Benchmarking Document

## Technology: Residential Air conditioners
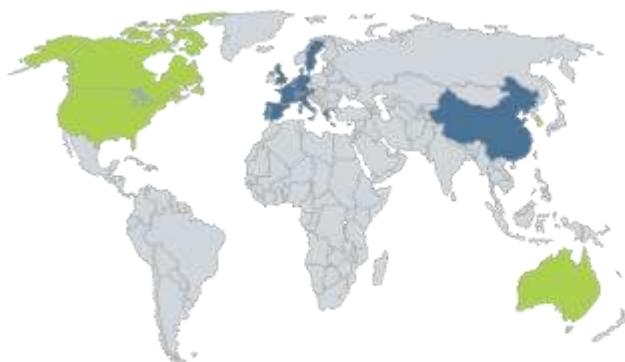
Introduction

This document explains the overall conclusions from mapping of air conditioner performance standards in five countries plus data for the EU10, comparing trends and performance in the countries mapped. For a detailed product definition see http://mappingandbenchmarking.iea-4e.org/, but in summary:

Definition & scope	*'Air conditioners used in dwellings and designed to maintain the temperature of indoor air at a given temperature level for a given heat load to be extracted.'* Including only (at this stage): • Products of up to 14 kW cooling capacity • Electrically driven vapour compression (Absorption units excluded) • Cooling only units, and • Cooling function of reverse cycle units • Air cooled condensers, and water/condensate spray assisted • Only air to air units (water chillers excluded)

Type	Unitary ('packaged', in single mounting, including double duct units)	Split units, (single room unit and single condenser linked by pipe-work, but NOT ducts)	Multi-split (two or more room units and single condenser linked by pipe-work, but NOT ducts)
Other variables noted	Mounting (Window / thru-wall; Other fixed mounting; Mobile) Variable speed drive / multi-speed compressor (yes / no) Refrigerant (designated according to ASHRAE refrigerant numbering system) Standby consumption (*note: No data submitted*)		

Note: Ducted air conditioners (central) and single-ducted (portable) units are excluded from this analysis.
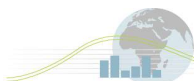
Benchmarking Energy Efficiency of New Air conditioners

Summary for Policy Makers

This report summarises the analysis and conclusions on the nature and performance of new air conditioners from Australia, Canada, China, Republic of Korea and USA, plus data for the EU including GfK[1] sales data for EU10 as a whole and data from an EU wide manufacturers' product certification scheme. The analysis only looked at unitary (packaged), split and multi-split products. Ducted products, such as ducted central air-conditioners, common in USA and Canada, were excluded from the analysis.

The key issues identified for policy makers are:

- Policies in the Republic of Korea, which has had the most stringent MEPS levels of participating countries since 2004, appear to have been highly successful in raising product standards towards practical/economic, if not technical limits. Whilst there may be some practical differences in the type of product that is dominant in the Korean versus other markets[2], the performance levels of Korean residential split air-conditioners are around 20% above performance levels of other countries for product weighted data, and by around 8% for sales weighted data. Other countries appear to be catching up though.

- The Australian and EU markets are catching up with the Republic of Korea in split product performance, and MEPS levels in China will become more stringent than those in the Republic of Korea during 2010.

- Simplistic analysis implies that split products apparently have a larger scope for improvement than unitary products.

- The previous policy focus on use of Energy Efficiency Ratio (EER) and the analysis presented here probably underestimate the improvements that have actually occurred in real operation of better products. One of the major innovations in recent years has been the use of variable speed compressors, which provide better instantaneous EERs in cooler weather (when running at less than full capacity). The Seasonal EER (SEER) metric much better reflects real performance, and these improvements, and is now the focus of policies in most regions.

- Products with variable or multispeed compressors can make significant savings in real life application. Such savings are made apparent by using the SEER metric in preference to EER. SEER is now being used in many cases as the performance metric of choice for market monitoring, incentives and minimum standards.

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[1] GfK is a global commercial provider of retail product sales data from 'point of sale' (i.e. checkout data from retailers), combined with other market and performance data provided by manufacturers.
[2] Cooling only products dominate the Republic of Korea market, whereas reverse cycle units dominate in EU and Australia for example.

- There appears to be significant scope for improvement in the full load efficiency of all but the very best of products. Since average sales weighted EERs lie between 3 and 3.5 and yet best products and achieving over 6 and the theoretical maximum is around 6.5.

- The full load EER of unitary products has hardly changed since 1996, split products have improved gradually and consistently at around 3% per year since 2000. This is likely to have been influenced by successive MEPS and labelling policies although no conclusive evidence of a direct link was established.
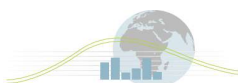
Table 1. Summary of characteristics of products in the data sets on air conditioners for new sales

| Aspect	Global trends, local variations
Cooling capacity *(robust)*	Average cooling capacity of **unitary** products is around 3.3 kW; for **split** products 4.8 kW. **Recent trend:** unitary products very little change in recent years; split products falling between 5% and 10% over three to five years.
Types of product in each market *(illustrative)*	Data availability did not allow the actual proportion of products within each market to be determined with any reliability. However, *of the types of product covered by the analysis* (note that significant products of some markets are excluded from this analysis), it appears that split products dominate the European, Australian and Republic of Korea markets; unitary products dominate the Canadian market (excluding central air-conditioning equipment). Inadequate data available to characterise the US market. **Recent trend**: No data available.
Refrigerant type *(not graded for robustness)*	Inadequate data available to fully characterise any markets, but a significant trend towards R410a HFC refrigerant is apparent for split and unitary products in the Australian and EU markets, with almost 100% of EU products using this refrigerant and nearly 60% of Australian products in 2008.
Reverse cycle capability *(not graded for robustness)*	The proportion of reverse cycle products is less than 10% for Canadian and Republic of Korea products, but has risen above 70% for EU and Australian markets.
Variable/multi speed compressor *(not graded for robustness)*	Data was only available for Australia and EU 10 (GfK data) and showed significant and rapid rise from less than 10% in 2003 to around 50% in 2007/2008.
Product stock and consumption *(not graded for robustness)*	Estimated stock was provided for the Republic of Korea at 7.7 million in 2006, Canada with 2.4 million in 2008, and China with 47 million in 2000. The only estimate of consumption was for the Republic of Korea with 34 TWh in 2006.
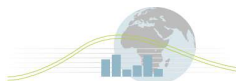
Table 2. Summary of energy performance issues on new unitary and split air conditioners.

| Aspect	Global Trends, local variations
Energy Efficiency Ratio (EER) *Product-weighted* *(indicative)*	Republic of Korea split products have average EER levels of 3.6 in 2009, 20% higher than the other countries which together have a spread of only 2% around 3.1. For unitary products, Canadian and the Republic of Korea products appear to have the better energy efficiency levels of around 3.0, with a total spread of only 12% in 2008 for participating countries and an average around 2.9. **Recent trends**: Product weighted EER for unitary products has hardly changed since 1996 for these markets. Product weighted efficiency levels for split products have been rising consistently at around 3% per year since 2000.
Energy Efficiency Ratio (EER) *Sales-weighted* *(indicative)*	Sales weighted EER for unitary products is around 3.0 for Australia and the Republic of Korea. Average EER for split products was 3.3 in 2008 with Republic of Korea split products performing around 8% higher than the other countries. **Recent trends**: Both unitary and split products appear to be improving efficiency at nearly 10% every two years in Australia and EU whereas products from the Republic of Korea are not showing any improvement trend for unitary, with a slight fall for split products.
Best and worst EER *(robust)*	Only the US dataset appears to show any significant improvement in the best EER with a jump of over 10% from 2007-2008. For split products the Republic of Korea has had the product with the highest or joint highest EER in every year covered by these datasets with 6.1 in 2006 and 5.7 in 2009. The best unitary product in any year achieved an EER of 4.2 with an EU product in 2005. The worst unitary product had an EER of 2.4 in 2009 from the EU, with the worst split product at an EER of 2.3 for a Canadian product in 2009.
Scope for improvement *(illustrative)*	Data implies that there is generally greater scope for improvement on split products than there is for unitary products. The ratio of performance of the average product in a country compared to the performance of the best product in any market for any year is between 65% and 73% for unitary products, and between 49% and 60% for split products.
Seasonal Energy Efficiency Ratio (SEER) *(n/a)*	SEER data were only available for 2009 from the Republic of Korea and Canada. There was therefore inadequate data to merit analysis. SEER could be included if this analysis is repeated in a future year but only if data is made available.
Standby *(n/a)*	Standby data was only available for Australia and implies a sales weighted average of 4W in 2008, and a worst performer of around 40W.

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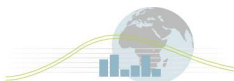
Principal limitations on analysis and datasets

Data was invited on unitary, split and multi-split type products and for the other characteristics as described in the table on page 2. Most of the data covers 2003 to 2009 and the majority is for split air conditioners, with some for unitary products and very little on multi-splits. Datasets include three mandatory government databases (Australia, Republic of Korea and Canada), two voluntary registration scheme databases (Eurovent and US ENERGY STAR) and high-level government statistics from China. Sales weighted data on energy performance was available for Australia, Republic of Korea and EU10 (from GfK).

The principal issues limiting the robustness of this analysis are:

- The comparability of the test methodologies could not be exhaustively verified due to their complexity and lack of access to all documents. However, all are declared to be based around ISO5151 and ISO13253. Normalisations were made for one known difference (for Republic of Korea, adjusted downwards by less than 2%) with others assumed to be directly comparable. and

- Most data is as declared by manufacturers, without third-party verification. The exceptions are sample testing intrinsic to the EU Eurovent Certification dataset, and that Canadian government data is all third-party verified.

- The various datasets include types of product which are defined in different ways in different countries. Best efforts have been made to filter out products deemed out of scope, and to ascertain that only the relevant products are included. Due to these differences in terminology and lack of access to the full test standards and other supporting documentation, direct comparability cannot be guaranteed in all cases. For these reasons, analysis is only included for separate product types, with no attempt to combine all products into one graph as that could be misleading.

- The products included do not represent the full market in any country. Data cannot therefore be considered as typical of the whole air-conditioning market in any country. For example, the most common type of residential air-conditioning in Canada and the US is the central ducted system which is excluded from this analysis.

- The 'EU10' GfK data covers ten EU countries[3] and required conversion from energy label class to EER, for which an average EER was assumed for each label class.

- Data for Canada and USA is not sales weighted. However, due to the fairly high volume of products included these datasets should be representative of the majority of products on the market (though only better performing products for the US ENERGY STAR data, see below), and so indicative conclusions can be drawn nevertheless.

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[3] EU10 for which GfK collected this data set are: Italy, Spain, Portugal, Greece, Great Britain, France, Germany, Netherlands, Belgium and Sweden. The data covers all 'GfK panel' (direct to consumer) sales of fixed (mobile excluded) air conditioners less than 12kW capacity. This includes split, multi-split and 'single' (packaged) products in the 10 countries, plus sales through the 'professional channel' (i.e. to wholesalers and contractors) of these products in Italy since 2008, and in Greece since 2007. It is estimated that this data accounts for 70% to 80% of the total residential market in those countries.
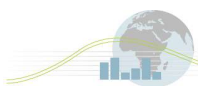
- Data for USA is from the ENERGY STAR programme and so does not represent the full market spread. Estimated market share covered by ENERGY STAR listed products has varied as in Table 3 below. In 2007 it was estimated[4] that around 50% of all air conditioner products offered by the 11 registered manufacturers were ENERGY STAR qualified. The US dataset has not been included in market analysis nor most of the graphs for these reasons. This dataset is, however, plotted alongside others in Figure 23 of Annex 1.

- It is generally difficult in air-conditioner statistics to distinguish between products sold into the residential market and products sold into the commercial market. This is one reason for the 14 kW capacity limit being adopted, assuming that products above 14 kW would be predominantly for commercial use. The proportion of products below 14 kW that is used mainly for commercial purposes is unknown and will probably vary in different markets. This has not been (and probably cannot be) taken into account in the analysis.

Table 3. Estimated market coverage of the products included in the ENERGY STAR room air conditioner category. Note US data is not included in most analysis in this report.

Year	2002	2003	2004	2005	2006	2007	2008	2009
% of market that was ENERGY STAR qualified[5]	37%	29%	35%	52%	36%	50%	43%	36%

Table 4. Comparison of test methodologies from participating countries.

Country	Test method(s)	Comments	Climate class
Australia	AS/NZS3823	"Cloned from ISO5151 and ISO13253"	T1
Canada	CAN/CSA-C368.1-M90 (R2002) (also CAN/CSA-C656-05)	Uses 10 CFR 430, Subpart B, Appendix F (and Appendix M for Central air conditioners)	Very close to T1[5]
Republic of Korea	KS C 9306	"In line with ISO 5151 and ISO 13253"	Modified T1 condition (indoor wet bulb 0.5DegC higher)
USA	10 CFR 430, Subpart B, Appendix F	Consistent with ASHRAE Standard 16/69	Very close to T1[6]
China	General: GB/T 7725-2004. Unitary: GB/T17758-1999	"Based upon ISO, US or EU standards, including those that underpin the ENERGY STAR programme"	Assumed T1
EU	EN14511-2004	"Compatible with ISO 5151 and with ISO 13253 standards"	T1

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[4] ROOM AIR CONDITIONERS - 2007 PRODUCT SNAPSHOT, US Department of Energy, page 4.
[5] Market estimates that may not be consistent between years, from sales census reports at http://www.energystar.gov/index.cfm?c=manuf_res.pt_appliances#asd
[6] The difference is only that caused by US test methodologies rounding to the nearest degree Fahrenheit.
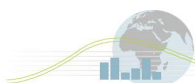
The data sets can be characterised into five distinct kinds:

1. Two of the six data sets are mandatory Government databases (Australia and Republic of Korea), which include full market coverage of individual products with sales data. For 2008 1,038 products were analysed for Australia, and 1,550 for the Republic of Korea.

2. Canadian data is from a mandatory federal database of individual products but does not include any sales data. Product type content of the original database varies significantly between different years[7], but 336 products were analysed for 2009.

3. Data for the USA is from the ENERGY STAR database for 2010 and so is only representative of the better products on the US market (see above). Historical products have been deduced from this database by means of the date of registration field, combined with assumptions about how long any given product would remain on the market. This does not include any sales data, but 650 products were analysed.

4. Data for the EU comes from two separate sources: Firstly GfK data covering EU10 which is sales weighted by energy label class with around 80% market coverage. Secondly an EU wide product certification scheme database from 2002, 2005 and 2009 from Eurovent which includes 2,422 products analysed for 2009. The Eurovent database includes all major EU manufacturers but total market coverage is unknown.

5. Data for China consists only of high-level government statistics with no individual product data. The test methodology and proportion of market covered for this data is unknown.

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[7] For example, the proportion of packaged terminal air-conditioners (PTACs) included varied from 0% to 78%, which could be due to anomalies during filtering of the database prior to submission.

Important Cautions for Interpreting Mapping and Benchmarking Information – Grading of conclusions for robustness

The aim of the Mapping and Benchmarking Annex is, within a defined 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. Grading of the outputs is provided so that policy makers can understand the relative reliability of outcomes and recommendations.

The data gathered by the Annex for analysis is necessarily from different and varied sources. In some cases sources and data quality vary significantly within a single set of information supplied for one country for a single product group. Clearly this problem is magnified when data is collected for a number of countries. Variability's within data for one country and/or between data for different countries include:

- Scope of market covered (best to worst, product types/sub-types)
- Proportion of all sales accounted for by products listed
- Whether data is provided as market average statistics, in product sub groups (by size, technology etc.) or as lists of individual product data
- Whether data is supplier declared values, or third party tested data
- Sales weighted or no/partial sales data
- Completeness of energy and associated product performance and type data
- Whether energy data is supplied as absolute values or as energy label classifications
- Test methodology (consistency, accuracy, validity)
- Consistency between successive years (i.e. if trends are valid)

Sometimes data sets require manipulation or adjustment before they become comparable with other data from the same country, and/or with data from other countries although this has been minimised and also explained where it was judged necessary. Further, the specific approaches taken have been detailed in the overall Mapping and Benchmarking Framework, with steps specific to particular products explained in the Product Definition and in the individual Country Mapping Sheets and, where necessary, within the Benchmarking document.

In addition, there may be local indirect influences on efficiency for regulatory or cultural reasons that may explain differences. Examples for air conditioning products include significant differences in the type of product dominating the markets: Split air conditioners in the Republic of Korea are predominantly of the cooling only type, whereas split units in Europe and Australia tend to be mostly reverse cycle type. This could contribute to differences in average performance. Secondly, it has been suggested that regulations on noise levels from equipment could influence the scope for improvement in efficiency for a given budget and product size. And thirdly, there may be differences in the tolerances allowed in reporting efficiency levels. All three of these issues are beyond the scope of

analysis in this report.

The variability's and known flaws across the data sets have been taken into account during analysis and drawing of any conclusions. Unfortunately it is not possible within the project budget to provide sensitivity analysis to quantify how robust the data sets are. Thus, in order to provide a reader with some indication of how confident they should be in the results, the analysis and graphics within the benchmarking documents have been labeled '**robust'**, '**indicative'** or **illustrative'** according to the judgement of the analysis team. *This assessment is necessarily a professional judgement because the variability's are complex and different in every case.*

Given it has not been possible to derive a set of water-tight definitions that can be applied to each individual case, the rationale influencing the judgement is provided in the framework below to provide some transparency:

1   Framework for Grading Mapping and Benchmarking Outputs

Data and output quality grading assessments have been made for a country's complete data set and, if necessary, also for sub-sets of the data where they differ. It is also possible that different quality assessments may be necessary for individual years of data within a sub-set, for example when different sources have been used for some years. In such cases the quality grading reflects the majority of the data, with annotations to explain anomalies. The quality grading framework is also separately applied to the conclusions or graphs comparing two or more countries' data sets.

2   For an individual country (mapping):

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

Conclusions from such data sets are as reliable as reasonably possible within boundaries outlined above.

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

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

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

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

3   For comparison between countries (benchmarking):

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

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

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

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

Illustrative – where:
- One or more significant parts of the data sets are themselves 'illustrative' and/or
- Data manipulations for the benchmarking process contain an element of speculation or significant assumption

Rather than being rejected completely, perhaps because the flaws in the data are at least consistent, such data could provide insight into the market situation and so is

worth reporting, but results must be treated with caution.

Grading of country data for air conditioners

Using the framework described above, the cooling capacity and efficiency (EER) data on air conditioner performance has been graded as in Table 5 and Table 6:

Table 5. Product data quantity and assigned quality for product weighted data.

Country	Number of products analysed (in most recent year)	Assigned quality	Comment / justification
Australia	1,038 (2008)	indicative	Mandatory Federal register. Full market 2003 to 2008.
Canada	336 (2009)	indicative	Mandatory Federal register. Covers 1996 to 2009 for unitary; 2009 only for split.
Republic of Korea	1,550 (2008)	indicative	Mandatory government register. Full market for 1996 to 2009. Data set for unitary products is small (less than 50 products in any year, less than 20 since 2006).
USA	650 (2009)	illustrative	ENERGY STAR voluntary scheme and only better products. Covers 2006 to 2010. Only unitary products included.
China	-		No product data available.
EU	2,422 (2009)	indicative	Eurovent voluntary certification database, all major suppliers represented. Data for 2002, 2005 and 2009.

Table 6. Product data quantity and assigned quality for sales weighted data.

Country	Assigned quality	Comment / justification
Australia	Robust	Mandatory Federal register. Full market 2003 to 2008
Canada	-	No sales data available
Republic of Korea	Robust	Mandatory government register. Sales data for 2006, 2007 and 2008. Data set for unitary products is small (less than 20 models per year since 2006).
USA	-	No sales data available
China	Illustrative	Test methodology not confirmed; not known if representative of whole market. Covers 2005 to 2008.
EU	Indicative	GfK market research data for 2002 to 2009. Conversion from energy label data assumes an average EER for each label class.
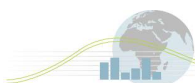
Additional notes on data analysis

1. The only normalisation that has been carried out is for the Republic of Korea dataset for which a small adjustment (less than 2%) was made to compensate for a very small difference in one test temperature. See Annex 2.

2. No adjustment has been made for variation in power supply voltage or frequency.

3. Energy Efficiency Ratio is expressed in Btu per hour/W for US and Canadian products, but in kW/kW for the other countries analysed. US and Canadian EERs were multiplied by 0.293 to convert to kW/kW for benchmarking.

4. No normalisation has been carried out on EER values to compensate for differences in average cooling capacity. This was not deemed necessary as EER did not vary with capacity for unitary products, nor did it vary at all with capacity for split products from the Republic of Korea, and by around 0.07 /kW for split products from other countries.

5. USA data is from ENERGY STAR and so represents the better products on the US market and data are therefore not comparable with full market data from other countries.

6. 'Product-weighted' data is derived from a simple listing of products as provided i.e. with no sales weighting. 'Sales weighted' data reflects the proportion of products actually sold.

7. The dataset on unitary products from the Republic of Korea contained few products (less than 20) in 2006 and each year since. This was deemed insufficient to justify their inclusion in the analysis and this data was removed from graphs.

8. Evaluating best and worst product data (see Figure 13, Figure 14, Figure 15 and Figure 16): The Australian, Canadian, Korean, Eurovent and USA data sets enabled identification of individual products, but as USA data was ENERGY STAR it could not be used to identify any 'worst products'. Hence this can only be considered an indicative perspective on best and worst products.

Characteristics of products in the data sets

Key issues arising from the characteristics of products in the data sets are summarised in **Table 1.**

Note that these characteristics cannot be deemed representative of the full market in any of these countries due to the exclusion of certain types of product from this analysis, and the high variability in the proportion of the full market that the analysed data represents.

Cooling capacity (indicative)

See Figure 1 (unitary) and Figure 2 (split). Despite some variation, the overall trend for cooling capacity of **unitary** products has been fairly level with a recent average of around 3.3 kW.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia (Sales weighted)								3.1	3.1	3.0	3.1	3.1	3.0	
Austria														
Canada (Product weighted)	3.6	3.0	3.8	2.7	2.6	3.9	3.4	3.3	3.3	3.1	3.5	3.6	3.5	3.4
Denmark														
France														
Republic of Korea (Product weighted)	3.3	3.5	2.7	3.0	2.9	3.1	3.0	3.0	3.1	3.0				
Switzerland														
UK														
USA (Product weighted)														
China														
EU (Product weighted)							4.3			3.8				3.7
Japan														
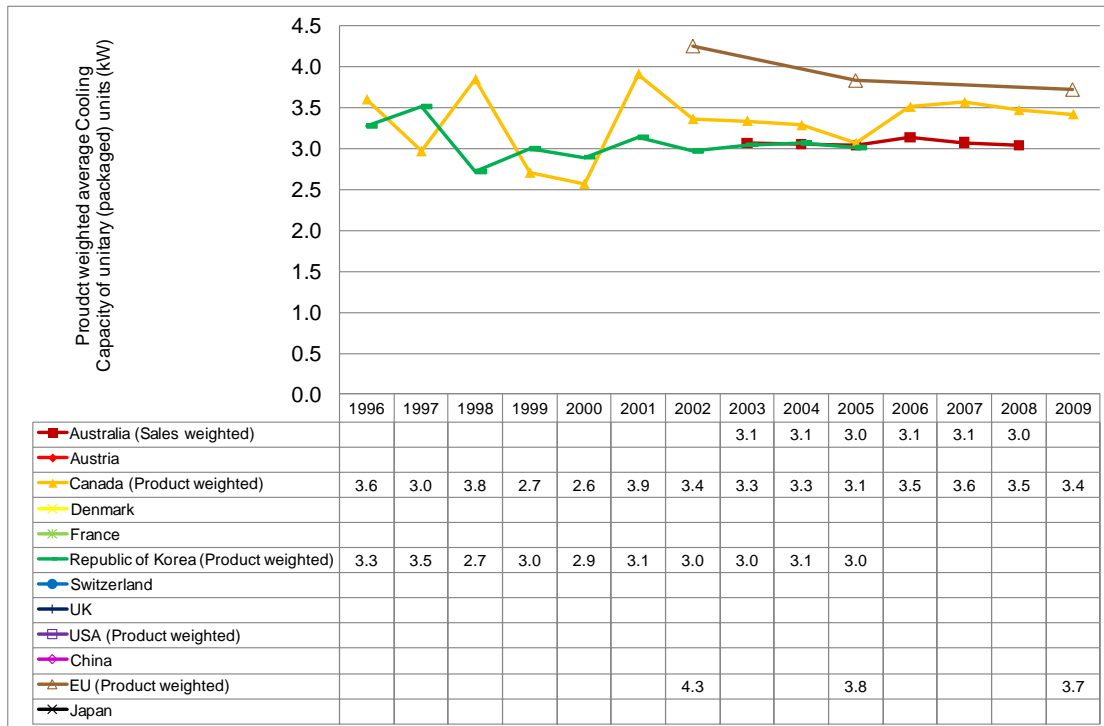
Figure 1. Graph of average cooling capacity for unitary (packaged) units (kW). Note that unitary data from the Republic of Korea since 2006 has been deleted (very few products); USA data was ENERGY STAR and so is not comparable (being a selective sub-set of the market).

Sales weighted data for **split** products from Australia and the Republic of Korea, and from China appears to show a downward trend in capacity in recent years (falling some 5% to 10% over 3-5 years), with an average for 2008 of around 4.8 kW.
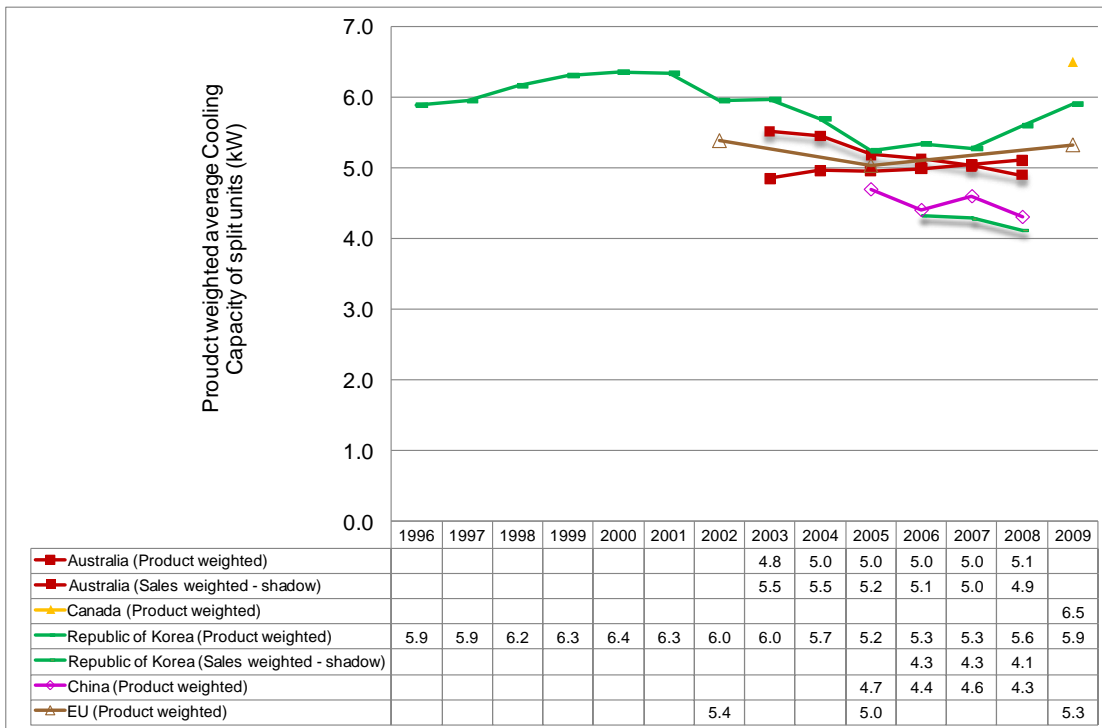
Figure 2. Graph of average cooling capacity for split units (kW).

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia (Product weighted)								4.8	5.0	5.0	5.0	5.0	5.1	
Australia (Sales weighted - shadow)								5.5	5.5	5.2	5.1	5.0	4.9	
Canada (Product weighted)														6.5
Republic of Korea (Product weighted)	5.9	5.9	6.2	6.3	6.4	6.3	6.0	6.0	5.7	5.2	5.3	5.3	5.6	5.9
Republic of Korea (Sales weighted - shadow)											4.3	4.3	4.1	
China (Product weighted)										4.7	4.4	4.6	4.3	
EU (Product weighted)							5.4			5.0				5.3

Types of product in each data set

Note that this data is not representative of the proportion of products on the full national market since several types of products are not included within the scope of this analysis. Most notably in Canada and the US the residential market is dominated by central ducted systems which are **not** included. For the avoidance of doubt regarding US and Canadian systems, the split products included do not relate to any ducted systems. Understanding of the full market could only be achieved if the scope of analysis and scope of submitted data are significantly expanded.

Figure 3 shows what proportion of product types were included in the data analysed for each country / region. Split products dominated in three datasets and accounted for two thirds of the 5,996 individual products for which data was analysed across all countries. Unitary products dominated the US and Canadian data sets (but note that they do not dominate the overall markets as ducted systems are excluded from the analysis). Unitary products accounted for just under one fifth of all product data analysed across all countries.

Note that the dataset from the Republic of Korea contained relatively few unitary products, reducing from a maximum of 45 in 1996 to only six in 2009. It was not considered statistically useful to plot datasets with less than 20 data points and so unitary data from 2006 was deleted from the analysis.
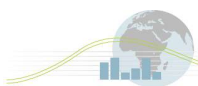
Multi-split products only appeared in the EU (GfK) data set with 3.9% of the market, but this data was not analysed for benchmarking.

The proportion of product types also varied over time within each dataset as, for example, different products were added to the scope of government schemes.

	Australia 08 (Sales Weighted)	Canada 09 (Product Weighted)	Republic of Korea 08 (Sales weighted)	EU 09 (Sales weighted)	USA 09 (Product Weighted)
■ % of Multi-Split models	0.0%	0.0%	0.0%	3.9%	0%
■ % of Packaged models	24.2%	84.5%	1.0%	0.6%	100%
■ % of Split models	75.8%	15.5%	99.0%	95.5%	0%

Product types shown are based on the data analysed
(and may not represent the whole market)
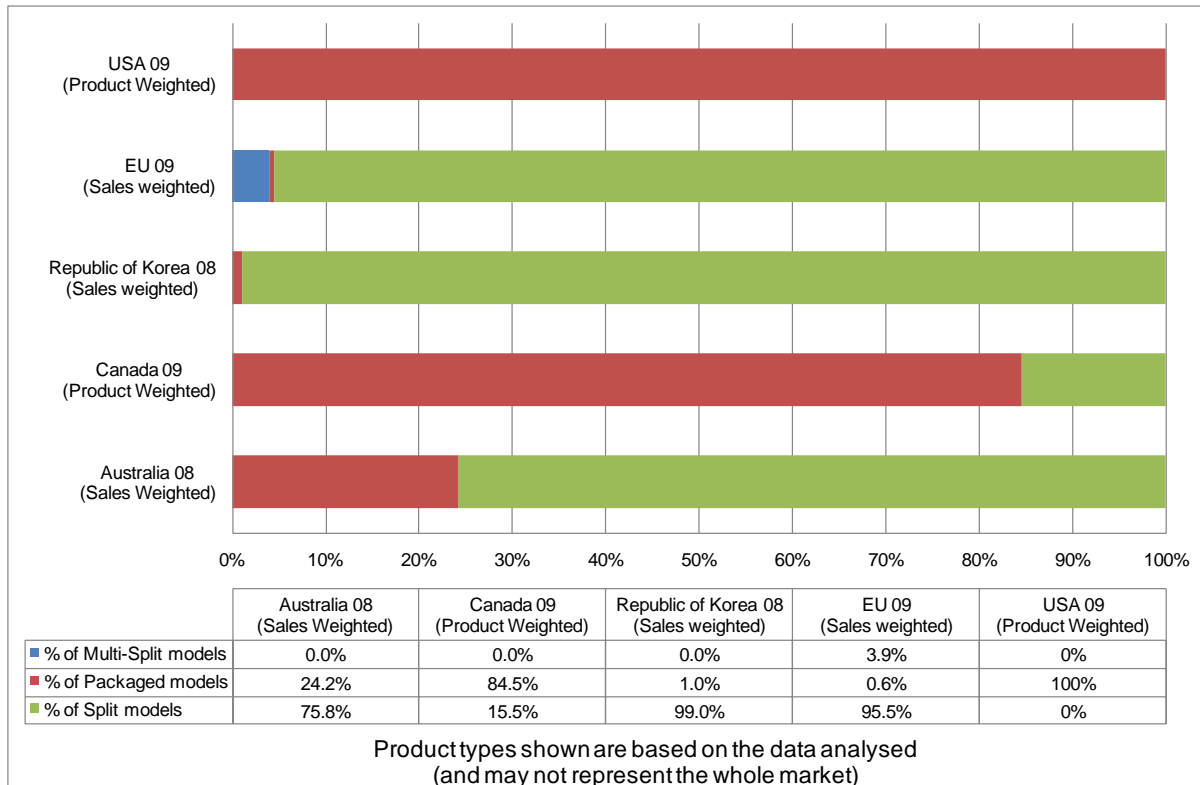
Figure 3. Breakdown of analysed data into the three product types within scope of this analysis.
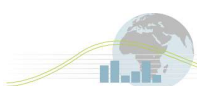
Refrigerant type

Data was requested on which refrigerant type the product was sold with but only the Australian and EU (Eurovent) datasets included this information. For simplicity this is reported as the proportion of products sold with refrigerant type R410a, which is a high-pressure HFC type refrigerant with Global Warming Potential (GWP) 1300 and Ozone Depletion Potential (ODP) zero. See Figure 4. The data for these two countries shows a rapid switch to this refrigerant which accounts for virtually all packaged products in Europe, and nearly 60% of those in Australia in 2008. This change has been driven by legislation on ozone depleting substances combined with some energy efficiency savings, although R410a has a higher global warming potential (GWP) than competing HFC refrigerants such as R134a.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia (Sales weighted)								12.5%	26.5%	40.5%	55.4%	57.3%	58.6%	
Austria														
Canada														
Denmark														
France														
Republic of Korea														
Switzerland														
UK														
USA														
China														
EU (Product weighted)							7.1%			68.2%				99.3%
Japan														
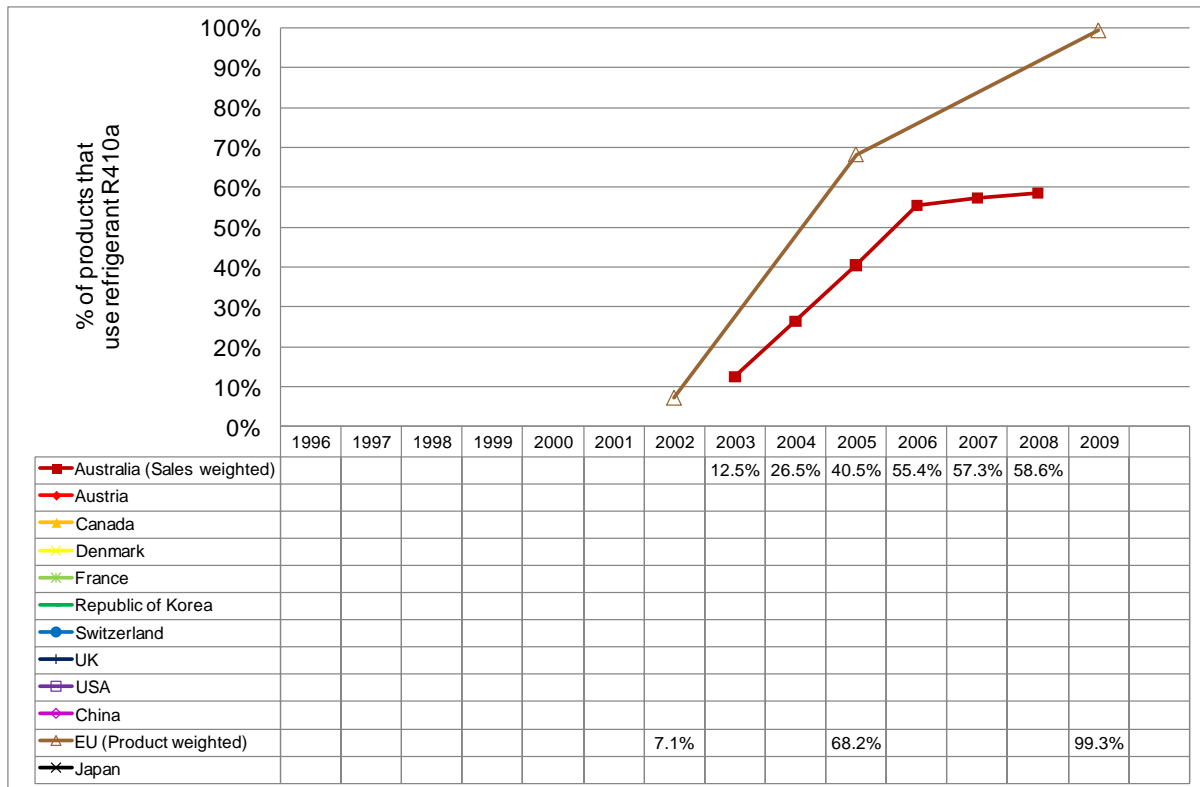
Figure 4. Proportion of products sold that use refrigerant R410a.

Proportion of reverse cycle products

Reverse cycle products can be used for cooling and heating, and are commonly referred to as heat pumps. Heating using a heat pump is significantly more energy efficient than using electrical resistance heaters. Data was requested on the proportion of each market that had this capability and this data was available for Australia, Canada, USA and EU (Eurovent), and also for the Republic of Korea for 2009 only. See Figure 5.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
■ Australia (Sales weighted)								69.8%	70.7%	69.8%	76.8%	77.2%	77.7%	
◆ Austria														
▲ Canada (Product weighted)	3.1%				0.3%	0.1%		1.8%	1.4%	0.4%	2.9%	1.4%		1.2%
✕ Denmark														
✳ France														
▬ Republic of Korea (Product weighted)														11.1%
● Switzerland														
━ UK														
☐ USA (Product weighted)										5.6%	5.7%	5.2%	5.1%	6.6%
◆ China														
△ EU (Product weighted)								53.6%		66.0%				85.8%
✕ Japan														
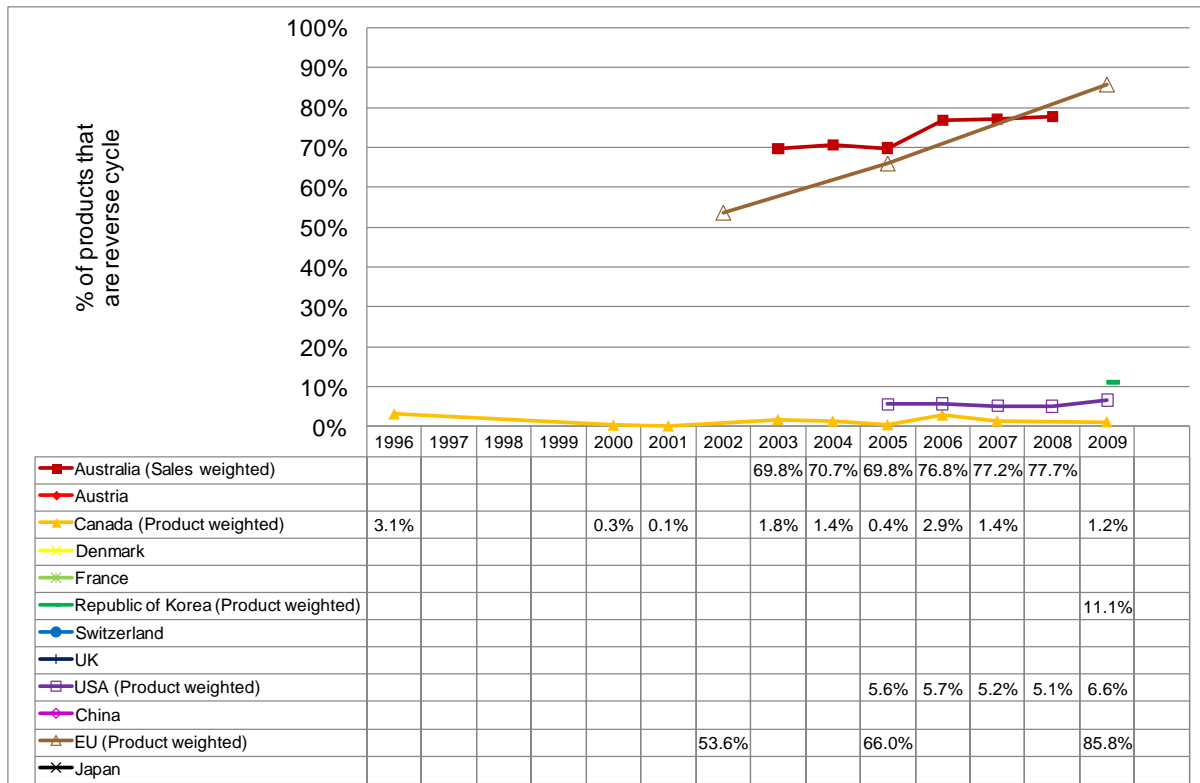
Figure 5. Proportion of each market that has reverse cycle capability (i.e. that can heat as well as cool).

Reverse cycle products of these types (unitary, split and multi-split) account for over three quarters of products in the Australian and EU markets but less than 10% in the USA and Canada, and 11% in the Republic of Korea. The proportion of this type of product will depend upon the relative demand for heating and cooling in each market, and cultural issues associated with what has historically provided heating where applicable.

Only very limited analysis has been undertaken on the EER of cooling only products compared to those with reverse cycle capability, indicating that average EERs are slightly better for reverse cycle units (but data sets are highly imbalanced).

Proportion of products with variable or multispeed compressors

Data was requested on what proportion of products sold are supplied with variable speed or multispeed compressors (which includes those that make use of inverters for motor control). These features allow the unit to adjust power input to suit the required cooling at that moment, as opposed to cycling on and off at full power. This can save a significant amount of energy in real life use over a cooling season, although savings are not evident under full load test conditions reported in this analysis. Seasonal energy efficiency ratio tests (SEER) will reveal savings from these features, which implies that Australian and EU products should perform well in this regard. See Figure 6. Data was made available from Australia and EU10 (GfK) and both showed similarly rapid rise in the prevalence of these features since 2003. Over half of these products in Australia had variable or multispeed compressors by 2008, with around half in Europe by 2009. Whilst no specific data was available for the Republic of Korea, government sources have confirmed that almost every product with a high EER is inverter driven and their market share is increasing. Similarly, government sources in China reported that the percentage is growing and was at least 10% in 2009.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia (Sales weighted)								5.1%	11.8%	19.3%	32.7%	47.5%	55.5%	
Austria														
Canada														
Denmark														
France														
Republic of Korea														
Switzerland														
UK														
USA														
China														
EU (Sales weighted)							4.2%	6.7%	11.6%	14.5%	24.4%	32.8%	37.1%	49.7%	
Japan														
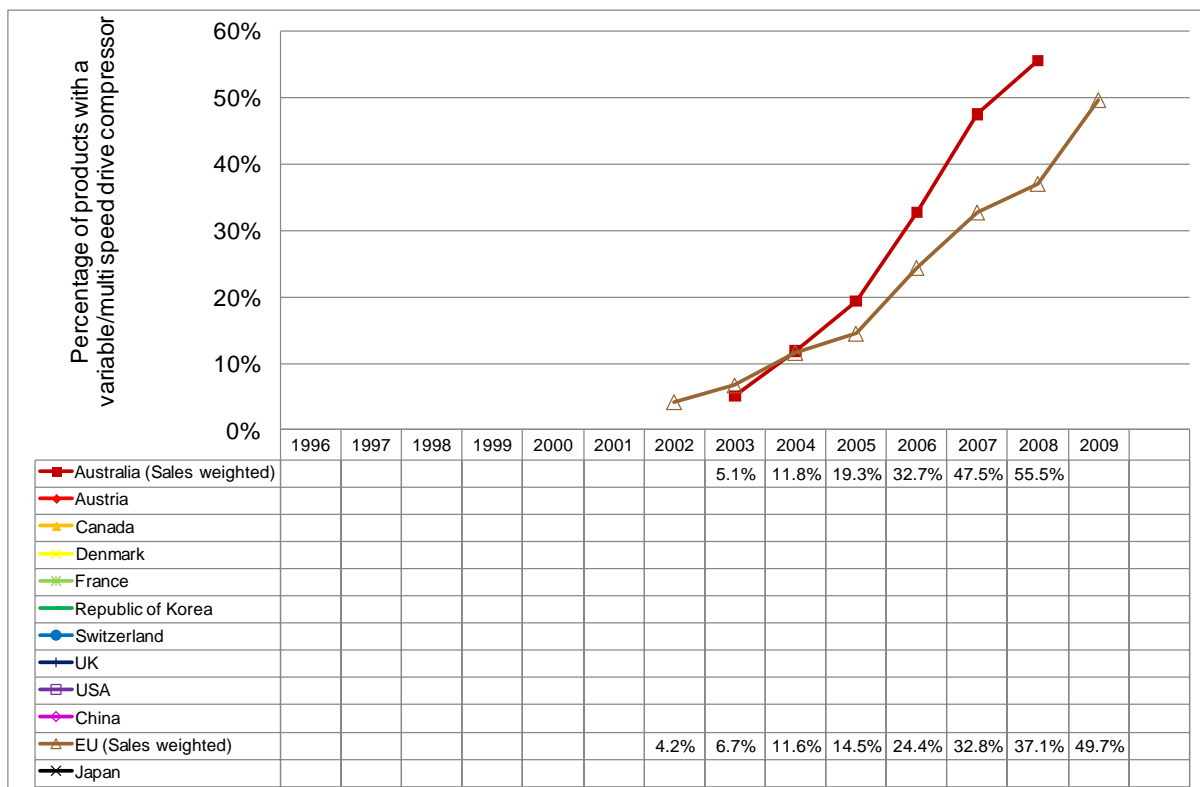
Figure 6. Proportion of products analysed reported having variable or multispeed compressors.

Energy performance

Key issues arising from energy performance are summarised in Table 2. Data was invited for the following metrics for energy performance:

- Energy efficiency ratio (EER)

- Seasonal energy efficiency ratio (SEER)

- Standby consumption, including crank case heater

These are described in the following sections.

Energy efficiency ratio (EER)

Energy efficiency for air conditioners has historically been measured using the energy efficiency ratio (EER). This is the measured cooling capacity at full load divided by electrical energy input. The units selected for use in this analysis are kW/kW. EER data from Canada and the US was converted into these units from Btu per hr/W by multiplying by 0.293. EER data was made available by all of the active participants.

The scatter graphs in Figure 7 and Figure 8 Illustrate the relative availability of data. Figure 7 shows that EER varies very little with cooling capacity for unitary products. Figure 8 shows a slight drop of EER with increasing capacity (around 0.07 per kW) for split products from Australia, Canada and the EU, whereas products from the Republic of Korea show no change of EER with increasing capacity. This aspect of performance is also reflected in MEPS which are often designed to drop at higher capacity levels (see Figure 19).

Figure 9 shows that product-weighted EER for unitary products has hardly changed since 1996 for these products and countries. The spread of performance is around 12% for 2008 with Canadian and Republic of Korea products appearing to have the better efficiency levels at around 3.0. US data is not plotted on this graph as it is ENERGY STAR data representing only the better products on the market (indicatively the top 30% to 50%, see Table 3) and so is not comparable. It is, however, plotted in Figure 23 (see Annex 1).

Product-weighted EER *(indicative)*:

Figure 10 shows that product-weighted efficiency levels for split products have been rising gradually and fairly consistently at around 3% per year since 2000 for these countries. It is also apparent that products from the Republic of Korea appear significantly more energy-efficient than those from the other countries: the spread of efficiency between other countries is less than 2% with an average at around 2.9, with products from the Republic of Korea consistently having an average EER at least 20% higher than the others at around 3.6 in 2009. The difference in average efficiency could be influenced by cooling only products dominating the market in the Republic of Korea, compared to reverse cycle units dominating

in Australia and the EU and other possible product differences that are beyond the scope of this analysis.
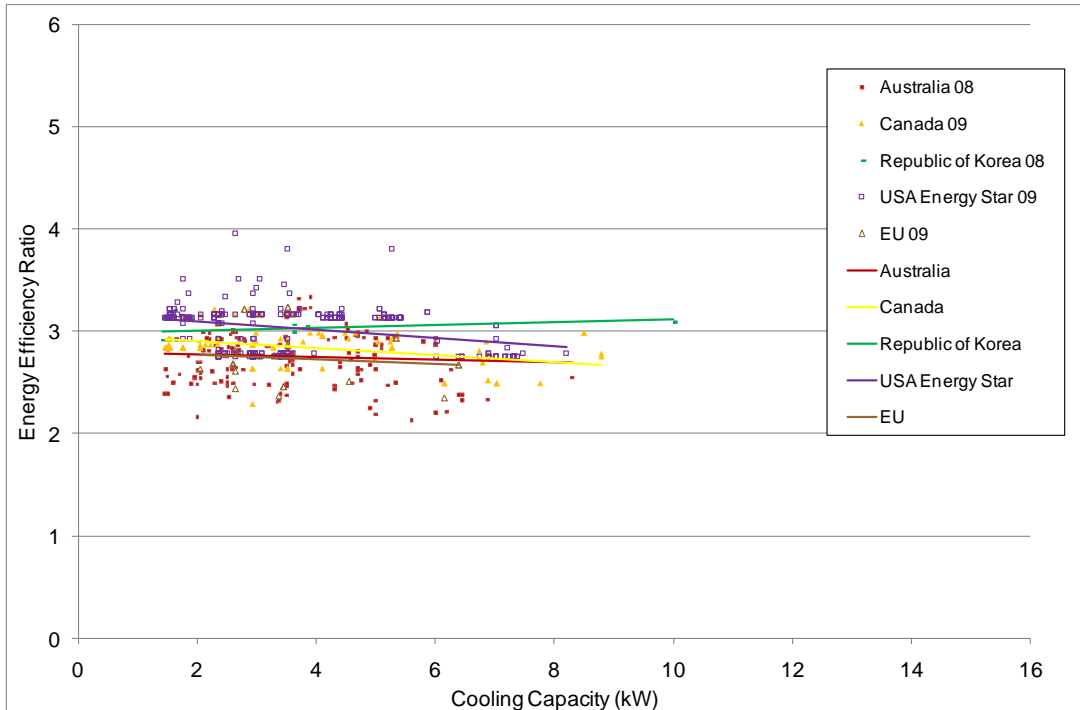
Figure 7. Scatter graph of EER against cooling capacity for unitary products. Data from the Republic of Korea contains only between 46 and 6 products per year and so trend should be treated with caution.
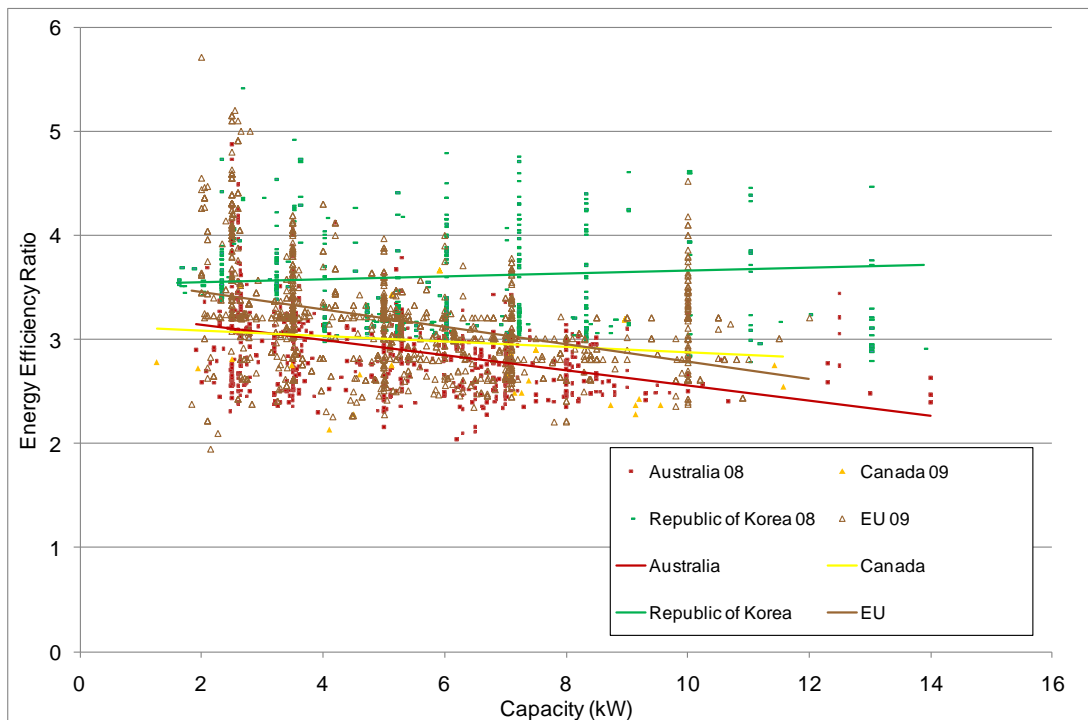
Figure 8. Scatter graph of EER against cooling capacity for split products.

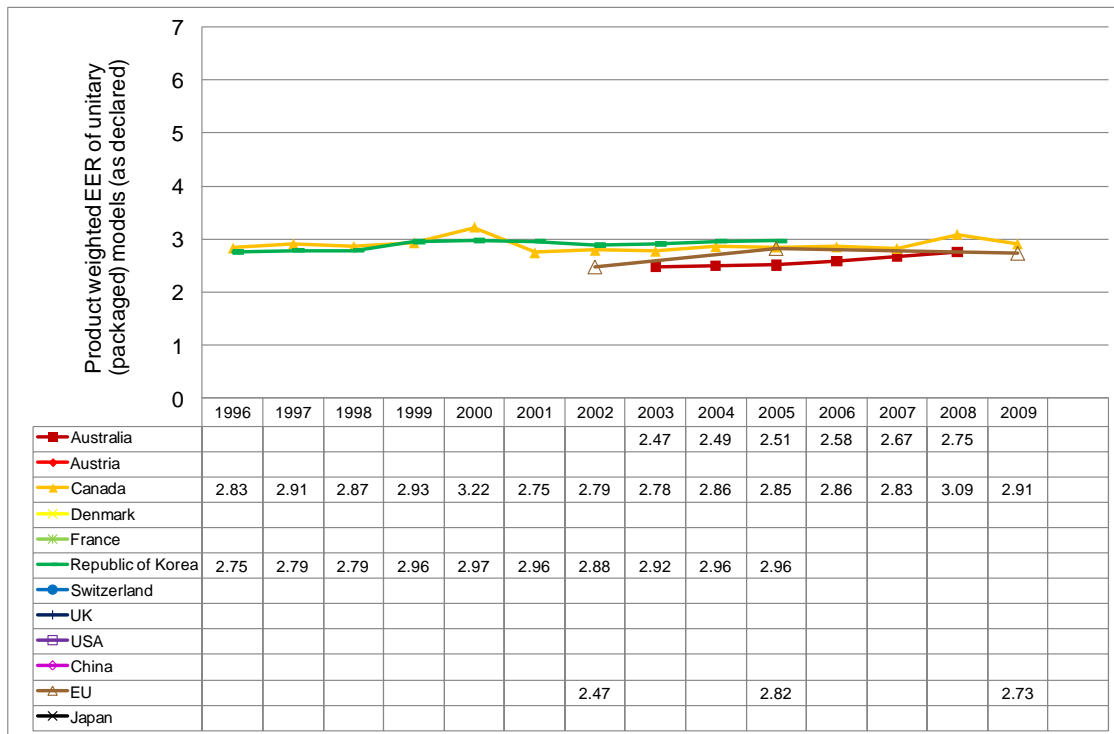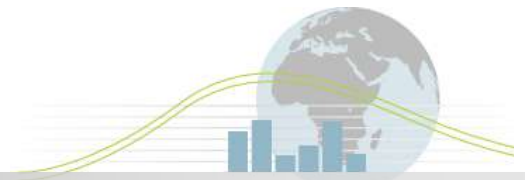|	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia								2.47	2.49	2.51	2.58	2.67	2.75	
Austria														
Canada	2.83	2.91	2.87	2.93	3.22	2.75	2.79	2.78	2.86	2.85	2.86	2.83	3.09	2.91
Denmark														
France														
Republic of Korea	2.75	2.79	2.79	2.96	2.97	2.96	2.88	2.92	2.96	2.96				
Switzerland														
UK														
USA														
China														
EU							2.47			2.82				2.73
Japan														

Figure 9. Product weighted energy efficiency ratio (EER) for unitary products. USA Data has been deleted as it is ENERGY STAR and so not comparable (see Figure 23 for graph including USA); Republic of Korea data has been deleted since 2006 due to low product numbers in the data set.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia								2.65	2.68	2.71	2.80	2.84	2.91	
Austria														
Canada														2.97
Denmark														
France														
Republic of Korea	3.04	3.03	3.06	3.07	3.11	3.22	3.31	3.36	3.46	3.55	3.55	3.55	3.56	3.61
Switzerland														
UK														
USA														
China											2.78	2.83	2.83	2.96	
EU							2.61			2.84				3.18
Japan														

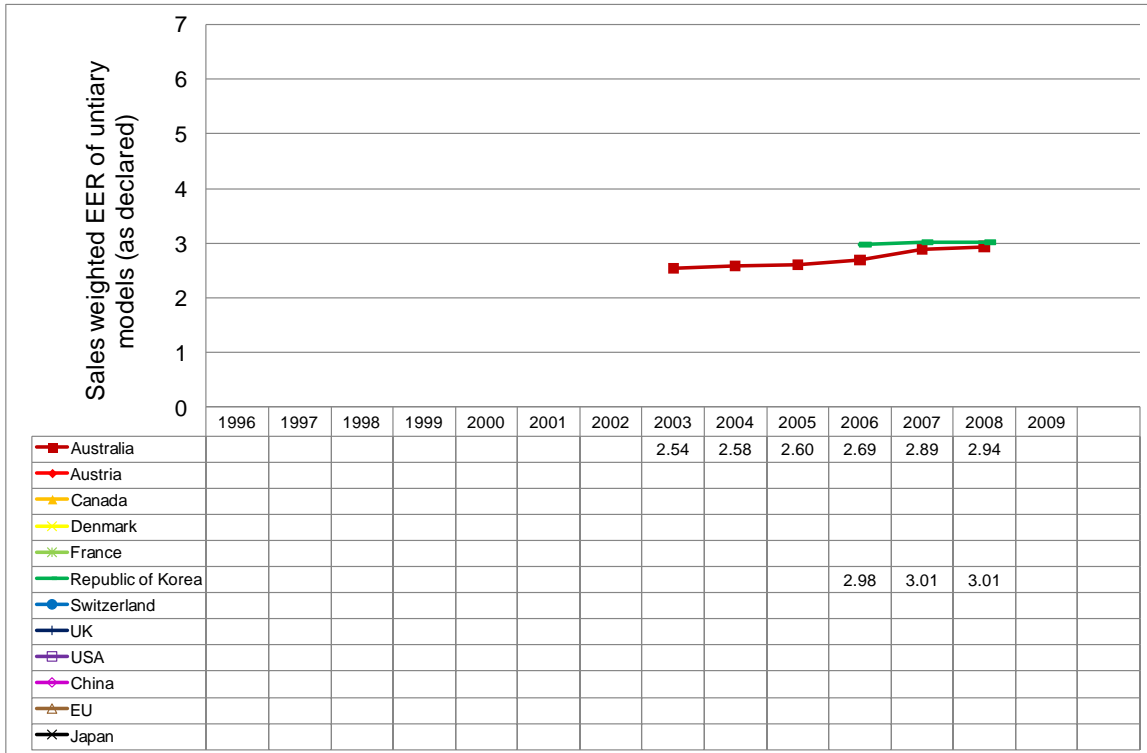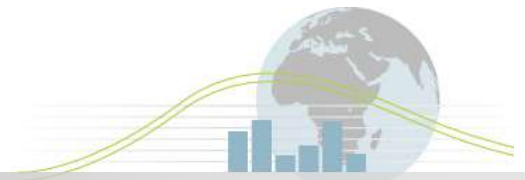**Figure 10. Product weighted energy efficiency ratio (EER) for split products.**
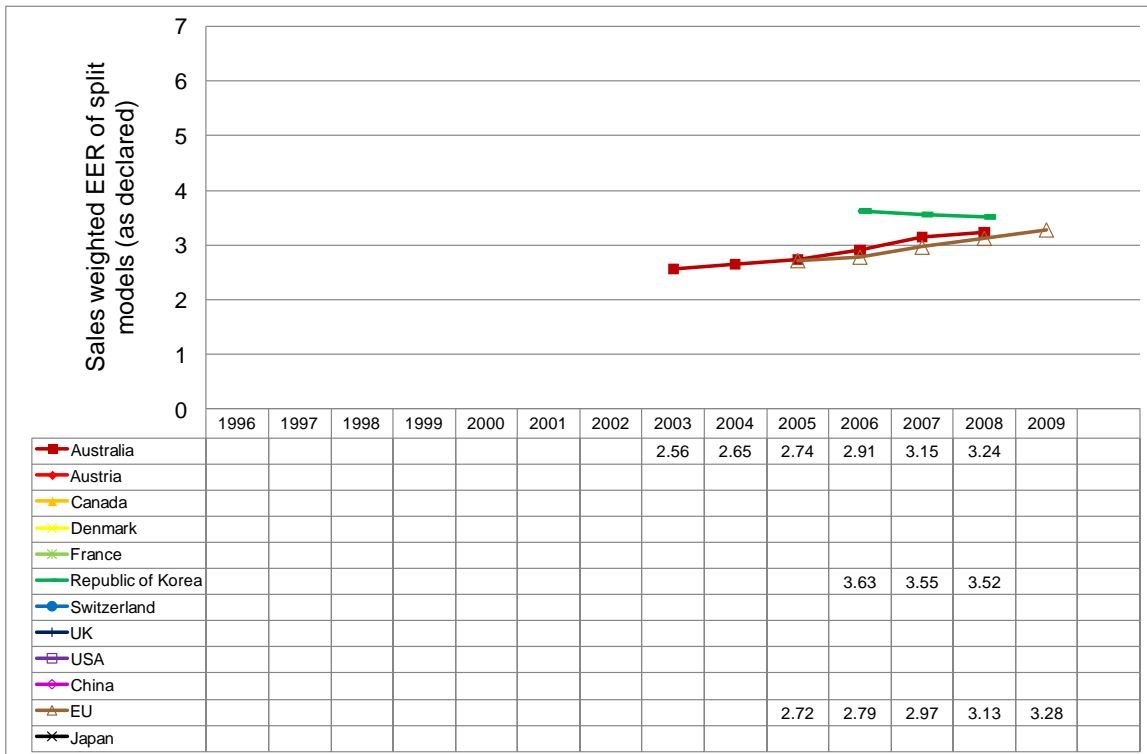
Sales weighted EER data *(robust)*:

Figure 11 shows sales weighted data for unitary products with an average of around 3.0, for which only Australia had significant amounts of data. Only a handful of unitary products from the Republic of Korea data set had associated sales data and so this line should be treated with caution. Australian data indicates that slightly more of the better performing products are sold than those below average since the sales weighted average has between 3% and 7% higher EER than the product weighted average.

Figure 12 shows sales weighted data for split products with reasonably substantial datasets available for Australia, Republic of Korea and EU10 and an average of 3.3 in 2008. Performance of the average products from Australia and EU 10 are almost indistinguishable over time, but products from the Republic of Korea show an average EER around 8% higher in 2009 although these products are not showing any improvement trend. As with the product-weighted results, differences in the type of product that dominates the market could affect average efficiency levels (EU/Australian market is predominantly reverse cycle; cooling only dominates the Republic of Korea market).

Both unitary and split products appear to be improving in efficiency at nearly 10% every two years in Australia and EU based on sales weighted data (three times the improvement rate apparent from product weighted data). Products in the Republic of Korea appear to have a higher average EER but performance levels seem static for unitary products (*caution: Small data set*), or falling very slightly (split products, by 3% 2006 to 2008). The sales weighted average EU data for split products (from GfK) shows an EER for 2009 within 7% of that for the Republic of Korea from 2008.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Australia								2.54	2.58	2.60	2.69	2.89	2.94		
Austria															
Canada															
Denmark															
France															
Republic of Korea											2.98	3.01	3.01		
Switzerland															
UK															
USA															
China															
EU															
Japan															

Figure 11. Sales weighted energy efficiency ratio (EER) for unitary products. Republic of Korea data is based on fewer than 20 products and so must be treated with caution.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Australia								2.56	2.65	2.74	2.91	3.15	3.24		
Austria															
Canada															
Denmark															
France															
Republic of Korea											3.63	3.55	3.52		
Switzerland															
UK															
USA															
China															
EU										2.72	2.79	2.97	3.13	3.28	
Japan															

Figure 12. Sales weighted energy efficiency ratio (EER) for split products.
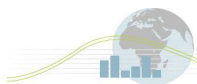
Best and worst products *(indicative)*:

Figure 13 and Figure 14 show EERs of the best products in each data set with the best unitary product having an EER of 4.2 and best split product with EER 6.1. It is only the US ENERGY STAR data set that appears to show any significant improvement in best EER for unitary products, showing a jump of over 10% from 2007-2008. The Republic of Korea's dominance for best products is not apparent in recent years for unitary products, perhaps reflecting that these are now a minority product in that country. For split products, however, the Republic of Korea has had the product with the highest or joint highest EER in every year covered by these datasets. The EU data set (from the Eurovent certification scheme) appears to show significant improvement in best product performance levels with a 40% jump in best EER since 2002, with products matching the best from the Republic of Korea in 2009. As noted before, cooling only products dominate the market in the Republic of Korea, compared to reverse cycle units dominating in Australia and the EU.

Products with the lowest (worst) EER levels are shown in Figure 15 for unitary with 2.4 for an EU product in 2009, and Figure 16 for split products with 2.3 for a Canadian product in 2009. Note that the approach to analysis of data from the Republic of Korea involved extrapolating backwards from a current dataset based upon when the product was registered and eliminating products that fell below the MEPS at that time (i.e. assuming compliance was achieved by the market) – hence, the poor performing products (below their stringent MEPS) were eliminated. This was not carried out for other countries and so comparison of worst products with the Republic of Korea is not valid. There appears to be less than 10% difference between the worst performing products between the EU (Eurovent database), Australia, Canada and China for split products, with the spread for worst unitary products being around 15% for these countries (note China is not included with unitary products).
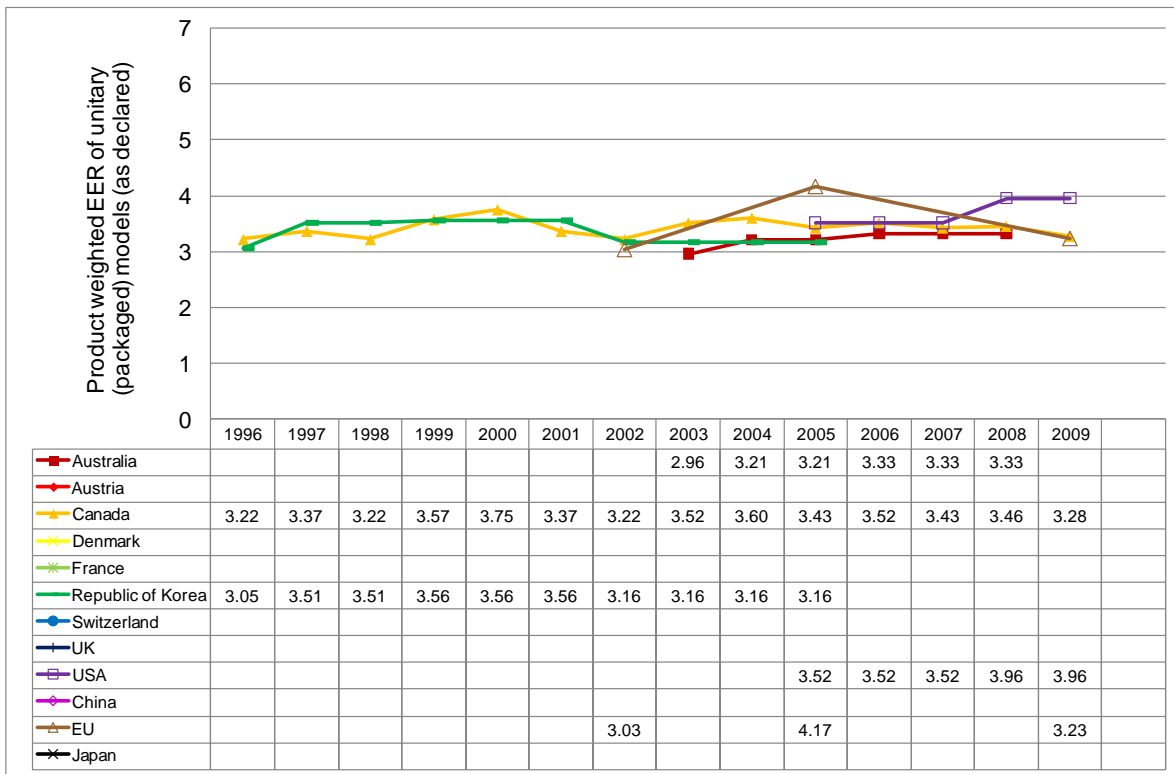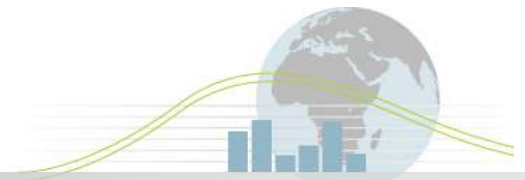
Figure 13. EER of the best unitary products.

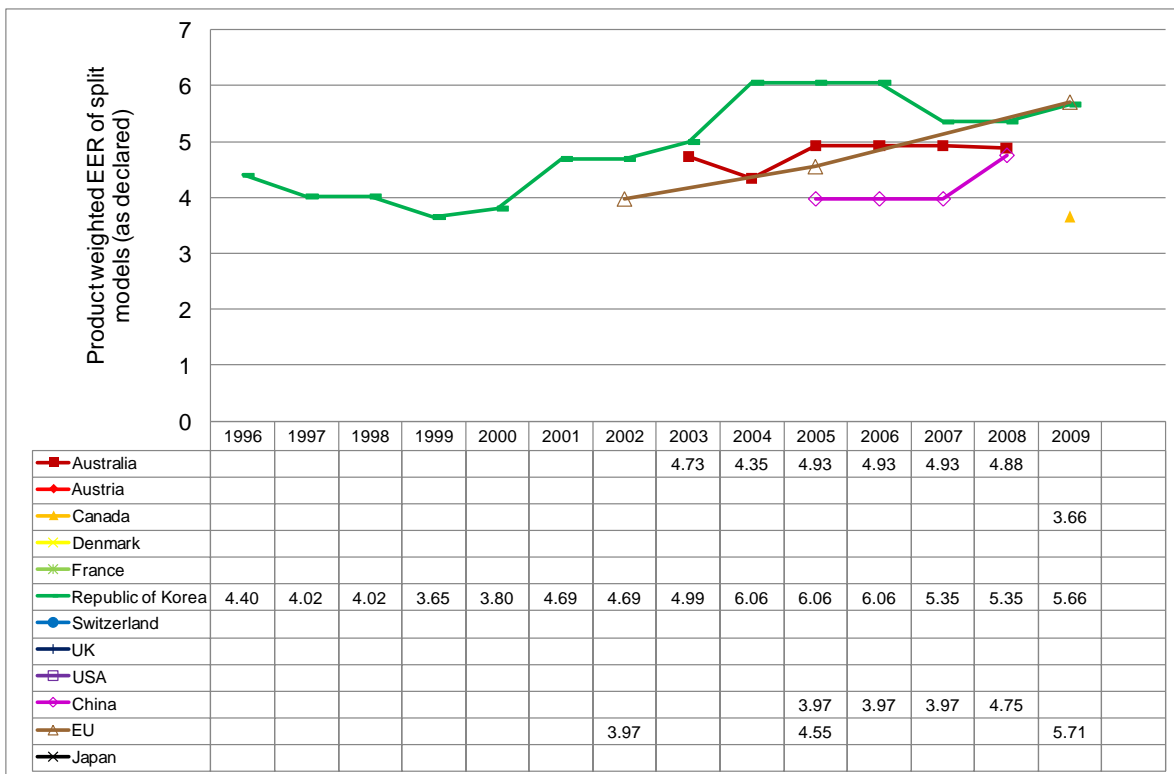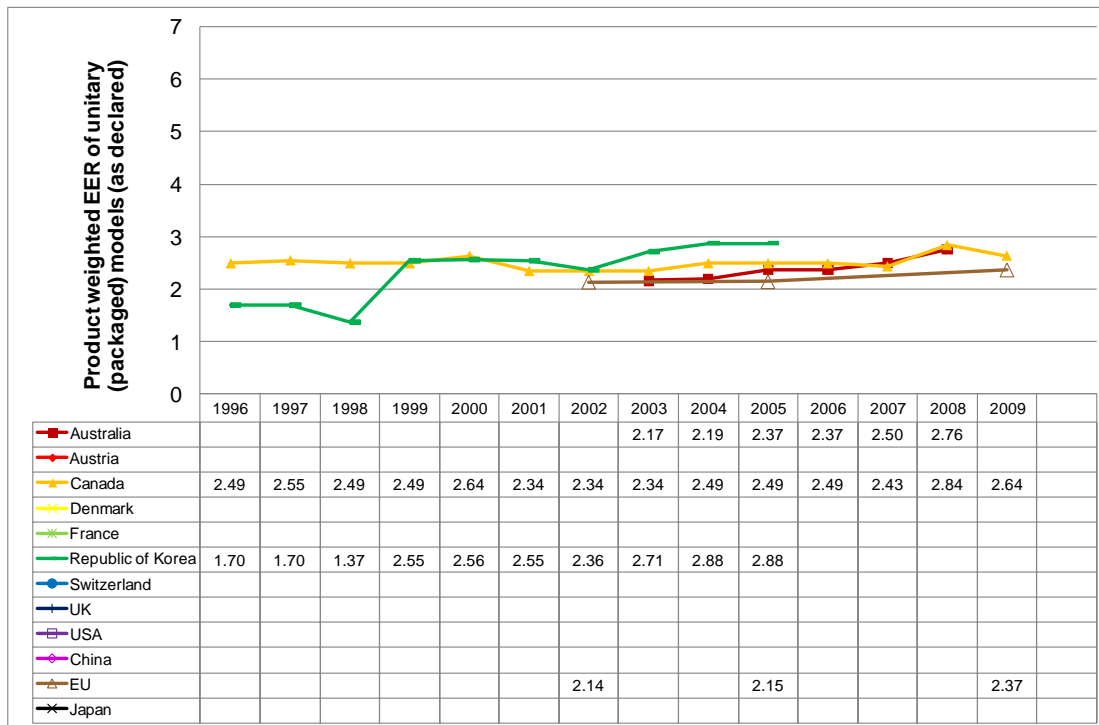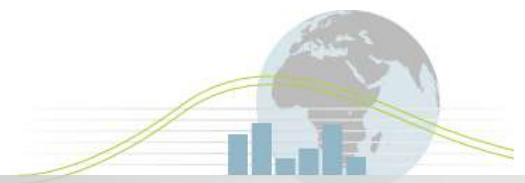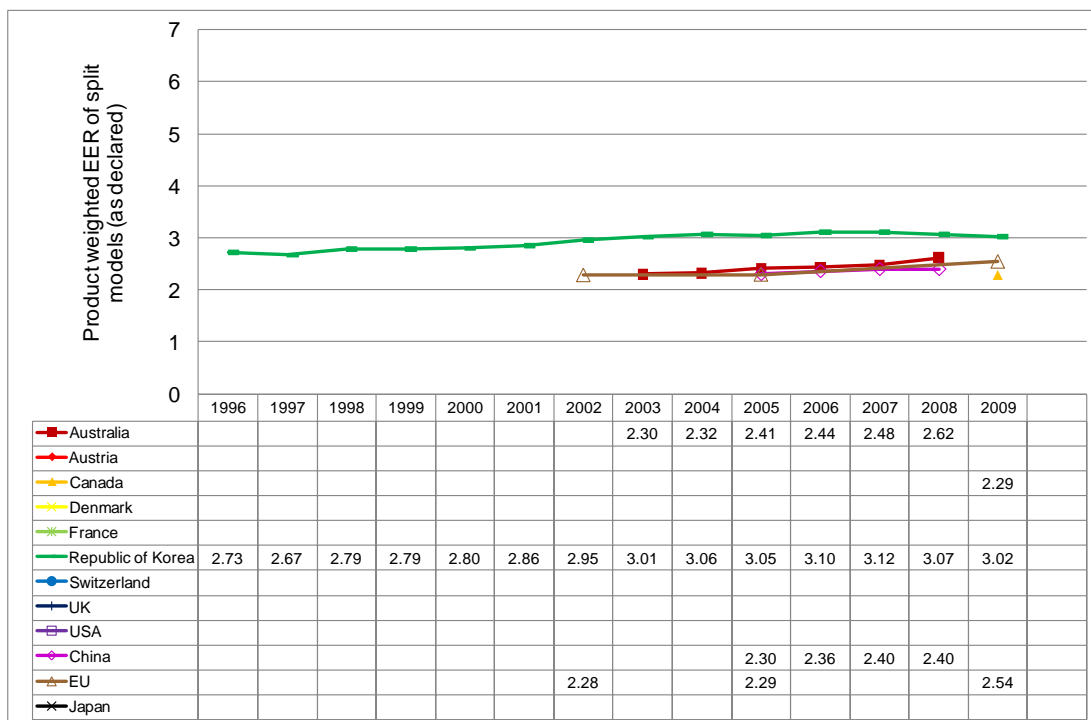|	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia								2.96	3.21	3.21	3.33	3.33	3.33	
Austria														
Canada	3.22	3.37	3.22	3.57	3.75	3.37	3.22	3.52	3.60	3.43	3.52	3.43	3.46	3.28
Denmark														
France														
Republic of Korea	3.05	3.51	3.51	3.56	3.56	3.56	3.16	3.16	3.16	3.16				
Switzerland														
UK														
USA										3.52	3.52	3.52	3.96	3.96
China														
EU							3.03			4.17				3.23
Japan														

Figure 14. EER of the best split products.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia								4.73	4.35	4.93	4.93	4.93	4.88	
Austria														
Canada														3.66
Denmark														
France														
Republic of Korea	4.40	4.02	4.02	3.65	3.80	4.69	4.69	4.99	6.06	6.06	6.06	5.35	5.35	5.66
Switzerland														
UK														
USA														
China										3.97	3.97	3.97	4.75	
EU							3.97			4.55				5.71
Japan														

|	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Australia								2.17	2.19	2.37	2.37	2.50	2.76		
Austria															
Canada	2.49	2.55	2.49	2.49	2.64	2.34	2.34	2.34	2.49	2.49	2.49	2.43	2.84	2.64	
Denmark															
France															
Republic of Korea	1.70	1.70	1.37	2.55	2.56	2.55	2.36	2.71	2.88	2.88					
Switzerland															
UK															
USA															
China															
EU								2.14		2.15				2.37	
Japan															

Figure 15. EER of the worst unitary products (note that data for the Republic of Korea has had all products non-compliant with MEPS removed and so is not comparable with other countries for which this has not been done).

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	
Australia								2.30	2.32	2.41	2.44	2.48	2.62		
Austria															
Canada														2.29	
Denmark															
France															
Republic of Korea	2.73	2.67	2.79	2.79	2.80	2.86	2.95	3.01	3.06	3.05	3.10	3.12	3.07	3.02	
Switzerland															
UK															
USA															
China										2.30	2.36	2.40	2.40		
EU							2.28			2.29				2.54	
Japan															

Figure 16. EER of the worst split products (note that data for the Republic of Korea has had all products non-compliant with MEPS removed and so is not comparable with other countries for which this has not been done).
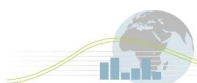
Scope for improvement *(illustrative)*:

In order to provide a measure of the scope for improvement in each market, the following metric has been used:

The ratio of performance of the average product in that country's market for that year compared to the performance of the best product in any market for any year.

This ratio was evaluated for unitary products and for split products separately, and calculated for each year for which data was available. The best split product in any year was from the Republic of Korea in 2006 with an EER of 6.06 (same in 2005 and 2004, cooling only). The best unitary product in any year was from the EU (Eurovent) in 2005 with an EER of 4.17 (reverse cycle unit).

See Figure 17 and Figure 18. This ratio for unitary products is between 65% and 73%, whereas for split products is between 49% and 60%. This implies that there is generally greater scope for improvement of split products than there is for unitary products.

The European eco-design (EuP) preparatory study for small air conditioning units[8] quotes the best in class worldwide as 6.4 at ISO conditions. This is for units from Japan of 2.2kW and 2.8kW capacity, although their type (split, unitary, etc) is not mentioned. A theoretical maximum EER for these units of both types is around 6.5[9] and so the best products are approaching this ceiling – but of course many others are far from it.

Once again, products from the Republic of Korea appear to show less scope for improvement than from other regions, although the gap has been reduced in recent years with notable improvements in the Australian and EU markets for split products.
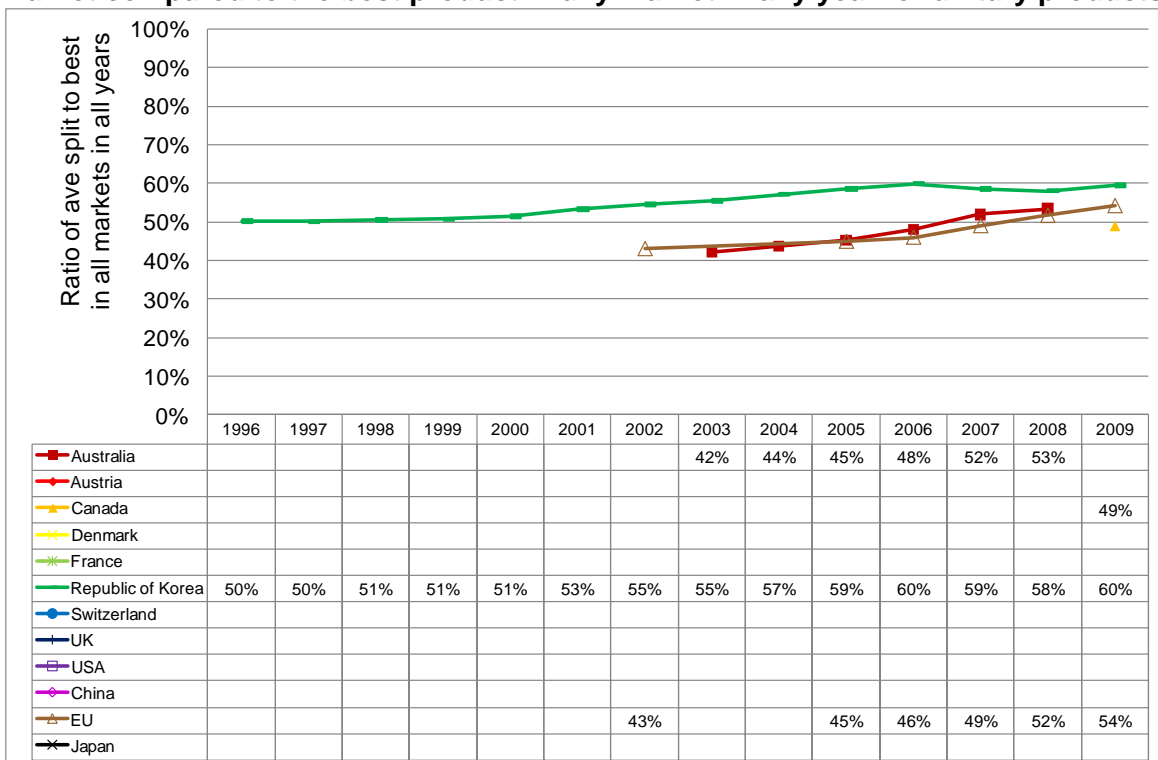
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[8] Armines, Preparatory study on the environmental performance of residential room conditioning appliances (airco and ventilation), Contract TREN/D1/40-2005/LOT10/S07.56606, Draft report of Task 6, TECHNICAL ANALYSIS OF BEST AVAILABLE TECHNOLOGY, July 2008. Page 25.
[9] Using the Carnot equation and realistic assumptions on Carnot efficiency, temperature differences and fan power.
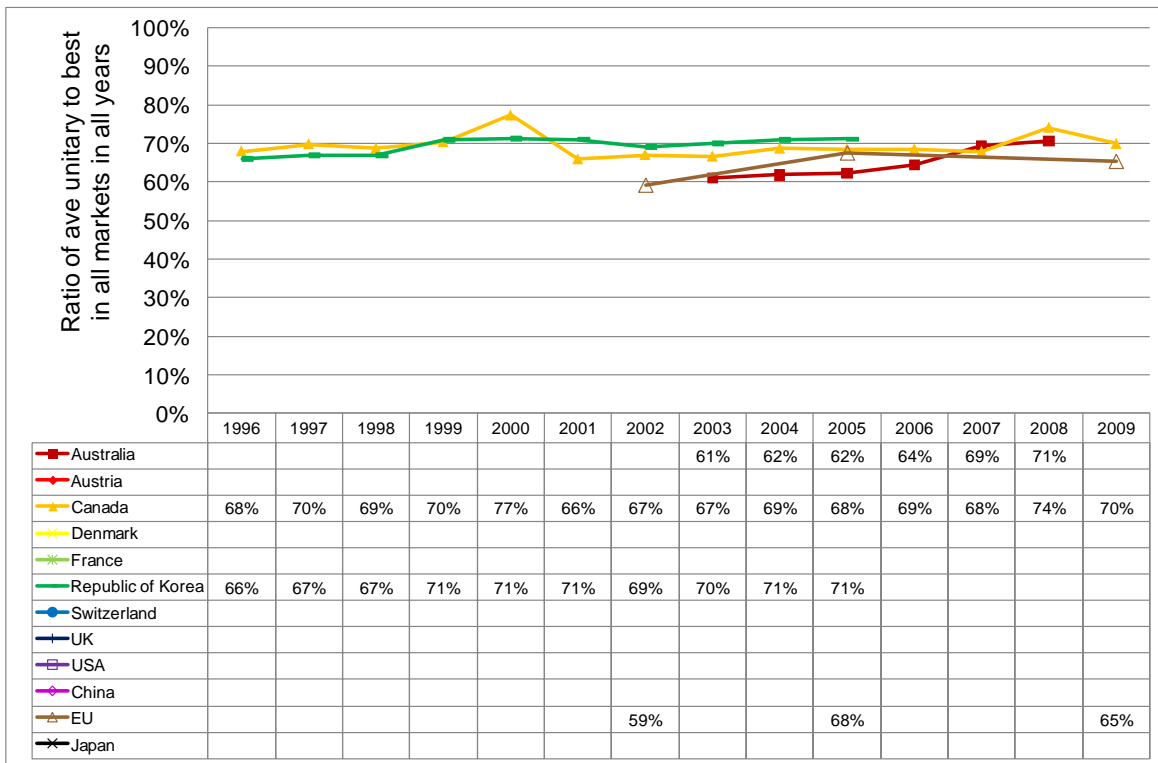
Figure 17. The ratio of performance (EER) of average product in each country's market compared to the best product in any market in any year for unitary products.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia								61%	62%	62%	64%	69%	71%	
Austria														
Canada	68%	70%	69%	70%	77%	66%	67%	67%	69%	68%	69%	68%	74%	70%
Denmark														
France														
Republic of Korea	66%	67%	67%	71%	71%	71%	69%	70%	71%	71%				
Switzerland														
UK														
USA														
China														
EU							59%			68%				65%
Japan														

Figure 18. The ratio of performance (EER) of average product in each country's market compared to the best product in any market in any year for split products.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia								42%	44%	45%	48%	52%	53%	
Austria														
Canada														49%
Denmark														
France														
Republic of Korea	50%	50%	51%	51%	51%	53%	55%	55%	57%	59%	60%	59%	58%	60%
Switzerland														
UK														
USA														
China														
EU							43%			45%	46%	49%	52%	54%
Japan														

Seasonal energy efficiency ratio (SEER) *(not graded for robustness)*

In real use, however, air-conditioners rarely operate at full load for more than a quarter of their working life. In the last few years, the seasonal energy efficiency ratio (SEER) has become widely accepted to reflect more accurately how efficient a product is likely to be over the full cooling season. This combines measurement of energy efficiency at several loading levels (and sometimes different outside temperatures) into a single figure which assumes given proportions of time at each loading level/temperature.

Whilst SEER has been part of the US MEPS since 1992, US product data was not available for this metric. SEER data was only available for Canada (2008 and 2009) and the Republic of Korea (2009, only for split products). SEER will be used for the revised EU energy label and eco-design requirements for air conditioners but it is not yet known when these will be adopted. Results are noted below, but only limited analysis is possible due to lack of data.

Canadian split products in 2009 showed an average product weighted SEER of 4.67 compared to an average SEER of 3.86 for the Republic of Korea. It is likely that the test methodologies for these two countries are different in deriving SEER figures and so the data are not comparable – further analysis would be necessary on this.

Note: SEER may not be applicable to all types of unit. For larger plant, Integrated Part Load Value (IPLV) or Integrated EER[10] (IEER) is used to take account of part load performance but this is not applicable to residential products.

Standby *(not graded for robustness)*

Data was also invited on standby consumption. This can be significant for air conditioners due to many having a 'crank case heater' which prevents refrigerant migration and mixing with crankcase oil when the unit is off, and also prevents condensation of refrigerant in the crankcase of the compressor. Crank case heaters are often left on all the time, despite normally not being required whilst the compressor is running as that generates sufficient heat by itself during that time. Standby data was only available for Australia, which showed that sales weighted average standby consumption in 2008 was 4W, with 2.4 W product weighted average. Worst performer[11] was around 40W.

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[10] IEER superseded IPLV from 1 January 2010 in AHRI Standard 340/360 Performance Rating of commercial and Industrial Unitary Air-Conditioning and Heat Pump Equipment, and in ENERGY STAR version 2.1 criteria for light commercial HVAC equipment.

[11] Not the extreme worst, but ignoring the worst 5% of outliers.
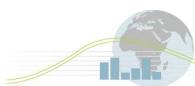
Product stock and consumption *(illustrative)*

Data on estimated stock of products was provided for Republic of Korea, Canada and China:

- Canada reported a growth of over 20% of stock of room air-conditioners between 2003 and 2008 to 2.36 million.
- The Republic of Korea reported a 2.4 fold increase in stock of air conditioners between 1997 and 2006 reaching 7.7 million products, with an annual consumption of 34,000 GWh per year.
- Data from China was used to estimate a stock of room air-conditioners at 47 million units in 2000.For context, more recent government statistics for China indicate that the total stock of all types of air conditioner in residential and commercial premises had reached 178 million in 2006 and 198 million in 2007.

4. Policies and their impacts

EER and efficiency policies

Table 7 summarises the policies in place for residential air-conditioners. The first country to establish labels for air conditioners amongst participants was Australia in 1992. Labels are now in place for every participating country, with the last coming into force in 2002 for the EU.

MEPS are in place in for every participant except the EU, with regular updates to scope and performance requirements. Figure 19 shows the MEPS levels in force at 2008, with Figure 20 showing the MEPS levels in force and planned at 2010. It is evident that the Republic of Korea has had the most stringent MEPS requirements since 2004, and it is likely that this has directly influenced their market resulting in them having the best performing products by EER and the highest average EER in these datasets.

The scatter graphs of
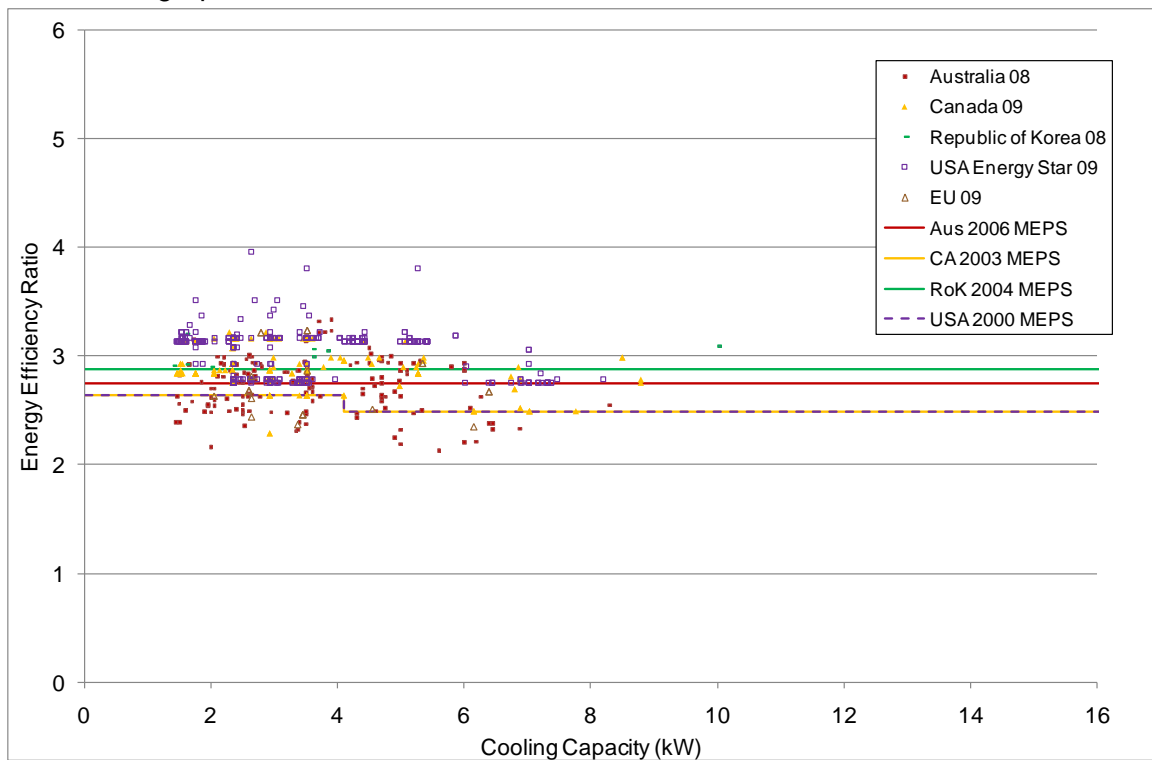
Figure 21 and Figure 22 show how product performance relates to some existing MEPS levels at 2008. It appears that at least half of the products available in the EU perform below the 2004 MEPS of the Republic of Korea. Many Australian products appear to be performing below MEPS levels active in that country, but this may relate to legacy products making their way (legally) through the supply chain after MEPS are introduced, or to possible mismatch in the scope of datasets and MEPS regulations.
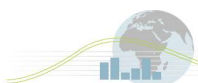
Table 7. Summary of policies in place for residential air conditioners for participating countries.

| Country	Labels	MEPS
Australia	Yes. Since 1992, updated 2000 and 2010. Includes standby since 2010.	Yes. Since 2004, updated 2006 and 2010. MEPS for heating mode since 2010.
Canada	Yes. Mandatory for EER since 1995. Voluntary for SEER. ENERGY STAR since 2001.	Yes. Since 1995, revised 2003 and 2011. SEER since 2006. SEER was used since before 2006 for ductless split and multi split (only EER for room air conditioners).
Republic of Korea	Yes. Since 1993. Reverse cycle included since 2009.	Yes. Since 1993. Reverse cycle since 2009.
USA	Yes. Voluntary ENERGY STAR since 1996.	Yes. Since 1990, revised 2000 and 2011.
China	Yes. Mandatory. Plus voluntary label for best products.	Yes. Due to be upgraded in 2011.
EU	Yes. Mandatory since 2002 for residential < 12 kW.	No. Regulation (under ecodesign Directive) being drafted 2010/2011.
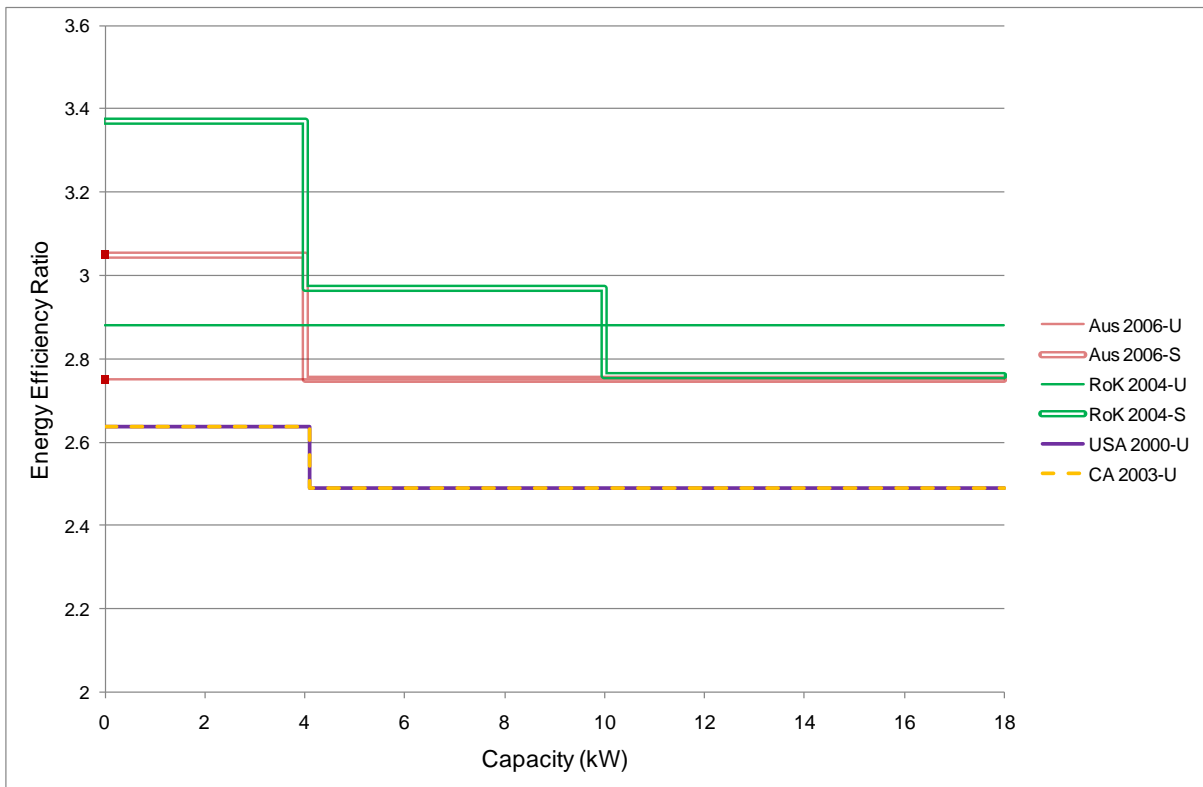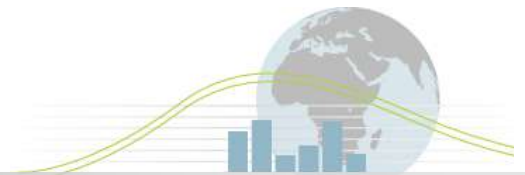
Figure 19. Overview of MEPS levels in force at 2008 for participating countries.
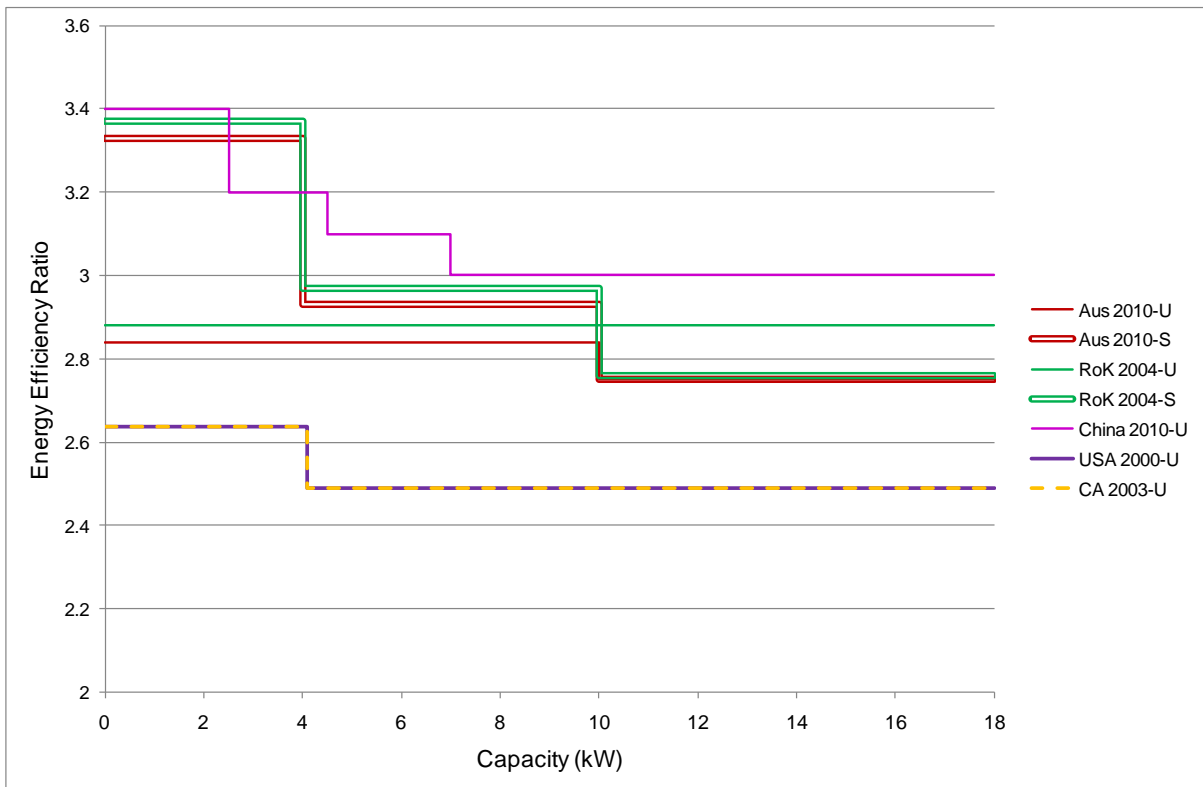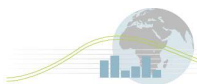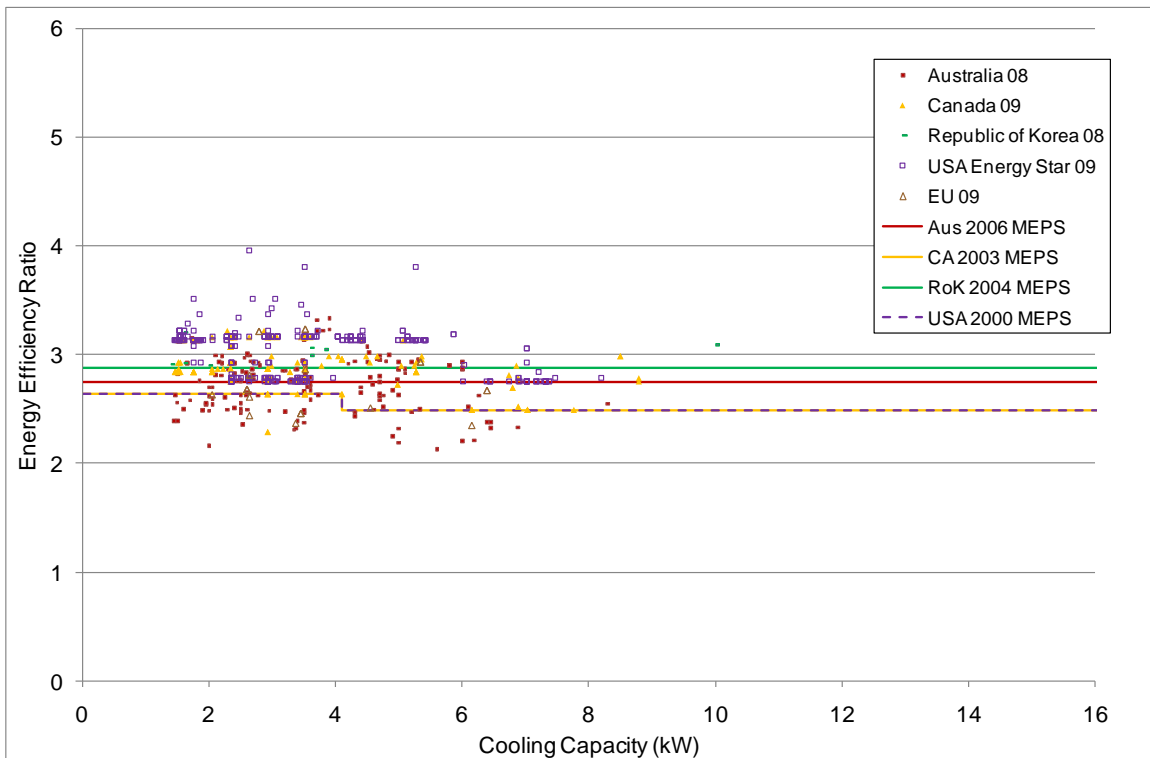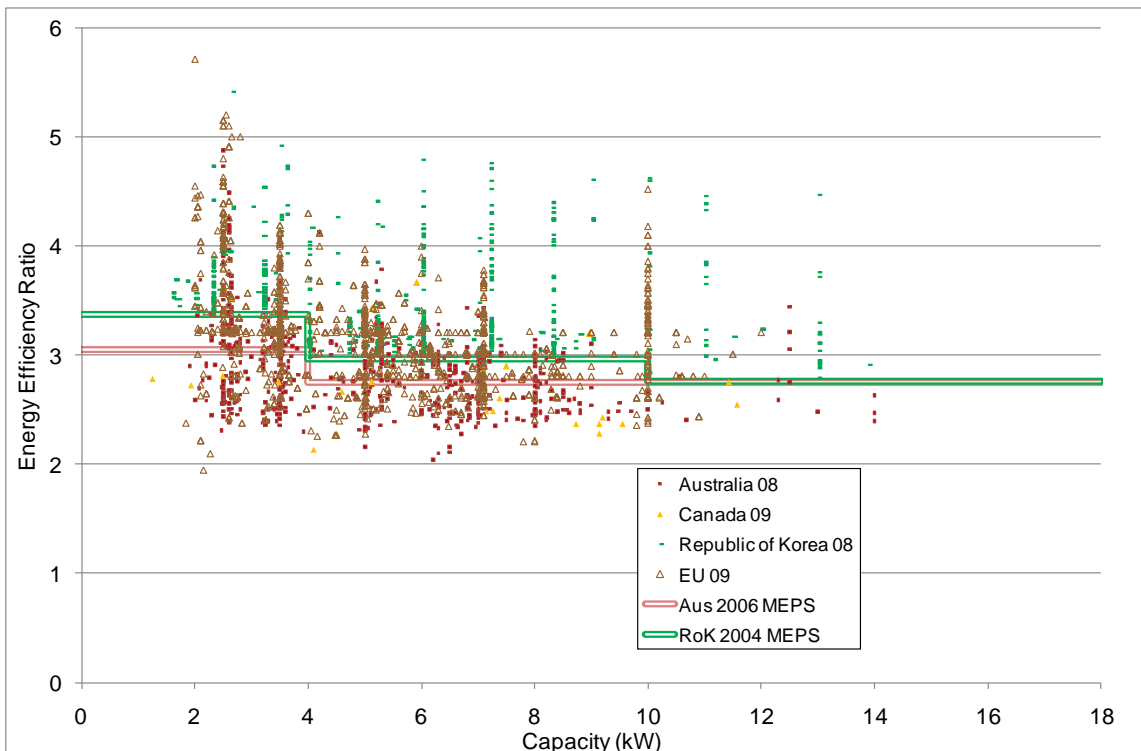

Figure 20. Overview of MEPS levels in force and planned at 2010 for participating countries.

Figure 21. Scatter graph of unitary products' EER against cooling capacity, showing MEPS in place at 2008.


Figure 22. Scatter graph of split products' EER against cooling capacity, showing MEPS in place at 2008.

5. Key issues for policy-makers

Firstly, it is important to note that the products covered by this analysis are not necessarily representative of the whole market in any of the participating countries. The following key issues have been identified for consideration by policymakers:

- Policies in the Republic of Korea, which has had the most stringent MEPS levels of participating countries since 2004, appear to have been highly successful in raising product standards towards practical/economic, if not technical limits. The Republic of Korea has also consistently had the best performing or joint best performing product in every year for which data is available. Split products from the Republic of Korea display less scope for improvement between the market average and best performing products.

- The Australian and EU markets are catching up with the Republic of Korea in split product performance, and MEPS levels in China became more stringent than those in the Republic of Korea during 2010.

- Simplistic analysis implies that split products apparently have a larger scope for improvement than unitary products.

- Previous policy focus on use of EER rather than SEER, and the analysis presented here, probably underestimate the improvements that have actually occurred in real operation of better products. One of the major innovations in recent years has been the use of variable speed compressors, which provide better instantaneous EERs in cooler weather (when running at less than full capacity), which is reflected in SEER testing and modelling. SEER can therefore be a more effective metric to monitor and influence for policymakers in terms of making real energy savings. Policies in Canada, the US and the Republic of Korea already address SEER although data availability seems poor. SEER will also feature in upcoming regulations in Australia and Europe.

- The proportion of products sold with variable speed or multi-speed compressors in the EU and Australia was at or approaching 50% by 2008, which should be making real in-use savings compared to single speed compressors.

- The full load EER of unitary products has hardly changed since 1996 for participating countries, but the full load efficiency of split products has been rising gradually and consistently at around 3% per year since 2000. This is likely to have been influenced by successive MEPS and labelling policies although no conclusive evidence of a direct link was established.

- There appears to be significant scope for improvement in the efficiency of all but the very best of products. Since average sales weighted EERs lie between 3 and 3.5 and yet best products and achieving over 6 and the theoretical maximum around 6.5.

- Standby consumption for air conditioners has become an energy policy issue. Regulations addressing this are in place in Australia and the Republic of Korea, and
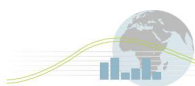
being proposed for inclusion in the upcoming European ecodesign measure on air conditioners. Evidence from Australia implies that standby consumption can be up to 40 W constantly, powering the crankcase heater as well as electronic controls.
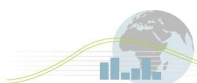
Annex 1. Graphs that include USA ENERGY STAR data.

US ENERGY STAR data was not plotted on the main graphs (e.g. Figure 9) in this report alongside other datasets because it is not comparable, being only the better products on the market. Graphs are included here for information only to show how this US data compares with data from other countries/regions.

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Australia								2.47	2.49	2.51	2.58	2.67	2.75	
Austria														
Canada	2.83	2.91	2.87	2.93	3.22	2.75	2.79	2.78	2.86	2.85	2.86	2.83	3.09	2.91
Denmark														
France														
Republic of Korea	2.75	2.79	2.79	2.96	2.97	2.96	2.88	2.92	2.96	2.96				
Switzerland														
UK														
USA										3.02	3.03	3.04	3.04	3.04
China														
EU							2.47			2.82				2.73
Japan														

Figure 23. Product weighted energy efficiency ratio (EER) for unitary products including USA data.

Annex 2. Summary of the data calculations undertaken

Only three types of adjustment were carried out on the datasets:

1. For US and Canadian data sets, conversion of capacity from Btu/hr to kW, by multiplying by 0.293/1000.

2. For US and Canadian data sets, conversion of US EER in Btu per hr/kW to EER in kW/kW, by multiplying by 0.293.

3. For the Republic of Korea: Normalisation of capacity and EER data to take account of a difference in the air temperature used during test. It was determined that the indoor wet bulb temperature during test (one of the 'Climate Class' temperatures) is 0.5°C higher than is used in other participating countries. One published report[12] provides analysis of what difference this makes to the reported EER figures, from which it is concluded that lowering the EER results by 1.2% (and capacity results by 1.6%) would render them comparable to ISO5151 Temperature class T1 results. Note that the Korean test methodology is being amended and the conventional wet bulb temperature of ISO 5151will apply from January 2011. Whilst there are very slight differences in test temperatures for the US methodologies, these are smaller than this for Korea, and arise due to rounding of the temperatures to the nearest integer temperature in Fahrenheit.

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[12] APEC-ESIS report: *Benchmarking Of Air Conditioner Efficiency Levels In Five Asian Countries*, Prepared For The Australian Greenhouse Office, Danish Energy Management, June 2004, page 11.