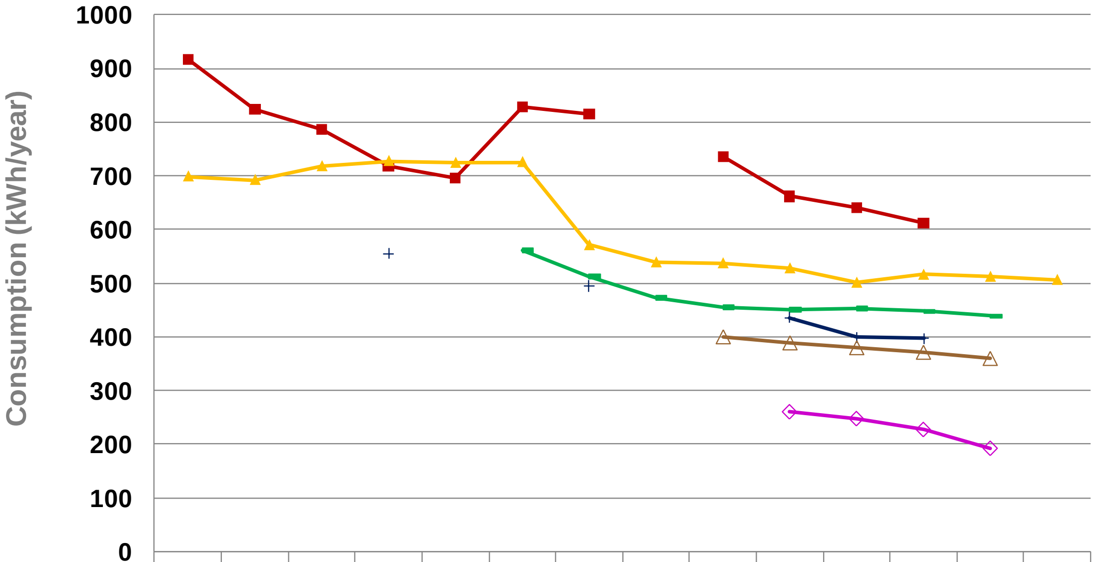
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia														
Austria														
Canada	1166	1105	1047	993	945	896	846	801	778	732	694			
Denmark	498	485	473	460	448	434	420	408	397	388	380	375	370	366
France														
Republic of Korea											587			
Switzerland														
UK	638	634	628	619	603	589	576	561	547	533	515	497	480	
USA														
China										420	415	410	400	
EU														
Japan														

Figure 17a: Robust Declared Product Weighted New Product Energy Consumption



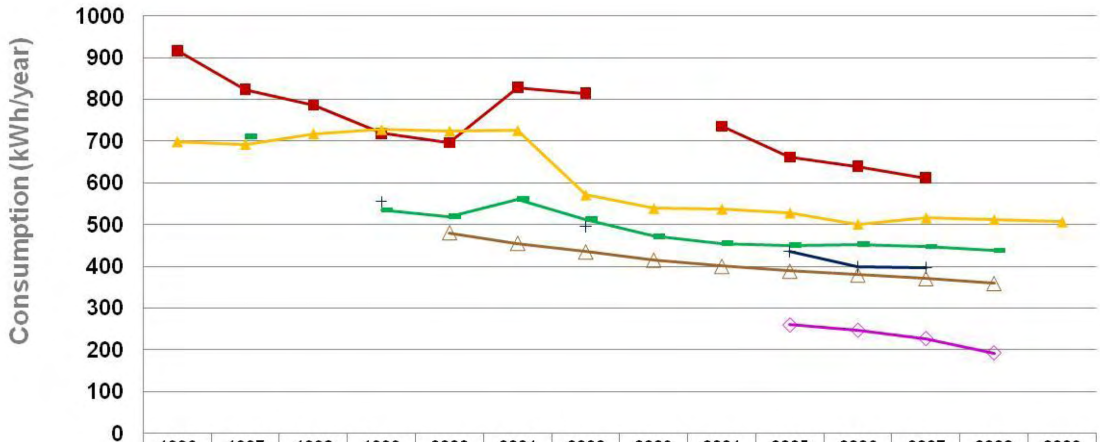
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	917	824	787	719	696	829	815		736	662	640	612		
Canada	699	693	718	728	724	726	571	539	537	528	501	516	512	506.6
Republic of Korea											453	447	439	
UK				555			495			436	399	397		

Figure 17b: Indicative Declared Product Weighted New Product Energy Consumption



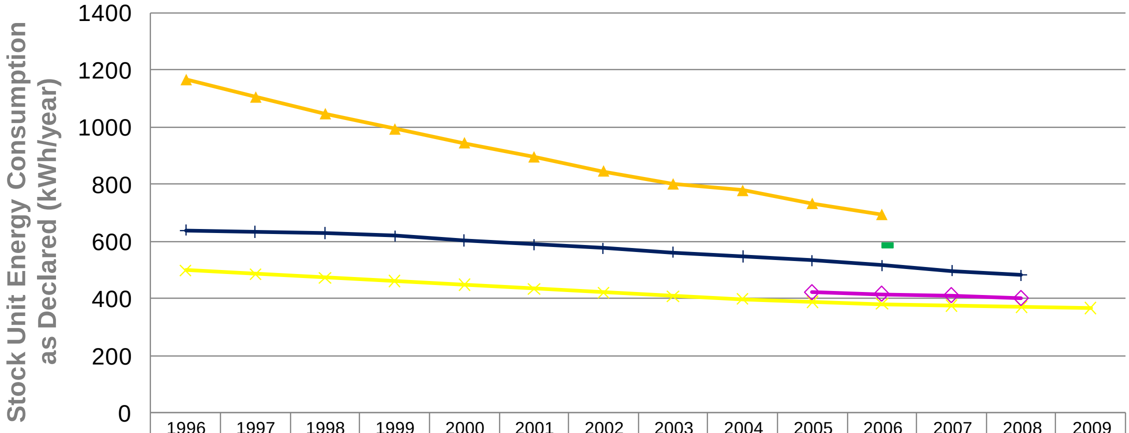
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	917	824	787	719	696	829	815		736	662	640	612		
Canada	699	693	718	728	724	726	571	539	537	528	501	516	512	506.6
Republic of Korea						562	513	472	456	450	453	447	439	
UK				555			495			436	399	397		
China										260	247	227	193	
EU									401	389	380	371	360	

Figure 17c: Illustrative Declared Product Weighted New Product Energy Consumption



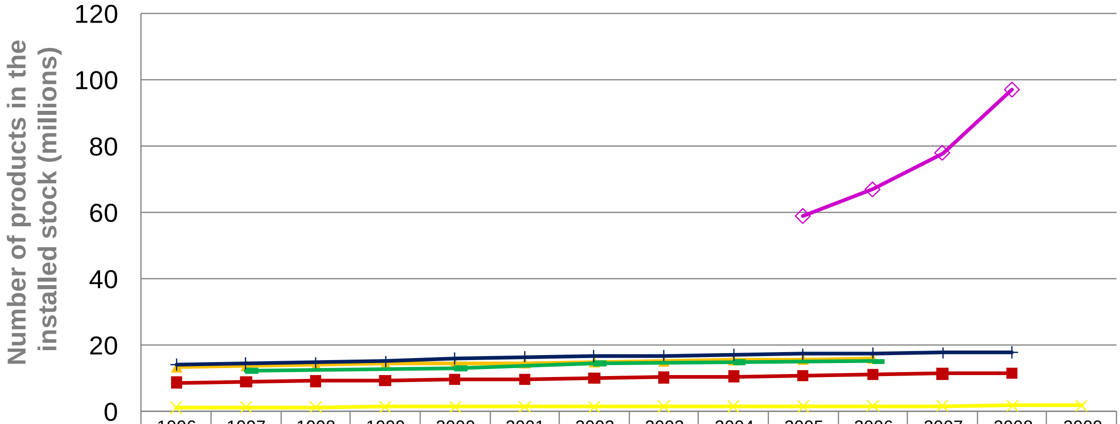
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	917	824	787	719	696	829	815		736	662	640	612		
Austria														
Canada	699	693	718	728	724	726	571	539	537	528	501	516	512	506.6
Denmark														
France														
Republic of Korea		711		535	520	562	513	472	456	450	453	447	439	
Switzerland														
UK				555			495			436	399	397		
China										260	247	227	193	
EU					481	456	435	416	401	389	380	371	360	
Japan														

Figure 20 Declared Product Weighted New Product Energy Consumption



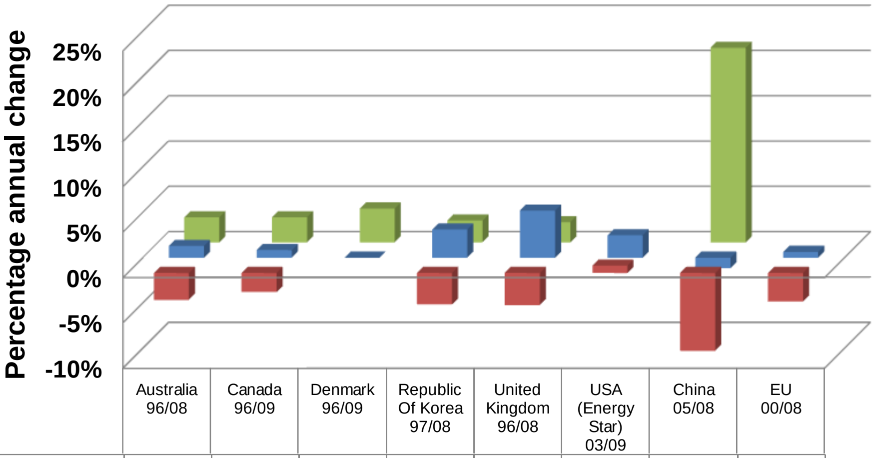
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia														
Austria														
Canada	1166	1105	1047	993	945	896	846	801	778	732	694			
Denmark	498	485	473	460	448	434	420	408	397	388	380	375	370	366
France														
Republic of Korea											587			
Switzerland														
UK	638	634	628	619	603	589	576	561	547	533	515	497	480	
USA														
China										420	415	410	400	
EU														
Japan														

Figure 21: Total Number of Products Installed (millions)



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	8.69	8.90	9.15	9.39	9.60	9.75	9.95	10.24	10.53	10.80	11.07	11.32	11.57	
Austria														
Canada	13.25	13.73	13.92	14.30	14.34	14.60	14.92	15.13	15.53	15.75	16.08			
Denmark	1.16	1.22	1.27	1.31	1.34	1.38	1.41	1.44	1.49	1.55	1.62	1.65	1.69	1.72
France														
Republic of Korea		12.36			12.94		14.38		14.82		15.04			
Switzerland														
UK	14.11	14.46	14.78	15.14	15.99	16.45	16.67	16.88	17.08	17.33	17.51	17.69	17.86	
USA														
China										59.00	67.00	78.00	97.00	
EU														
Japan														

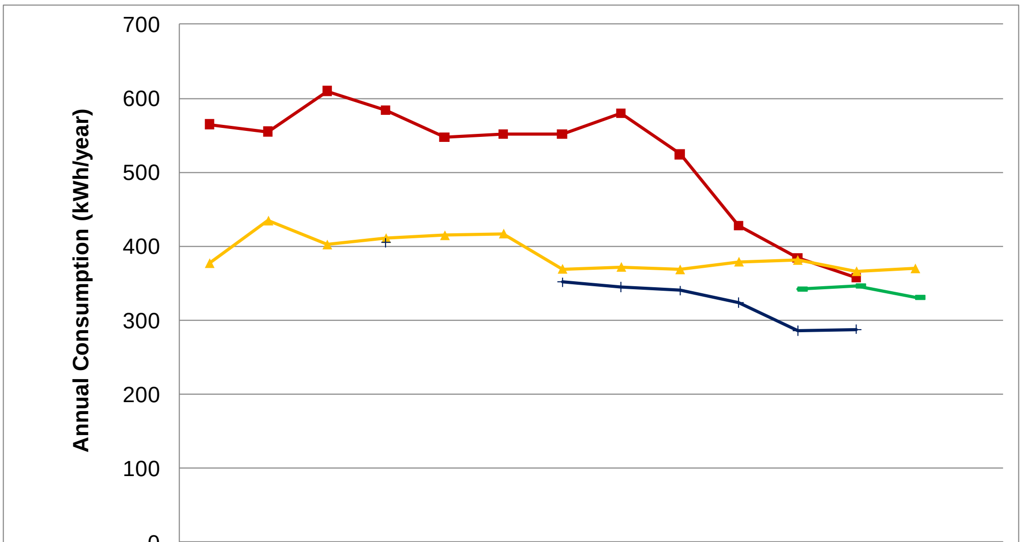
Figure 22: Illustrative Visual Summary of changes in volumes, unit energy consumption and products installed for all periods data available



	Australia 96/08	Canada 96/09	Denmark 96/09	Republic Of Korea 97/08	United Kingdom 96/08	USA (Energy Star) 03/09	China 05/08	EU 00/08
Product Weighted UEC (normalised)	-2.97%	-2.10%		-3.48%	-3.56%	0.80%	-8.59%	-3.15%
Gross Volume of all Compartments (adjusted)	1.31%	0.83%	0.00%	3.11%	5.19%	2.47%	-1.18%	0.64%
Number installed	2.76%	2.76%	3.73%	2.41%	2.21%		21.47%	

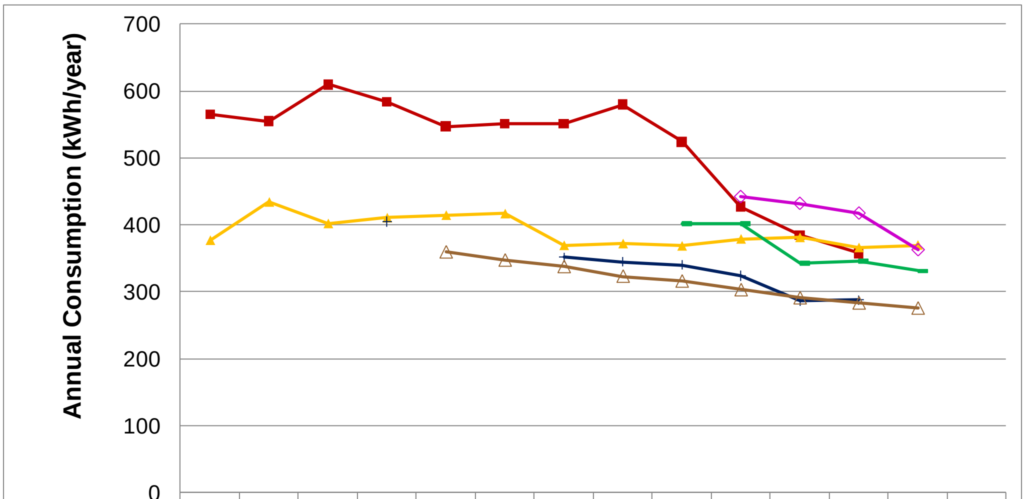
Annex 3: Graphics and Data Tables for Freezers

Figure 3a: Robust Normalised New Product Weighted Energy Consumption (kWh/year)



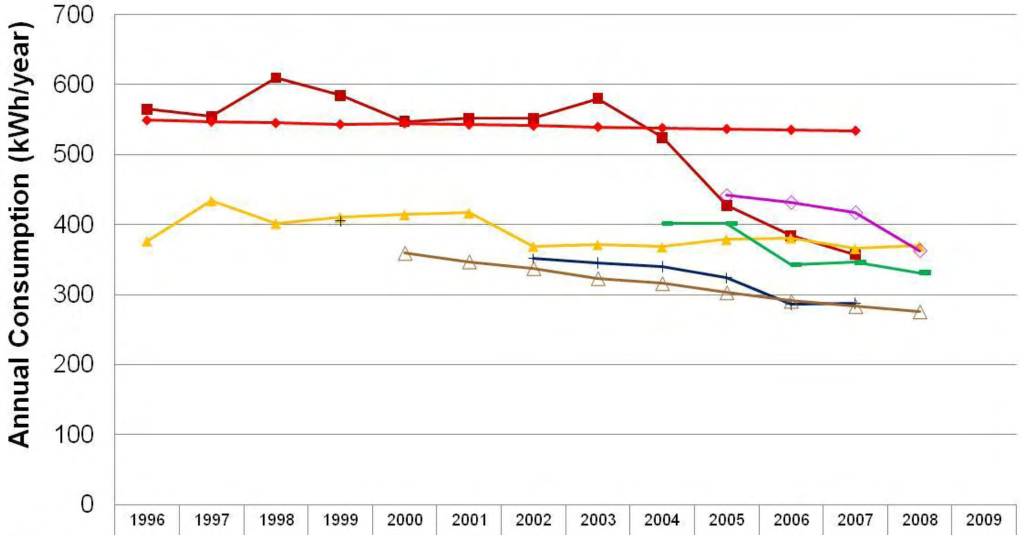
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	565	555	610	584	547	552	552	580	524	427	384	358		
Canada	377	434	402	411	414	417	369	372	368	379	381	366	370	
Republic of Korea											342	346	331	
UK				405			351	345	340	324	286	288		

Figure 3b: Indicative Normalised New Product Weighted Energy Consumption (kWh/year)



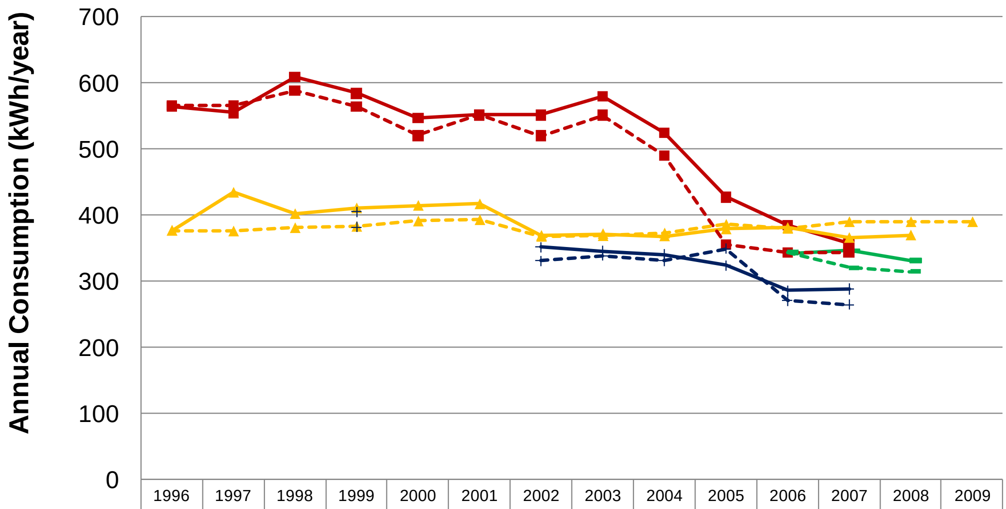
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	565	555	610	584	547	552	552	580	524	427	384	358		
Canada	377	434	402	411	414	417	369	372	368	379	381	366	370	
Republic of Korea									401	402	342	346	331	
UK				405			351	345	340	324	286	288		
China										442	432	417	362	
EU					359	347	337	323	316	303	291	283	276	

Figure 3c: Illustrative Normalised New Product Weighted Energy Consumption (kWh/year)



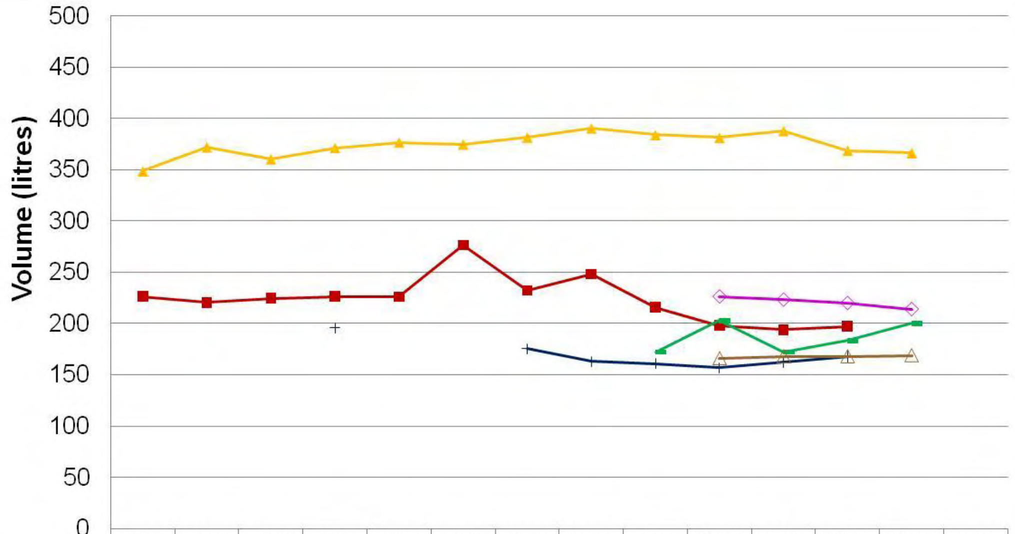
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	565	555	610	584	547	552	552	580	524	427	384	358		
Austria	549	547	545	543	545	543	541	539	538	537	535	534		
Canada	377	434	402	411	414	417	369	372	368	379	381	366	370	
Republic of Korea									401	402	342	346	331	
UK				405			351	345	340	324	286	288		
China										442	432	417	362	
EU					359	347	337	323	316	303	291	283	276	

Figure 4: Indicative Normalised New Product Sales Weighted (SW) and Product Weighted Energy Consumption (kWh/year)



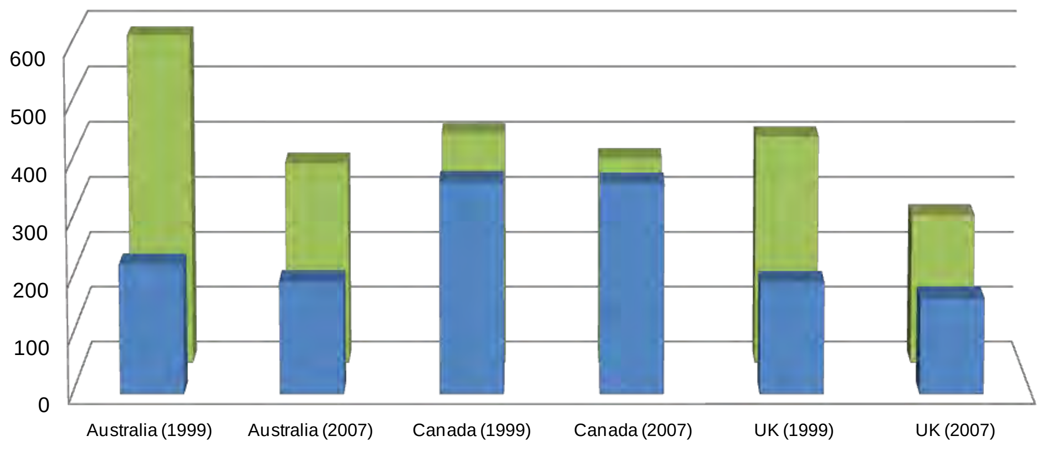
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	565	555	610	584	547	552	552	580	524	427	384	358		
Canada	377	434	402	411	414	417	369	372	368	379	381	366	370	
Republic of Korea											342	346	331	
UK				405			351	345	340	324	286	288		
Australia SW	567	566	588	565	520	552	520	551	490	355	344	343		
Canada SW	377	376	381	383	391	393	368	369	373	386	380	390	390	390.0
Republic of Korea SW											344	321	315	
UK SW				382			331	339	331	349	271	265		

Figure 8: Illustrative Average Unadjusted Frozen Compartment Volume (litres)



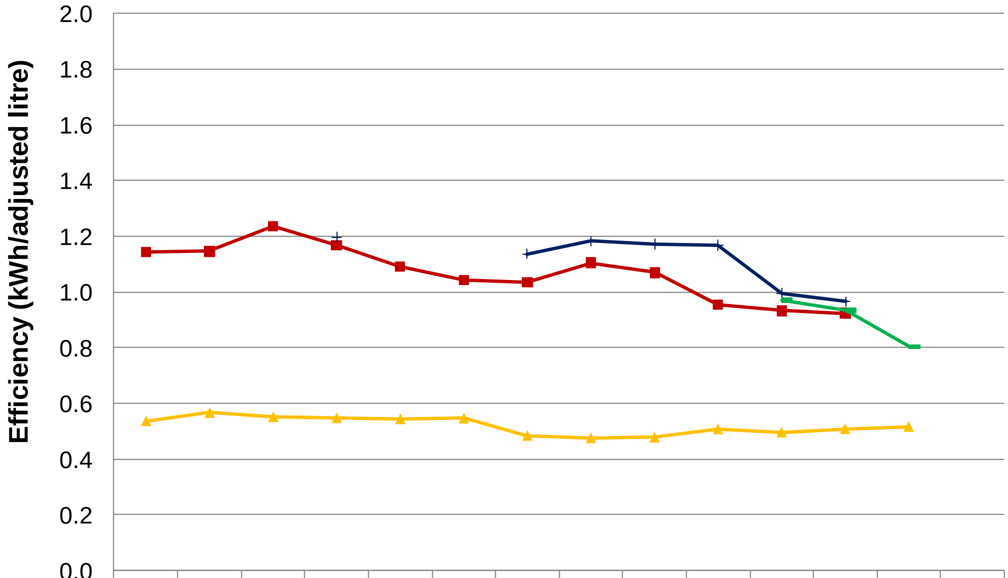
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	226	221	224	226	226	277	232	248	216	198	194	197		
Canada	349	372	361	371	377	375	382	390	384	381	388	369	367	
Republic of Korea									172	203	172	183	200	
UK				196			175	163	161	157	163	168		
China										226	223	220	214	
EU										166	168	168	169	

Figure 9: Illustrative Visual Representation of Comparative Volumes and Normalised Energy Consumptions for 1999 and 2007



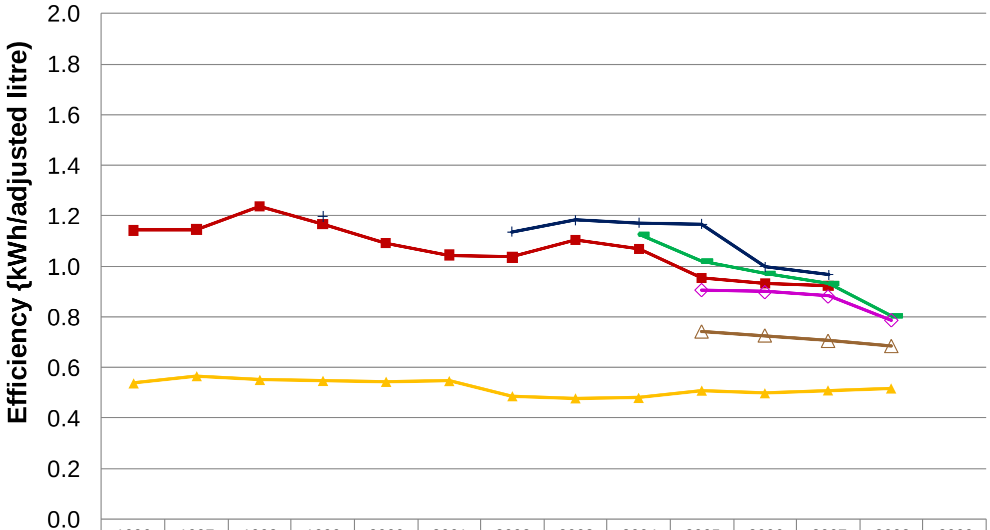
	Australia (1999)	Australia (2007)	Canada (1999)	Canada (2007)	UK (1999)	UK (2007)
Ave. Freezer Volume (litres)	226	197	371	369	196	168
Ave. Annual Consumption (normalised kWh/year)	584	358	411	366	405	265

Figure 14a: Robust Normalised Efficiency of New Products (kWh/yr/adjusted volume)



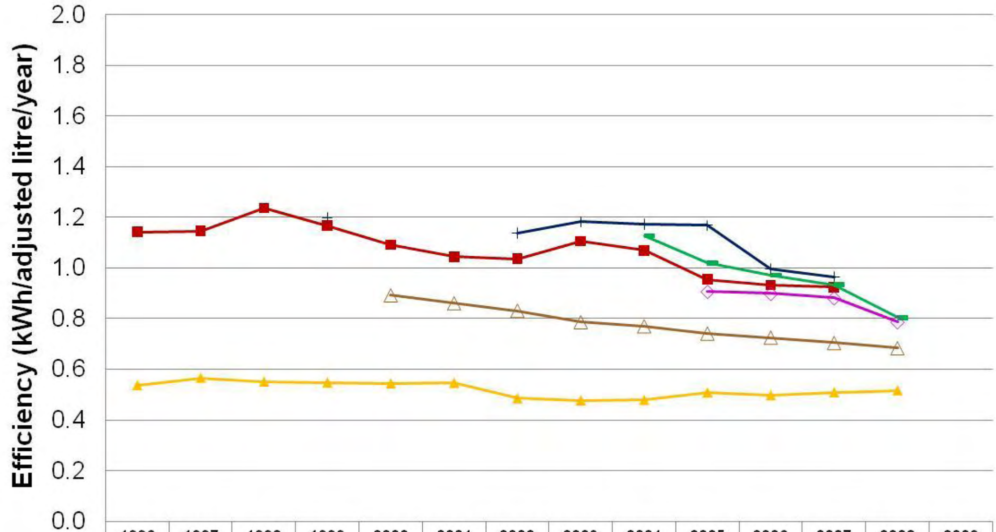
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	1.14	1.15	1.24	1.17	1.09	1.04	1.04	1.1	1.07	0.96	0.93	0.92		
Canada	0.54	0.57	0.55	0.55	0.54	0.55	0.49	0.5	0.48	0.51	0.50	0.51	0.52	
Republic of Korea											0.97	0.93	0.80	
UK				1.20			1.14	1.2	1.17	1.17	1.00	0.97		

Figure 14b: Indicative Normalised Efficiency of New Products (kWh/yr/adjusted volume)



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	1.14	1.15	1.24	1.17	1.09	1.04	1.04	1.1	1.07	0.96	0.93	0.92		
Canada	0.54	0.57	0.55	0.55	0.54	0.55	0.49	0.5	0.48	0.51	0.50	0.51	0.52	
Republic of Korea									1.13	1.02	0.97	0.93	0.80	
UK				1.20			1.14	1.2	1.17	1.17	1.00	0.97		
China										0.91	0.90	0.88	0.79	
EU										0.74	0.73	0.70	0.68	

Figure 14c: Illustrative Normalised Efficiency of New Products (kWh/yr/adjusted volume)



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	1.14	1.15	1.24	1.17	1.09	1.04	1.04	1.1	1.07	0.96	0.93	0.92		
Canada	0.54	0.57	0.55	0.55	0.54	0.55	0.49	0.5	0.48	0.51	0.50	0.51	0.52	
Republic of Korea									1.13	1.02	0.97	0.93	0.80	
UK				1.20			1.14	1.2	1.17	1.17	1.00	0.97		
China										0.91	0.90	0.88	0.79	
EU					0.89	0.86	0.83	0.8	0.77	0.74	0.73	0.70	0.68	

Figure 15: Robust Comparison of Energy Consumption (kWh/year) for Individual Models by Volume (litres), with a best fit (power) line added (kWh/year)

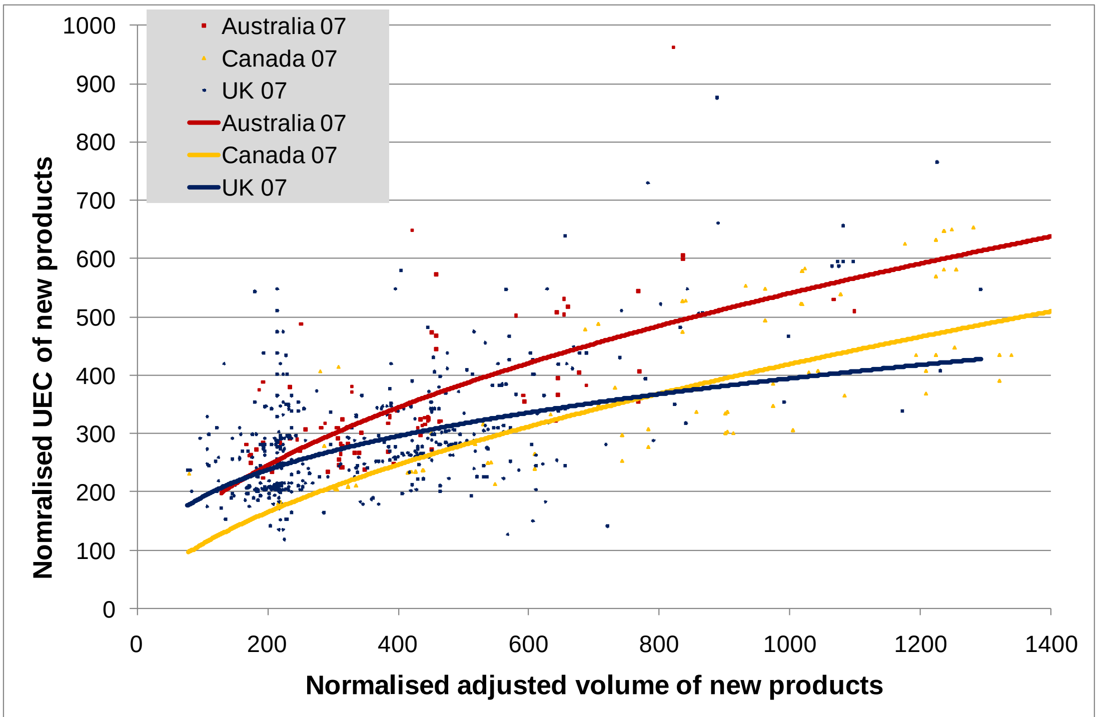
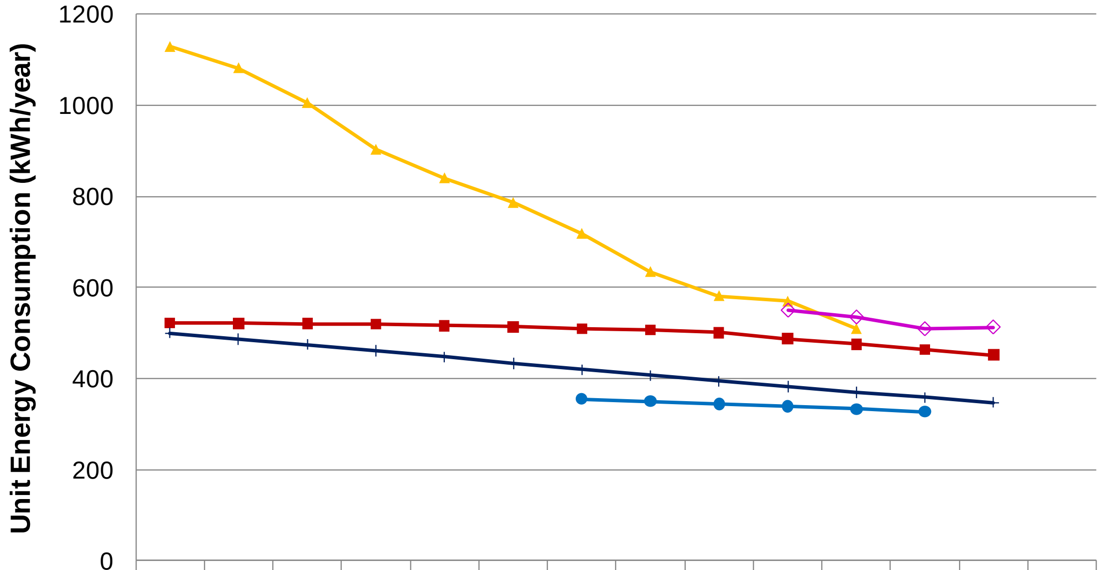
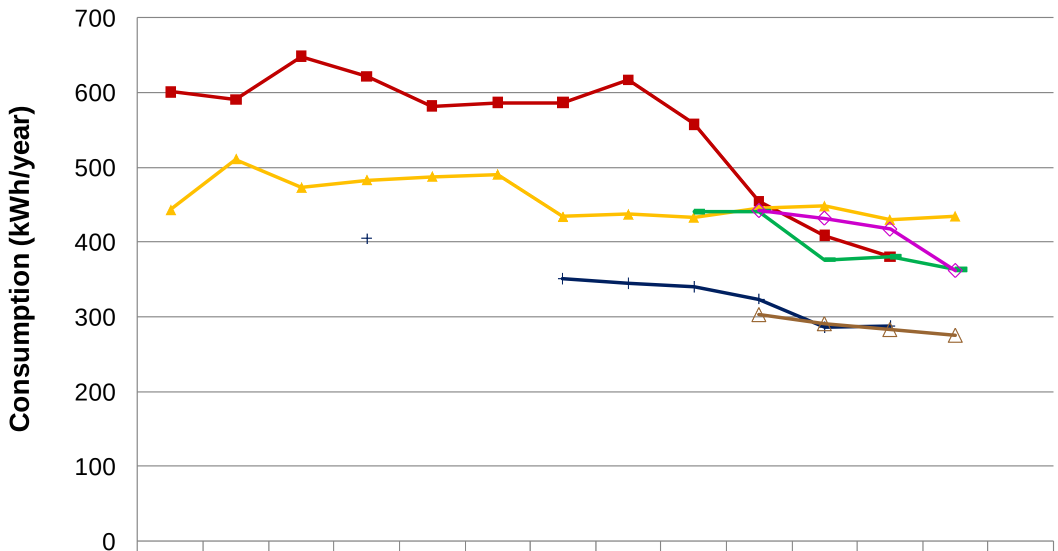


Figure 18: Illustrative Declared Product Energy Consumption of Stock (kWh/year)



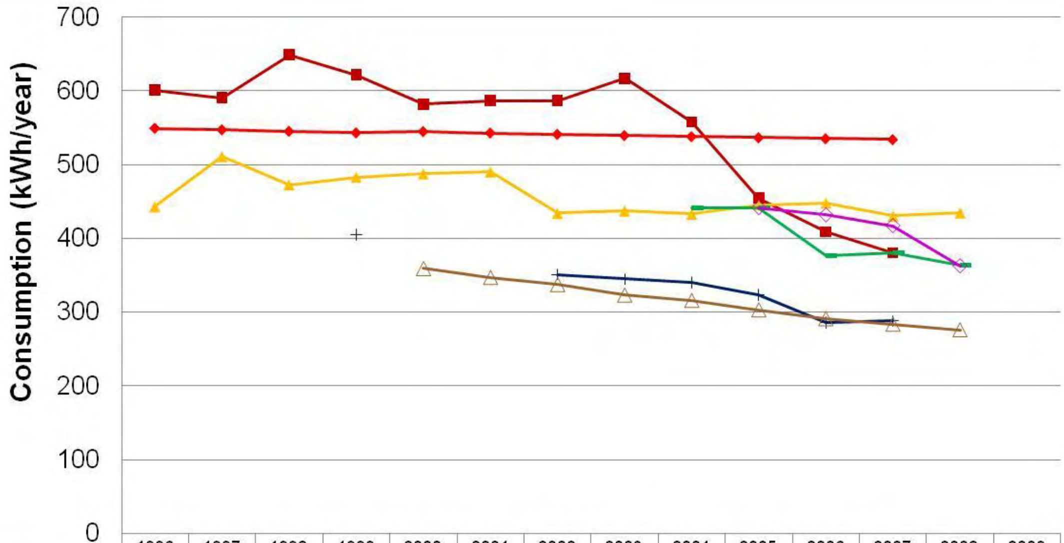
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	522	521	520	519	516	513	510	506	501	487	475	463	452	
Canada	1129	1082	1006	903	840	786	718	634	581	569	509			
Switzerland							355	350	344	339	333	327		
UK	499	486	474	461	447	433	419	406	394	382	370	358	347	
China										550	535	509	513	

Figure 19b: Indicative Declared Product Weighted New Product Energy Consumption



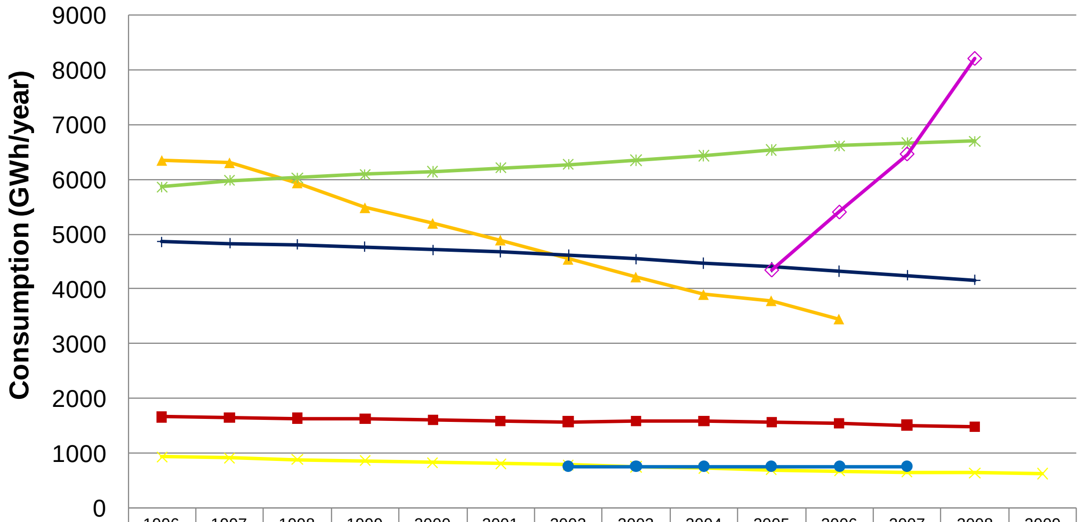
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	601	590	649	622	582	587	587	617	558	455	409	380		
Canada	443	511	473	483	488	490	434	437	433	446	448	430	435	
Republic of Korea									441	441	376	380	364	
UK				405			351	345	340	324	286	288		
China										442	432	417	362	
EU										303	291	283	276	

Figure 19c: Illustrative Declared Product Weighted New Product Energy Consumption



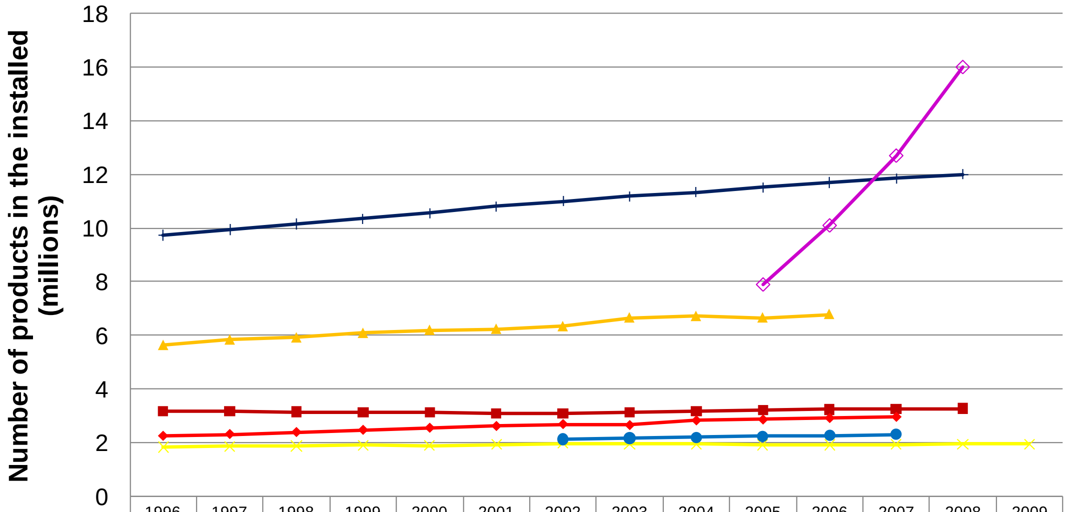
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	601	590	649	622	582	587	587	617	558	455	409	380		
Austria	549	547	545	543	545	543	541	539	538	537	535	534		
Canada	443	511	473	483	488	490	434	437	433	446	448	430	435	
Republic of Korea									441	441	376	380	364	
UK				405			351	345	340	324	286	288		
China										442	432	417	362	
EU					359	347	337	323	316	303	291	283	276	

Figure 23: Illustrative Total Stock Energy Consumption (GWh/year)



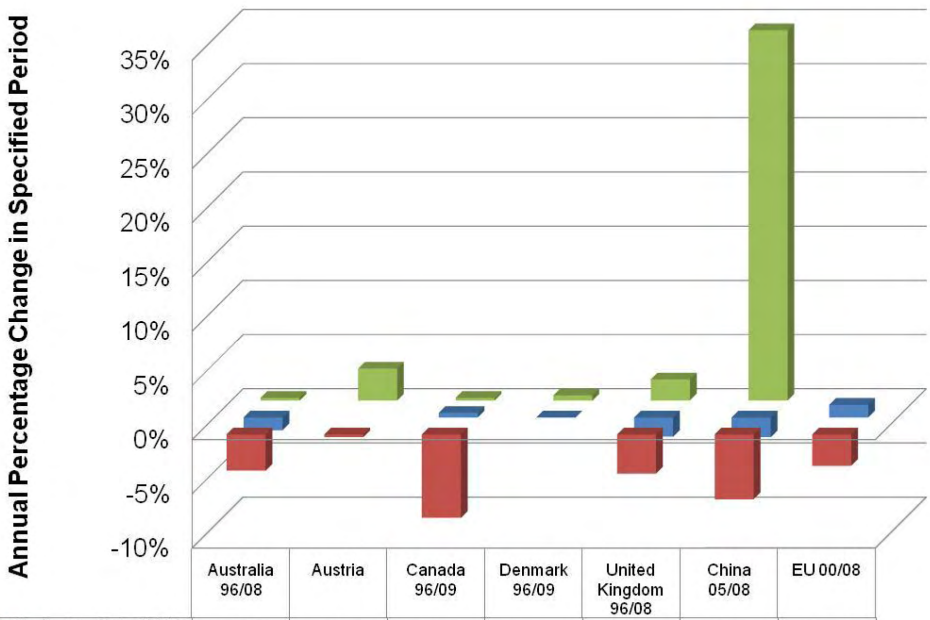
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	1660	1645	1635	1621	1608	1586	1570	1583	1590	1568	1539	1508	1477	
Canada	6354	6311	5943	5489	5204	4898	4546	4222	3901	3789	3454			
Denmark	931	909	883	860	827	805	783	748	721	692	672	653	636	620
France	5862	5980	6034	6092	6145	6216	6273	6350	6440	6544	6620	6664	6700	
Switzerland							754	756	755	755	754	752		
UK	4861	4835	4813	4772	4718	4677	4616	4545	4469	4399	4325	4247	4167	
China										4345	5404	6464	8208	

Figure 24: Illustrative Total Number of Products Installed (millions)



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	3.18	3.16	3.14	3.12	3.12	3.09	3.08	3.13	3.18	3.22	3.24	3.26	3.27	
Austria	2.24	2.30	2.38	2.46	2.54	2.61	2.68	2.65	2.83	2.86	2.92	2.96		
Canada	5.63	5.83	5.91	6.08	6.19	6.23	6.33	6.66	6.71	6.66	6.79			
Denmark	1.83	1.86	1.88	1.90	1.89	1.93	1.96	1.94	1.94	1.92	1.92	1.93	1.94	1.95
Switzerland							2.12	2.16	2.19	2.23	2.26	2.30		
UK	9.73	9.95	10.15	10.35	10.56	10.81	11.01	11.19	11.34	11.53	11.70	11.86	12.01	
China										7.90	10.10	12.70	16.00	

Figure 25: Illustrative Visual Summary of Annual Changes in Volumes, Unit Energy Consumption and Products Installed for all periods data available



	Australia 96/08	Austria	Canada 96/09	Denmark 96/09	United Kingdom 96/08	China 05/08	EU 00/08
Product weighted UEC (normalised)	-3.34%	-0.25%	-7.69%		-3.61%	-5.99%	-2.90%
Gross Volume of compartment (adjusted)	-1.17%		0.43%	0.00%	-1.77%	-1.82%	1.17%
Number installed	0.24%	2.95%	0.24%	0.47%	1.95%	34.18%	

Annex 4: Alternative Analysis Using Differing Correct Factors for Test Temperature

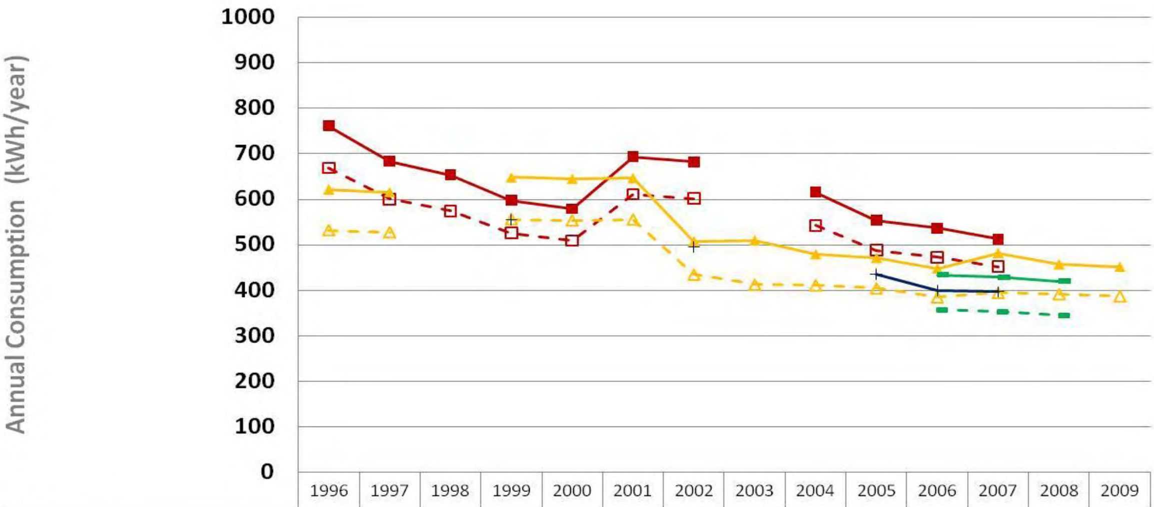
Annex 1 details the conversion factors used in this analysis and report to “normalise” product energy performance values between countries which use differing internal and external temperatures during product testing. However, an alternative set of conversion factors has been proposed as follows:

	Percentage Increase/Reduction in Energy Consumption for each ^{o}C difference in testing temperature
Internal Freezer Compartment	*3.5%*
Internal Fresh Food Compartment	*2%*
External Temperature	*5%*

Use of these correction factors leads to significant differences in the resulting average energy consumptions and efficiencies of products within countries. However, while the absolute values change, the relative average performance of products from countries outside the EU remains broadly the same, with an overall movement of all none EU countries relative to countries within the EU. This is demonstrated in Figure 26 which shows the normalised annual product energy consumptions using the original (sold lines) and alternative (dashed lines) conversion factors. The absolute values for annual energy consumption have fallen for Australia, Canada and Korea (by 12%, 15% and 17% respectively), but these countries have moved little relative to each other. The key difference is the major change in comparative performance of products within these countries relative to products from the EU (demonstrated by their movement relative to the UK)[43]. Similar movements are shown in Figures 27 and 28a/28b which illustrate the average efficiency of products over time, and the unit energy consumption of products by volume in 2007 using the original conversion factors and the alternative.

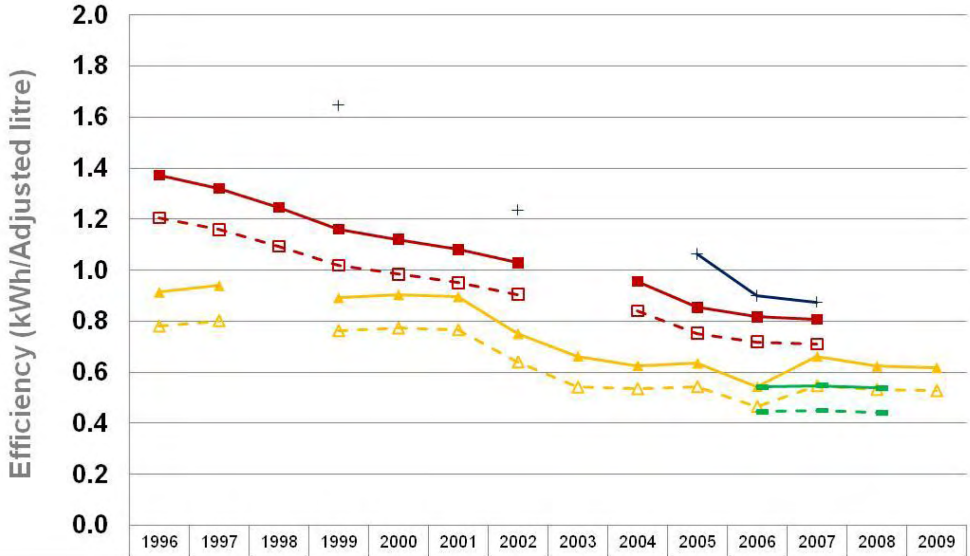
While it is clear such movements would result in absolute changes in the values quoted throughout this report, it is believed that the observations and recommendations made would remain broadly the same and thus remain valid.

[43] Note that from EU countries only the UK was able to supply model level data. However, as all EU countries (and Switzerland) have the same testing regime, any changes in comparative performance relative to the UK will be identical to the changes in comparative performance relative to all EU countries (and Switzerland).



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	762	684	654	598	579	694	683		616	554	537	513		
Australia - alternative	669	601	574	526	509	611	602		543	488	473	452		
Canada	622	616		648	645	647	508	510	479	471	448	482	457	451.6
Canada - alternative	532	528		556	554	555	435	413	412	405	385	395	393	387.9
Republic of Korea											434	429	420	
Republic of Korea - alternative											357	353	346	
UK				555			495			436	399	397		

Figure 26: Annual Energy Consumption of Refrigerator/Freezer Combinations Using Original and Alternative Conversion Factors for Normalising Differing Testing Temperatures (kWh/year)



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia	1.37	1.32	1.25	1.16	1.12	1.08	1.03		0.96	0.85	0.82	0.81		
Australia - alternative	1.20	1.16	1.09	1.02	0.98	0.95	0.91		0.84	0.75	0.72	0.71		
Canada	0.91	0.94		0.89	0.90	0.90	0.75	0.7	0.63	0.64	0.54	0.66	0.62	0.62
Canada - alternative	0.78	0.80		0.76	0.77	0.77	0.64	0.5	0.54	0.54	0.47	0.55	0.5	0.5
Republic of Korea											0.54	0.55	0.54	
Republic of Korea - alternative											0.45	0.45	0.44	
UK				1.65			1.24			1.06	0.90	0.88		

Figure 27: Annual Energy Efficiencies of Refrigerator/Freezer Combinations Using Original and Alternative Conversion Factors for Normalising Differing Testing Temperatures (kWh/year)

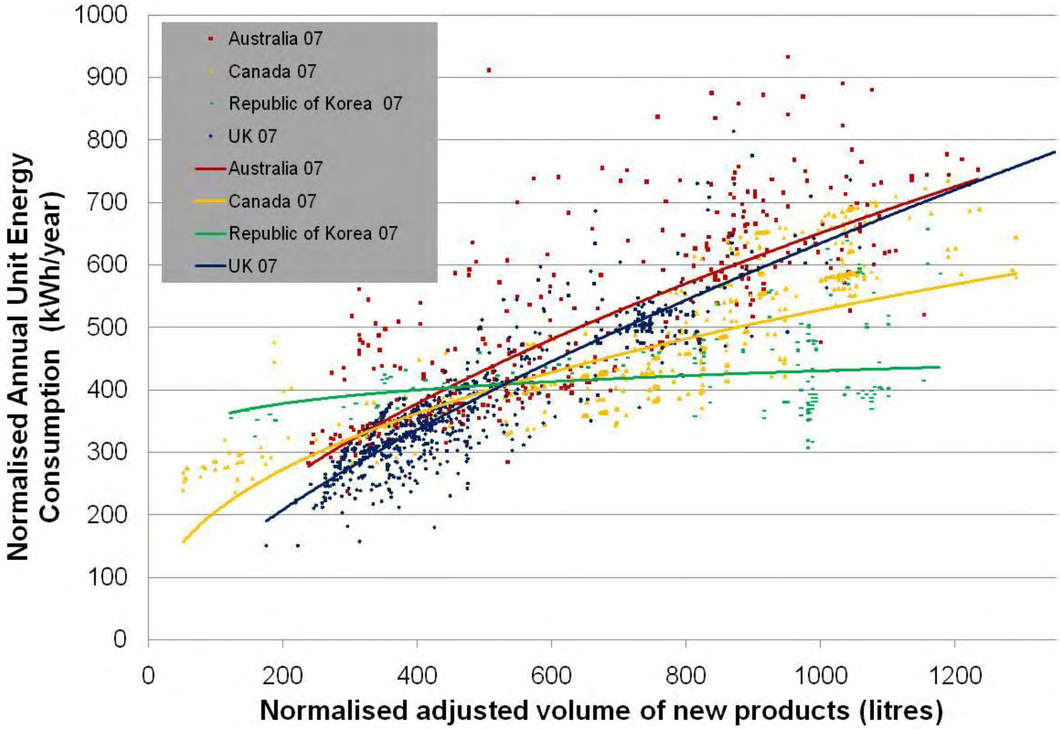


Figure 28a: Robust Comparison of Energy Consumption (kWh/year) for Individual Models by Volume (litres), with a best fit (power) line added using Original Conversion Factors

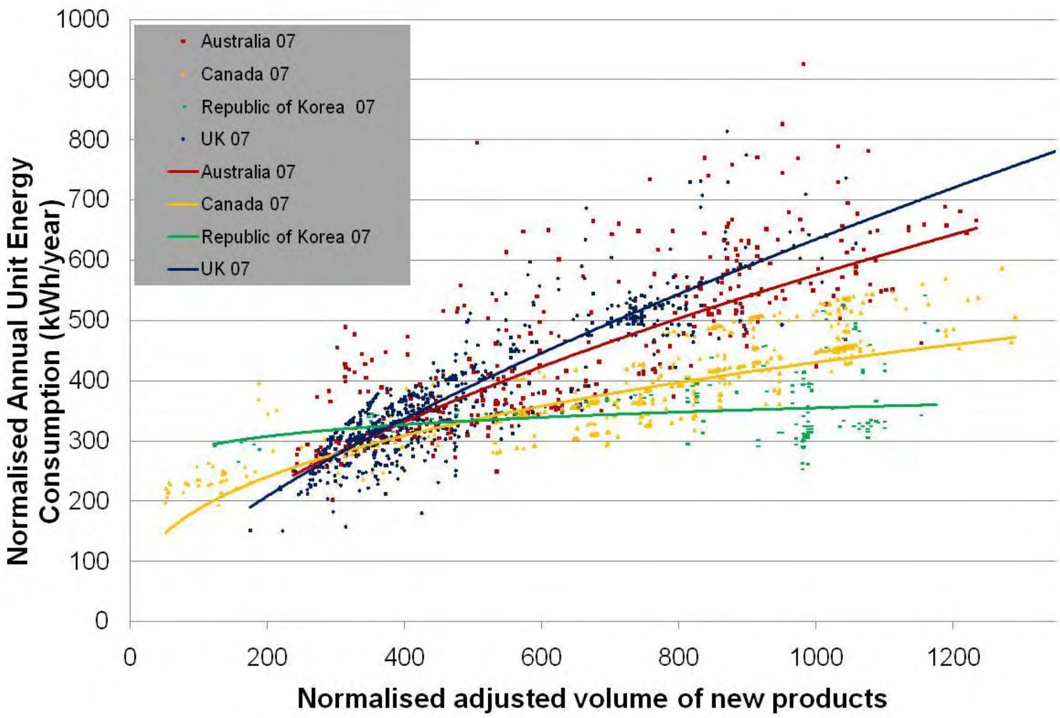


Figure 28b: Robust Comparison of Energy Consumption (kWh/year) for Individual Models by Volume (litres), with a best fit (power) line added using Alternative Conversion Factors