Household refrigerators: Monitoring efficiency changes in Europe and Australia over the last 10 years

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Abstract

Sales data gathered by a commercial market monitoring agency includes information regarding energy efficiency and consumption, size and price and thus has allowed detailed tracking of trends in household refrigerator characteristics in Australia and Europe for over ten years.

For Europe, GfK sales data from 2004 – 2014 has been analysed in this paper. For Australia, more detailed sales data has been available over a much longer time period (1993 – 2014), so this provides a useful comparison with the European trends. As a result of mandatory product registration, the sales information by model in Australia can be complemented with comprehensive product details to allow tracking of all key features.

For household refrigerators, this paper analyses market trends in energy efficiency, absolute energy consumption, size and price in Europe and Australia; examines the impact and timing of regional policies, including MEPS and energy labelling; proposes explanations for patterns observed; compares and contrasts the Australian and European trends and context, allowing the two regions to learn from previous policy approaches, and makes recommendations regarding MEPS and energy labelling, as well as market monitoring and product registration.

Background

Energy Labels and minimum energy performance standards (MEPS) for energy using products are crucial policy instruments that support on-going market transformation towards higher energy efficiency and lower energy consumption. Appropriate levels for Energy Label classes and their relationship with MEPS levels are key for the effectiveness of these policy instruments: if most models are already in the best Label class and no challenging MEPS are implemented, innovation can stall (see examples dishwashers or ovens in [1]). Label efficiency classes that are still beyond the current market generate market pull while challenging MEPS levels push poor performing products to a higher efficiency level. Together, these instruments ensure that the efficiency of products is improving continuously (example refrigerators and freezers in [1]).

To ensure that policy measures are effective, it is critical to understand the market in terms of what products are sold and their attributes (including efficiency). Understanding the market empowers policy makers to make orderly and well informed decisions about the optimal level for new MEPS and Energy Label class limits and their timing in order to achieve maximum effectiveness. If sales data are available over a longer period, it is possible to develop stock models to estimate trends in energy consumption and other attributes [2] – this can be used for assessing past savings from previous policies as well as projecting future savings from proposed new policies (see [3] for an example). A database containing all models that are on the market can also support ongoing market surveillance – it facilitates selection of models for compliance tests and can show all similar models belonging to the same 'model family' for which the test results are applicable.

Australia: Label re-grades are based on systematic market monitoring

Since energy labelling commenced in 1986, Australia has had a mandatory product registration system for all products that are covered by Energy Labelling and MEPS. Initially this was administered at a state level, but is now national. New Zealand introduced mandatory regulations for product energy efficiency in 2002 and shares the same registration system and program requirements for nearly all products. Each model that is put on the market has to be registered with its energy specifications. Many other important economies have similar product registration systems: e.g. Brazil, Canada, China, India and the USA [4]. The Australian product registration database has a public

component that is used to inform consumers about energy saving products: An app for mobile phones as well as a website listing allows consumers to see all products on the market sorted by efficiency (or any other attribute) as well as the operating cost (energy cost over the product lifetime) of any model [5]. At the same time, the government uses the data for assessments when revising MEPS and Energy Labels. In addition, the Australian government has been monitoring the market for whitegoods with sales data purchased from GfK from 1993 to 2014 [3]. In New Zealand, suppliers are required to provide sales data for each model annually. The NZ government publishes a report with aggregated data, including energy and efficiency trends as well as energy savings [4].

In Australia and New Zealand, the energy label for refrigerators and freezers was re-graded in 2000 and again in 2010. In 2010 the scale was shifted so that the stars earned for most products were reduced by two stars and the number of available stars was increased to 10 stars. At this stage no products on the market earn more than five stars. MEPS levels were first introduced in 1999 (the same year as in Europe) and were upgraded in 2005 (to broadly align with US 2001 MEPS levels). Regulatory proposals to adopt US 2014 MEPS levels in 2018 are under development [6]. The energy labelling system will be upgraded again in parallel with the introduction of this new MEPS level. One of the important aspects will be the use of the recently published IEC62552-3 [7] with energy measurements at two ambient temperatures to determine the product energy consumption, so this can more closely match normal use.

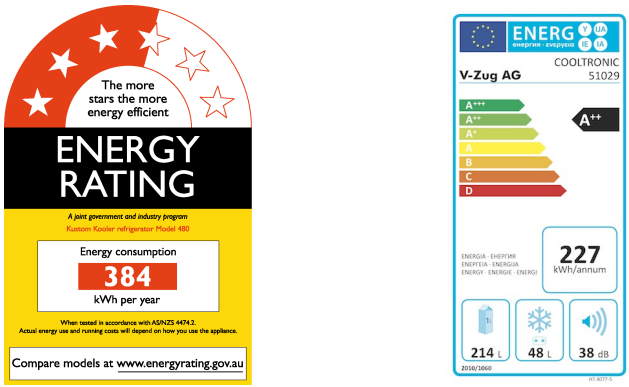

Figure 1: Australian and European Refrigerator Energy Labels, both from 2010

Note that the energy values are not directly comparable due to different sizes and test methods.

Europe: lack of market data can lead to suboptimal policies

Europe has no systematic market monitoring system: there is no product registration requirement, and no sales data are purchased, analysed and published on a systematic basis. Little is known about the market developments and the effect of past policies. Whenever market information is needed for a policy preparatory study or an impact assessment, available data is gathered by consultants. The data, which is usually provided by industry, is often incomplete and out-of-date and the different datasets cannot be directly compared over time and between countries. As a consequence, some Ecodesign and Energy Label requirements may have been designed at sub-optimal levels and energy saving opportunities may have been missed. Several of the Energy Labels recently introduced have required revision shortly after their introduction to the market: many products are already in the top-A+++-classes of the new Labels for washing machines, dishwashers, and tumble driers[1]. The Evaluation study of the Energy Labelling Directive [8] recommended that Europe should establish a product registration database to facilitate market surveillance and data collection for preparatory study market analysis.

The original EU refrigerator and freezer Energy Label, introduced in 1995, has never been re-scaled. Instead the original A-G scale was amended with the addition of new classes A+ and A++ in 2004 and A+++ in 2011. MEPS banned label classes D, E and F in 1999, B and C in 2010 and finally A in two

[1] Easily visible on the lists of most energy efficient products on www.topten.eu

steps: 2012/2014. Currently a revision of the current Ecodesign and Energy Labelling regulations for household refrigerators and freezers ([9] and [10]) is in preparation.

European and Australian refrigerator markets

Few current details are known about the European refrigerator market. The preparatory study from 2007 concluded that it was saturated with ownership at one appliance per household and a stock energy consumption of 82 TWh/year for the EU-27 [11]. The Energy Efficiency Status report from 2012 [12] presents some partial GfK sales data from Austria and Italy and price information from ten EU countries. An EU mapping and benchmarking report from 2012 [13] reports on average refrigerator and freezer volume (205l / 75l) and annual energy consumption (288 kWh/year in 2011), based on GfK sales data up to 2011 from 14 EU countries.

For Australia past reports have described the market trends. The 'Greening Whitegoods' report [14] analyzed sales data from 1993 to 2009 and found that between 1993 and 2009 the sales weighted energy consumption was trending downward at -2.9% per year for the entire period. In 2009 the average annual energy consumption was 480 kWh. The impact of the MEPS levels announced for 2005 is clearly visible: just prior to the implementation, energy consumption fell considerably below the long term trends.

Analysis undertaken in 2012 estimates that adoption of new MEPS levels in Australia and New Zealand in around 2018 will result in a further 30% reduction in energy over a 3 year period [6], depending on the implementation date.

Paper objectives

This paper aims to support the revision process of the refrigerator Energy Label and Ecodesign regulations in Europe with solid, current market data that allows evaluation of the impact of policies in the past. It also demonstrates the potential of information obtained from systematic market monitoring. This potential is underlined by the case study from Australia, where a near-perfect combination of sales and model registration data provides precise information on the market over time.

Data and Methods

Europe

Thanks to funds from the WWF Switzerland [15], the Topten study team was able to purchase refrigerators sales data from GfK [16], a professional market analysis company that operates in many countries around the world. In Europe, GfK covers around 90% of the refrigerator market, and all 28 Member States. Sales data, together with many product characteristics, are obtained by GfK from retailers.

The data obtained for this paper covers refrigerators with and without a freezer compartment for the years 2004 – 2014 and has been aggregated for 21 EU countries[2]. Separate freezers are not included. For each Energy Class (A+++ to G) GfK provided sales and sales weighted values for average price, energy consumption, and refrigerator and freezer volume. In addition, for France and Portugal, the same information was obtained at a country level, thanks to funding by Ademe [17], the French Environment and Energy Management Agency.

A full report [18], including analysis of data for washing machines and tumble driers, is available from www.topten.eu.

Australia

In Australia all refrigerator models must be registered with government when they are placed on the market. A public component of this registration database provides technical information on each current model. The government holds a long term database of all registrations ever submitted (nearly

[2] AT, BE, CZ, DE, DK, ES, FI, FR, GB, GR, HR, HU, IE, IT, NL, PL, PT, RO, SE, SI, SK.

30 years). Data from the products database can be combined with GfK model level sales data to provide highly accurate tracking of sales weighted characteristics of the market for each year. This Australian approach is the gold standard in market monitoring.

Energy and efficiency comparisons between Australia and Europe have to be interpreted with caution. The declarations are based on different test methods in the two regions – e.g. Australian and NZ models are tested at a higher ambient temperature than European refrigerators.

Results and discussion

Europe

The number of refrigerator units sold remained more or less stable in the 21 EU countries that have been included in the analysis. Over the last then years the annual sales fluctuated between 14.3 million (2009) and 15.6 million units (2006/2007). In 2014, 14.9 million units were sold [18].

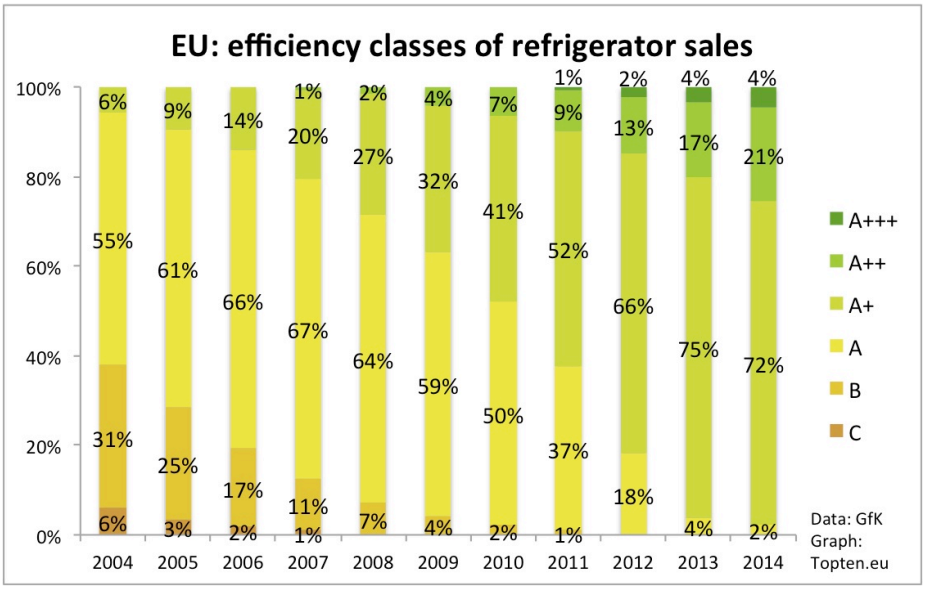

Figure 2: The EU market has improved by more than one efficiency class in 10 years

Figure 2 shows continuous improvements in refrigerator efficiency from 2004 to 2014. The average efficiency index has improved by 34% in this period (Average EEI 2014: 39)[3].

Table 1: Energy Efficiency Index (EEI) of Label classes

Class	Max. EEI 2004 - 2011	Max. EEI since 2012
A+++		22
A++	30	33
A+	42	42*
A	55	55
B	75	75
C	90	95

Label classes according to [10, 19, 20]. *The A+ EEI was temporarily increased to 44 from December 2011 until July 2014. This was related to the measurement tolerance being lowered at the same time.

In 2004 classes A and B dominated the market. New, better classes were required, and class A+ quickly gained market share after its introduction in 2004. Ten years later this label class is dominating the market. Classes B and C had both virtually disappeared from the market before they were banned in 2010. The Ecodesign regulation from 2009 had a stronger effect: the disappearance

[3] Average EEI was calculated by assigning the maximum EEI to each class.

of class A was visibly accelerated by a MEPS level of A+ effectively applying from July 2012 . A++ is slowly gaining market share, A+++ appears to be following a similar trend.

Data from France and Portugal shows that these trends can vary between EU countries [18] – despite identical legislation: in these countries A+ dominated the 2014 sales, but A++ sales only accounted for 11% (France) and 12% (Portugal), which is below the EU average of 21%. A different picture can be clearly seen in Switzerland, where A+ cold appliances have been banned since 2013: in 2014, A++ sales accounted for nearly 80% of the total Swiss refrigerator sales [1].

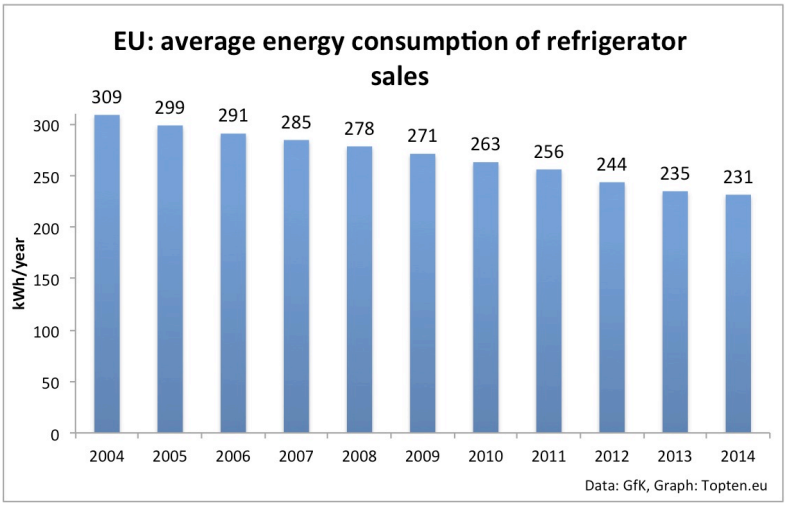

Figure 3: Average energy consumption has decreased by 78 kWh/year (25%)

Figure 3 illustrates that the market response to the Energy Label and MEPS policies, driven by industry innovation, has had the desired effect: average energy consumption has constantly been decreasing over the last ten years. The energy reduction of 25% down to an average declared energy value of 231 kWh/year is significant. The volumetric efficiency (kWh/l) improved by 27% over the period. However, the savings are smaller than the 34% improvement in the efficiency index shown in Figure 2. The difference cannot be explained by increased volume (Figure 4). Instead, the deviation is likely to be caused by factors that are not shown explicitly on the Energy Label: the current efficiency definition grants credits for certain special features such as a Frost Free function, built-in appliances, compressors that are rated for tropical climates, or a chill compartment. Since the European EEI formula rewards these features, it is probable that they have become more common. Another misleading aspect of the EEI formula is that different reference lines are used for different categories, making it much more difficult for refrigerators without freezer compartment to reach good efficiency levels than for refrigerator-freezers. A shift to a higher share of refrigerator-freezers is also likely to have contributed to the energy consumption reduction being lower than the gains in the label efficiency index.

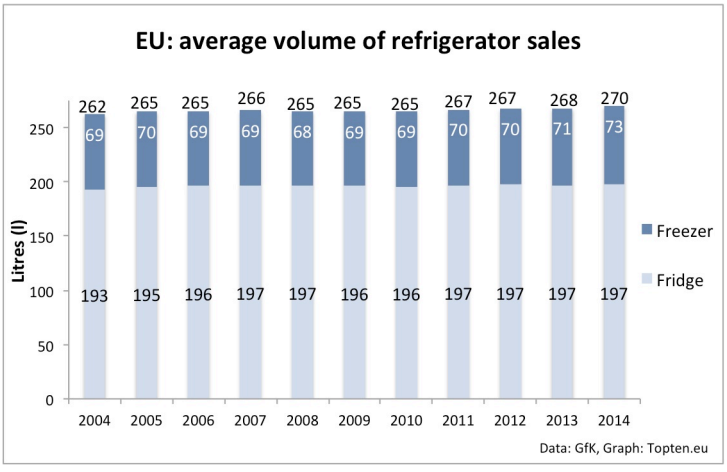

Figure 4: Total volume has increased by 8 litres (3%), the Freezer compartment by 4l (5%)

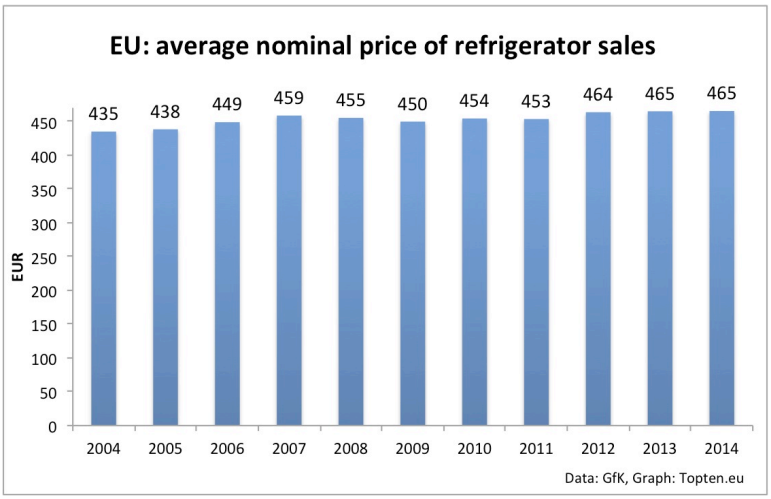

Figure 5: Average nominal price has increased by EUR 30 (7%)

While efficiency improved by 34%, the average nominal price paid for refrigerators only increased by 7% over the same period. Total lifecycle costs for consumers, based on the average price and declared energy consumption, were reduced by 13% from EUR 1130 in 2004 to EUR 985 in 2014[4].

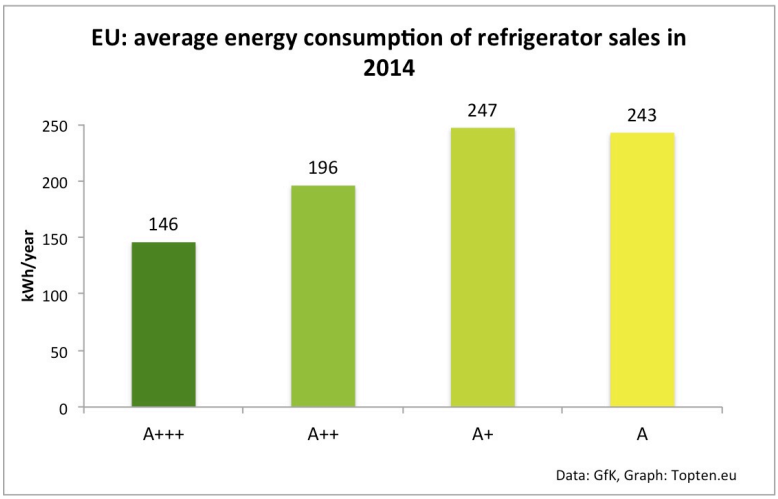

Figure 6: A+++ refrigerators save > 40% energy over A+ refrigerators, A++ > 20%

Energy consumption differences between efficiency classes are large for refrigerators: a move from A+ to A++ saves 21% electricity, a move from A+ to A+++ is a 41% reduction. While the consumption difference between A+ and A++ reflects exactly the EEI difference between the two classes (Table 1), the EEI difference is a bit larger (48%) from A+ to A+++ than the reduction in energy consumption from the sales weighted analysis. Analysis of the average volume per class shows that the reason for this difference is likely the larger volume of A+++ refrigerators: total volume of A+++ refrigerators was 15% larger than of A+ models (freezer compartment: +17%) [18]. Still, the gains in efficiency clearly outweigh the effect of the larger volume on energy consumption.

Higher efficiency of refrigerators delivers a large electricity saving potential for Europe. A move from the 2014 average efficiency (EEI=39) to A++ would lead to 15% energy savings – over the entire lifetime of the appliances that are sold in a specific year. Based on annual sales and average annual energy consumption, these savings amount to 7.8 TWh for one year of sales (or annual stock savings

[4] Assumptions: 15 years of lifetime, energy cost of 0.15 Euro/kWh.

if the entire stock was replaced)[5]. An estimate, which included separate freezers in this calculation, results in nearly 10 TWh of annual savings. These savings could have been hypothetically obtained with the 2014 sales, if the minimum efficiency requirement had been moved to A++ (the Swiss MEPS level).

Australia

The number of refrigerator units sold in Australia has been stable for around 10 years at close to 1 million units per annum [14].

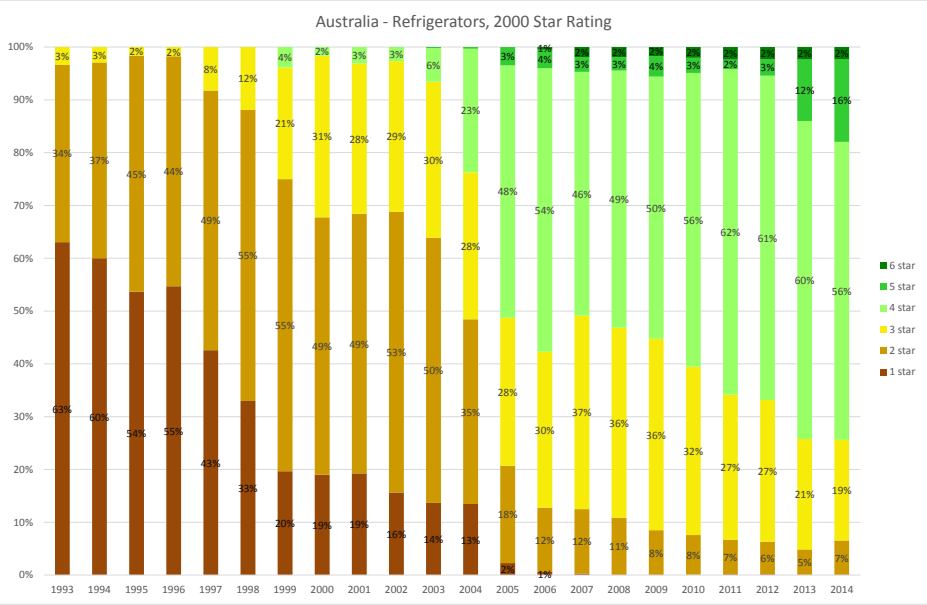

Figure 7: Refrigerator sales from 1993-2014, according to the star rating from 2000

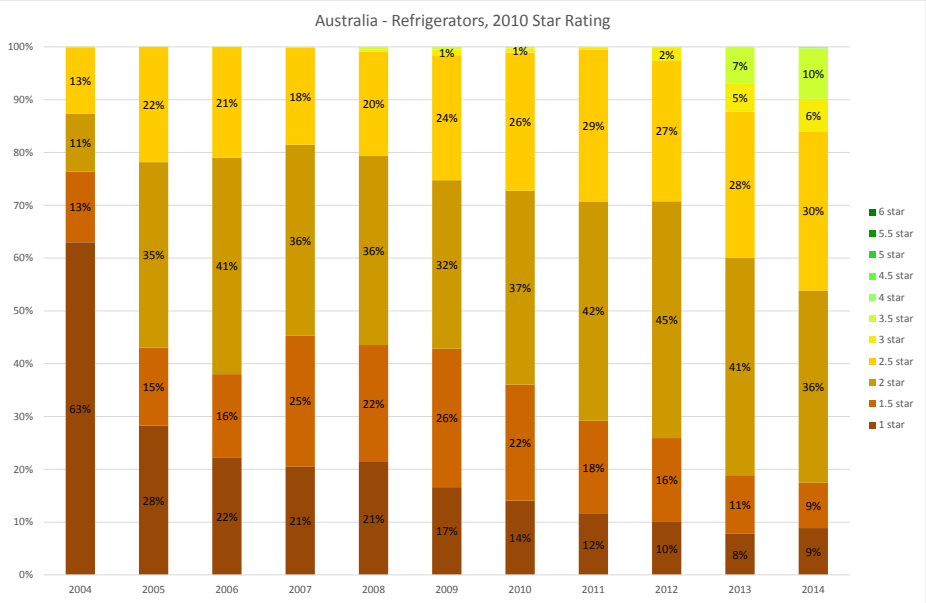

Figure 8: Refrigerator sales from 2004 to 2014, according to the star rating from 2010

[5] We project the lifetime savings of the appliances by their year of sale. It is a simpler approach than estimating the savings if the entire stock was replaced, but this approaches the figure of annual stock savings (after full replacement). Assumed lifetime was 15 years. Freezer sales were estimated at 25% of refrigerator sales, based on [1].

Figure 7 shows the share by star rating for refrigerators during the period 1993 to 2014 in accordance with the star rating equations implemented in 2000. This rating system applied to the market from 2000 to 2010 so will be the period where it had most effect. Some obvious step changes in efficiency improvements are apparent around the introduction of new MEPS levels in 1999 and 2005. Figure 8 is equivalent for the period 2004 to 2014 in accordance with the star rating equations applied to the market from 2010. The rate of change from energy labelling slowed for several years after the introduction of stringent MEPS levels in 2005, which is expected to some extent. However, the effect of the energy label after 2005 was also diminished as most products were rated at 4 or 5 stars under the 2000 algorithm that applied at the time, which is perceived as high (or at least acceptable) efficiency by consumers in Australia. Since 2010, after the introduction of the newly re-graded star rating, the rate of improvement in star rating has increased visibly, suggesting that re-grading the label classes do result in increased market pull.

In Australia, the energy labelling classes (or thresholds) are defined relative to the Base Energy Consumption, or the 1 star line. For refrigerators, a 23% reduction in energy is required for each additional star earned for all star ratings. The relative size of each class is therefore uniform for all classes, but the actual kWh decrease per star becomes smaller as the total energy decreases, reflecting the fact that each extra kWh is more difficult to save as the total energy reduces. Intermediate classes of half stars are also shown in the label.

Table 2: **Energy requirements for refrigerator label classes in Australia and New Zealand (2010 star rating algorithm)**

Label class	Max. energy compared to reference 1 star
6 star	27.1%
5.5 star	30.8%
5 star	35.2%
4.5 star	40.1%
4 star	45.7%
3.5 star	52.0%
3 star	59.3%
2.5 star	67.6%
2 star	77.0%
1.5 star	87.7%
1 star	100.0%

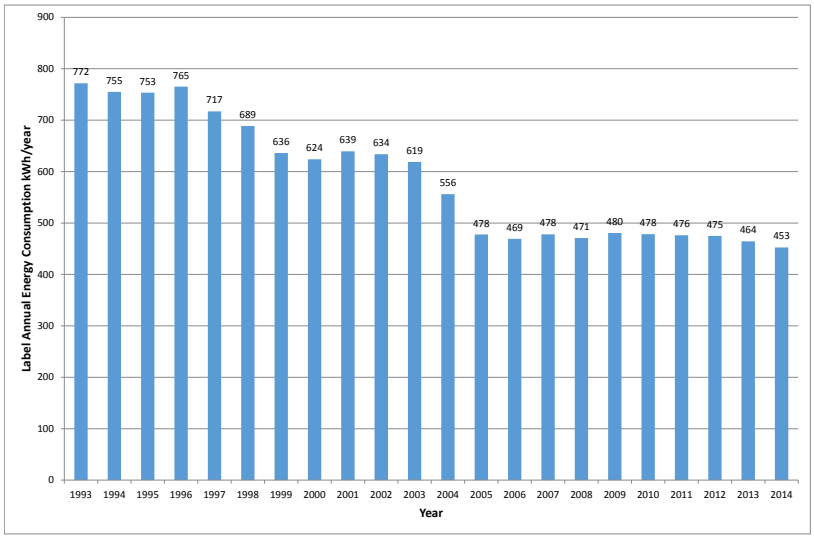

Figure 9: Change in annual energy consumption of refrigerators in Australia

New MEPS levels were introduced in Australia in 1999 and 2005. The impact of these is clearly visible in Figure 9. For some years after a new MEPS level the background rate of improvement appears to slow. The 2.9% annual improvement shown in [14| has decreased to about 1% after 2009. Average size of products increased by 23% during the 20 year period where data is available (Figure 10), while energy reduced by 41%. This equates to a volumetric efficiency improvement of 52% over 20 years. Energy savings from 2002 to 2014 are around 30% (looking at the period 2004-2014 would tend to understate the energy reduction because most of the MEPS 2005 saving were achieved by 2004). An evaluation of MEPS and labelling impacts in 2010 found that the energy savings from labelling and MEPS were greater than predicted in the original studies conducted prior to each of these MEPS regulations [3].

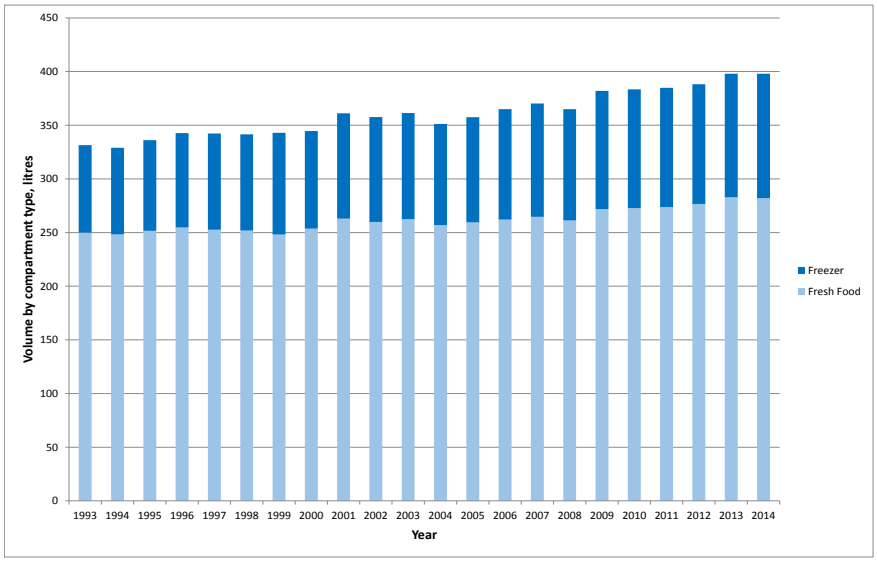

Figure 10: Changes in compartment volume over time in Australia

The size of refrigerating appliances sold in Australia has been increasing slowly for many years. Over a period that is comparable to the European data (2004 to 2014), total size has increased by 13% (compared to 3% for Europe).

Nominal prices paid for products in Australia have been fairly stable for many years, despite the increasing share of larger appliances with more features, such as automatic defrost (which is now almost universal for most product types). Real prices, corrected for changes in inflation, have decreased by 35% over the past 20 years. This is a feature that is common in many markets around the world.

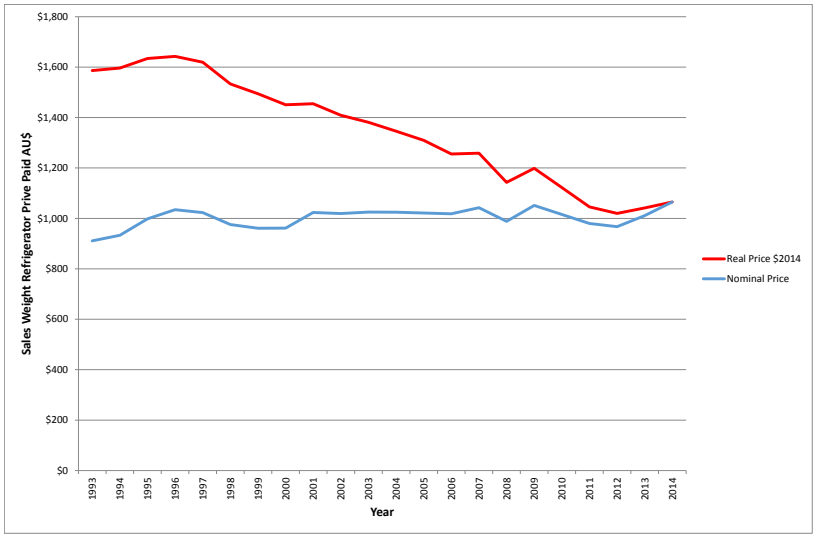

Figure 11: Changes in nominal and real prices paid for refrigerators in Australia

In Australia, the change in energy for each label class is evenly spaced across all star ratings so, as expected, the energy change per label class is not as dramatic as in Europe. Comparing energy for each label class needs to be interpreted carefully, because if there is any size bias in the formula that calculates the label class, this will show up in the average energy per class. A useful metric for examining price and energy trends is $ per litre of adjusted volume and energy per litre of adjusted volume, as shown in Table 3.

Table 3: Analysis of model data by star rating for Australia in 2013, Group 5T

Star Rating =>	1	1.5	2	2.5	3	3.5	4
Average price AU$	$954	$464	$614	$840	$921	$660	$1,588
Average volume (l)	436	223	327	431	417	322	461
Average adjusted volume (l)	518	262	383	499	489	374	528
Average Energy (kWh/year)	707	413	445	465	395	303	335
Models	4	16	73	90	10	11	2
Sales (units)	16	22'422	115'391	190'315	21794	45'326	759
Price/Adj. Vol (l)	$1.84	$1.77	$1.60	$1.68	$1.89	$1.76	$3.01
Energy/Adj. Vol (l)	1.38	1.60	1.21	0.95	0.85	0.82	0.64

Note: Group 5T is a frost free refrigerator-freezer with a top freezer with total sales of around 400,000 units per year (40% of the market). Star rating bins with few models or few sales need to be interpreted with care. The adjusted volume takes into consideration different compartment temperatures (freezer compartment volume is multiplied by a greater factor than refrigerator volume).

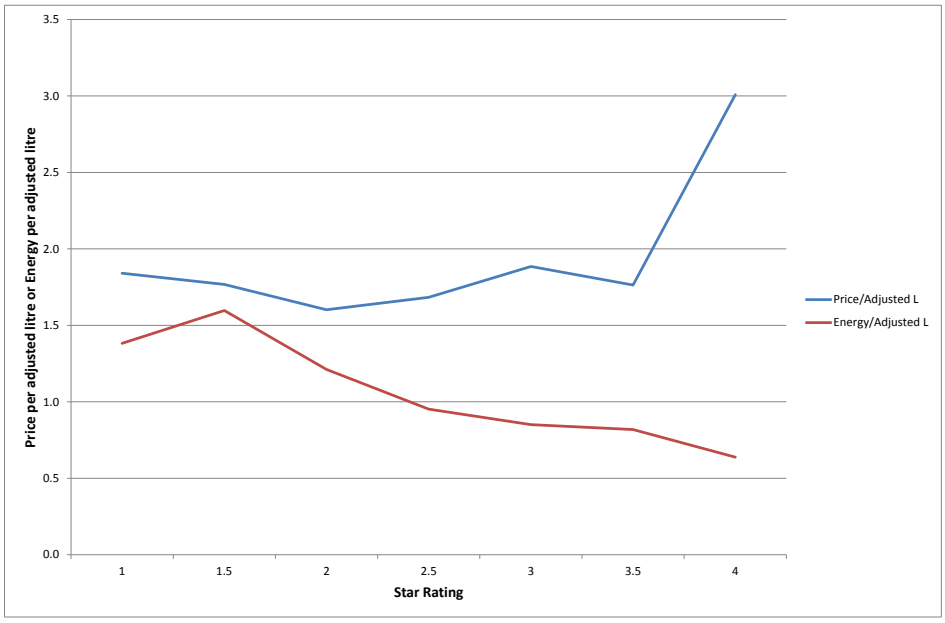

Figure 12: Analysis of price and energy per unit volume by star rating in Australia in 2013, Group 5T

The detailed analysis of individual model data shown in Table 3 and Figure 12 illustrates that the highest available efficiency class appears to attract a significant price premium for this particular product type. However, this needs to be interpreted cautiously as the price for the highest label class in this case is calculated from only 2 models (out of a total of about 300 models) with sales of less than 1,000 (out of a total of 400,000). Analysis of other refrigerator and freezer types shows that the highest available star rating on the market attracts a significant price premium for some of the types, but not for all. Analysis also shows that there is no systematic size bias in the star ratings across product categories, which is a useful finding.

Detailed market analysis of price versus energy efficiency for refrigerators on the Australian market found that, within the range of available products on the market, there was generally weak negative or often no correlation between price and energy consumption [21].

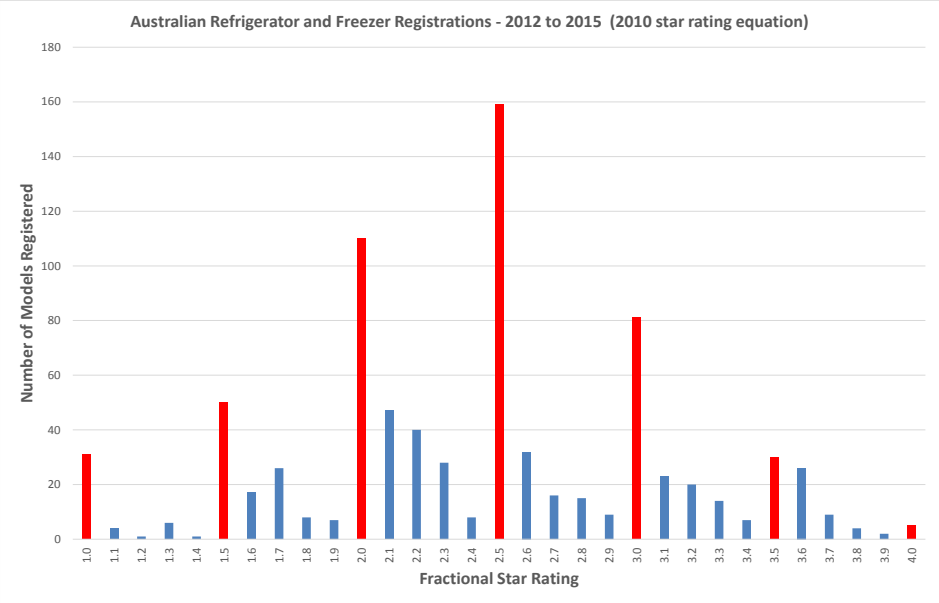

Figure 13: Distribution of star ratings for refrigerator and freezer registrations

Figure 13 shows that, while star ratings of all products registered are essentially a normal distribution, there is a much higher than expected prevalence of models with a star rating index that achieves the next highest label class within each half star bin, as shown in red. This illustrates that the label exerts a continuous upward pull on manufacturer designs with respect to energy efficiency. Suppliers have to comply with tight verification tolerances in the test standard and also supply test reports with registrations, so this effect is primarily the result of small engineering improvements in products rather than the exploitation of test tolerances. There could be small effects from selective sampling. This pattern can be explained to some extent by the fact that manufacturers do not bother to re-register their products when they make small energy improvements, except with the cumulative effect of these changes over time results in the product reaching the next half star threshold.

Can the European and Australian refrigerator markets be compared?

A comparison of analysis of refrigerator sales from Europe and Australia show many similar trends such as increasing efficiency and decreasing average energy consumption for both regions. However, there are also differences between the markets and how they respond to local policies.

Energy consumption values have to be compared with caution, but seem to be clearly higher in Australia. This is no surprise, as Australian refrigerators are larger than European models. This is likely to be function of demographic and climatic factors: a significant proportion of the Australian population do not live in dense urban areas as in Europe, but rather in sprawling suburban regions, where shops may be some distance away. Most families do larger weekly shopping rather than regular small purchases of food, so a larger storage capacity is a consequence.

Australian MEPS seem to have had a much stronger impact on the market than MEPS in Europe: their effect is clearly shown in Figure 7 and Figure 9, but this is less obvious in the equivalent EU figures. Australian 2005 MEPS were very stringent: when they were announced in 2000, there was no product on the market that would meet the level and all products had to be improved by an average of 30% within five years. After the implementation of stringent MEPS, the improvement rate from labelling slowed. In Europe, MEPS are usually implemented at low efficiency levels[6], while much of

[6] A barrier for more stringent MEPS in Europe might be the requirement that MEPS must be set at the Least Life Cycle Cost (LLCC) level, for the calculation of which constant prices are assumed. In [24] H.P. Siderius shows that prices of efficient technologies decrease over time, and proposes to use experience curves to forecast future real prices instead.

the market transformation is achieved by the ongoing pull effect of the Energy Label. As a consequence, the market improvement has occurred at a more consistent rate in Europe.

Another factor contributing to changing market responses in Australia might be the two Label re-grades, which took effect in 2000 and 2010, and visibly increased the underlying rate of efficiency improvement. European label classes have remained more or less the same, with new efficiency classes simply added on top.

Not only do the stringency and timing of policies impact the market trends, but also the definition of what is an energy efficient refrigerator – that is the mathematical formulas assigning an energy efficiency class to a refrigerator's measured energy consumption. While in Australia Label classes are evenly spaced (always 23% efficiency steps, or around 11% for half star classes), the EU Label classes require different improvements between 21% and 33% per class, which is a considerable energy reduction for a product that is already quite energy efficient. Both regions use a system of different product categories, which have different reference lines (based on adjusted volume and energy) and include a different range of products. The energy label reference line in Australia is based on the adjusted volume to the power of 0.67 ($V_{adj}^{0.67}$) to better reflect the relative changes in surface areas with size. This results in a reference line that is a curve and substantially corrects for size bias in the rating system for larger products. As straight lines are used in Europe, some size bias is inevitable. Also in contrast to Europe, in Australia there are no allowances or 'correction factors' for frost free products, chillers or any other features.

Conclusions

This paper tells a success story about household refrigerators: their energy efficiency has constantly improved over the last ten years, both in Europe and Australia. Data from Europe shows constant sales figures, a 34% efficiency improvement, a 25% reduction in average energy consumption and a very moderate price increase. Australia also shows constant sales figures with an 11% improvement in efficiency over the period 2004 to 2014 and a 19% reduction in energy. The lower levels of improvement in Australia are a reflection of the analysis period – an energy reduction of 30% was achieved from 2002 to 2014 due to new MEPS levels introduced in 2005 (much of the resulting energy savings were already achieved by 2004). Nominal product prices in Australia appear to be constant over time, with real prices falling by as much as 35% over the past 20 years. New refrigerators save energy, and consumers save money due to lower lifecycle costs in both Europe and Australia.

The data presented in this paper shows that Energy Labels and MEPS can be important drivers towards higher energy efficiency and lower energy consumption. A review of data for other product categories shows that energy efficiency can stall if efficiency improvements are not rewarded, for example, where there are no higher efficiency classes to challenge the market. To maintain market pull, Labels and MEPS need to be revised periodically, to take into account the efficiency innovations achieved by industry. Australia shows that stringent MEPS can have a big impact on the market, and that Label class re-scaling can be realized without major problems [22], although such changes do require careful planning and implementation. Defining sensible label classes necessitates some insight into how fast energy efficiency is likely to improve over time and the likely technological improvements that each industry can utilize into their future products (and their cost). This requires a good deal of judgment and expertise, as well as excellent and up-to-date data!

For monitoring the effect of past policies, making timely decisions on revisions, designing new policies at appropriate levels and quantifying energy consumption and energy savings, systematic market monitoring is invaluable. Sound data and its analysis, as presented in this paper, may come at significant cost, but can support policy makers decidedly to draw better and more effective policies, independent of industry readiness to provide own data.

With its market monitoring system, Australia can show Europe the way: the combination of GfK sales data with detailed model information from the mandatory product registration system allows tracking of highly detailed information on market changes and also supports effective market surveillance. Europe would benefit substantially from the introduction of a similar mandatory product registration system (providing detailed information about all models on the market) as well as a systematic market monitoring based on sales data from a commercial market monitoring organization for all Energy

related products. The potential benefits are substantial: for example, in Australia, the energy cost consumers pay to operate all refrigerators each year is about 100,000 times more than the cost of purchasing and analyzing the market data for refrigerators each year. Undertaking this analysis is most likely a good investment. Even if such data can lead to only to a 1% improvement in energy consumption over time, the benefit cost ratio is more than 1,000 to 1. Analysis in this paper has shown that substantially larger improvements can be achieved in practice.

Recommendations for EU refrigerator and freezer policy

New A to G Label, empty top classes:

For the past two years, only label classes A+ to A+++ remain on the market. These classes are known to have limited effect on consumer purchasing decisions [e.g. 23], while the original A-G Label is clearest for consumers [8]. Australia shows that a re-grading of Label classes can increase the Label's market pull effect. The opportunity of the current EU Label revision should be used to go back to an A-G scheme, with the two top classes empty initially to account for future innovations.

Announce future MEPS:

Australia shows that stringent MEPS can have a big impact on the market. New MEPS in Europe can cut off the lower end of the market to realize the 10 TWh of potential savings per year quantified in this paper: today's class A++ should be announced as the forthcoming MEPS level in two years.

Simplify the EEI calculation formula to remove misleading features:

The EEI calculation formula must allow a direct comparison of different products by removing the current rewards for special features: one reference line (or curve) for all categories is sufficient (temperature differences are already considered in the adjusted volume) and the misleading correction factors for tropical compressors, Frost Free function, built-in models and chill compartments should be removed. The Australian reference curve has removed size bias for larger products. With the approach rationalized and revitalised, the Energy Label in Europe will do more to support the most energy-saving models, and higher efficiency will more directly translate into saved electricity.

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