Do energy efficient appliances cost more?

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Abstract
This paper provides information on the trends in energy performance and prices of major appliances in the US, Australia, Japan and Europe and examines the impact of national Standards and Labelling (S & L) appliance programs. The results indicate that not only is the average energy consumption of appliances falling, but that they have also become cheaper. This is contrary to many expectations that the introduction of mandatory S & L programs would increase the price that consumers pay for appliances.

Against a background of general improvements in manufacturing efficiency and off-shore supply, interviews with industry verify that energy saving technologies have been introduced at a lower cost than predicted by typical engineering analysis. This has considerable significance for cost-benefit and CO_2 mitigation studies, which are based on assumed future prices for efficient technologies.

This paper recommends that while engineering analysis still provides a useful indication of future costs, experience suggests that this method alone may tend to over-estimate prices. It may be appropriate to apply techniques used in other technology fields, such as 'learning-by-doing', to mimic the relationship between the reduction of costs and market growth, in order to better estimate the future cost of appliances.

Introduction
The cost implications of improving the energy efficiency of appliances is a vital input for those involved in developing sustainable energy policies. Residential appliances contribute 30 % of all electricity generated in OECD countries, producing 12 % of all energy-related carbon dioxide (CO_2) emissions. They are the second largest consumer of electricity and the third largest emitter of greenhouse gas emissions in the OECD. By 2020 it is estimated that residential appliance electricity consumption will have grown by 25 % compared to current levels (OECD/IEA, 2003).

As a result, understanding the extent to which demands for more efficient appliances will impact on costs and prices is important in determining the pace and stringency that policy measures are introduced, and fundamental in undertaking cost-benefit analysis. Given the interest in the relative cost of CO_2 abatement measures, to date there has been only a moderate level of detailed analysis of appliance cost trends and efficiency.

Estimates of the future cost and price of efficient technologies are used in most pre-implementation (ex-ante) analysis of policy options. Generally these are derived from *engineering assessments*: a costing of the components required to improve efficiency in particular appliances. Typically this methodology finds that more energy efficient technology will be more expensive than conventional technology.

With hindsight, we have the opportunity to check these assumptions. Tracking appliance efficiency and price over a period of time provides the opportunity to measure trends and to understand the true cost of policy options. This will provide greater certainty of outcomes and will also enable efficiency

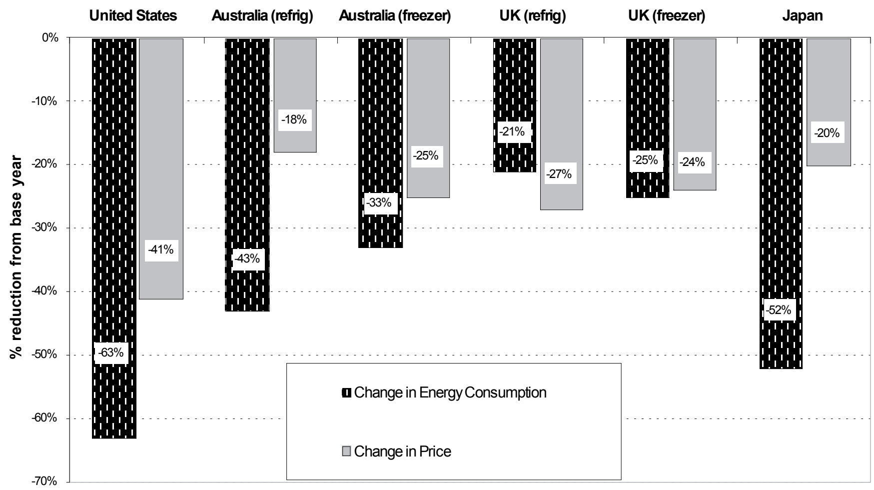

Figure 1: Summary of efficiency and real price trends for cold appliances (varying timescales)

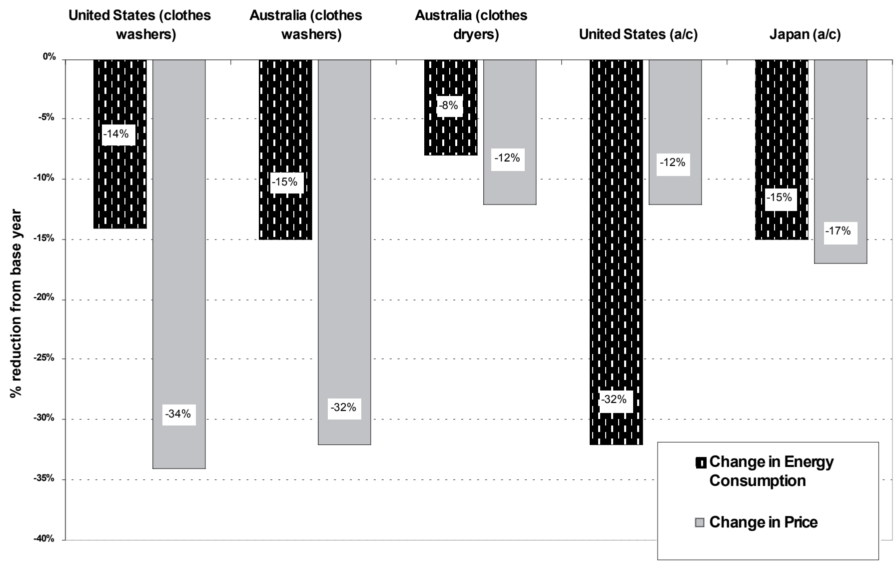

Figure 2: Summary of efficiency and real price trends for clothes washers, clothes dryers and air conditioners (varying timescales)

targets to be optimised on a least lifecycle cost basis, for the benefit of policy-makers, manufacturers and consumers.

International Experience

Unfortunately detailed long-term information on price and efficiency trends are not collected systematically for all products. In general, such information is restricted to products subject to national regulations for labelling or minimum energy performance standards (MEPS), and therefore covers a limited set of appliances over the period of implementation. However, many major household appliances have been subject to regulations in the larger economies for a number of years, albeit that timescales vary between countries. This analysis therefore focuses on refrigerators, freezers and refrigerator-freezers; clothes washers, dryers and air conditioners in the following countries, where available: United States, Australia, United Kingdom, European Union and Japan.

As summarised in Figure 1 and Figure 2, these residential appliances have become considerably more efficient while at the same time are actually costing consumers less now in real terms than they have at any time over the past ten to fifteen years. These findings appear remarkably consistent across a number of country markets, despite the fact that there are differences in the penetration and type of appliances, and in the requirements of Government programs.

IMPACT OF NATIONAL REGULATIONS

In this analysis it has also been possible to examine the impact of national regulatory programs on a case by case basis, by overlaying the date when regulations were introduced, as in the following examples taken from the United States, Australia

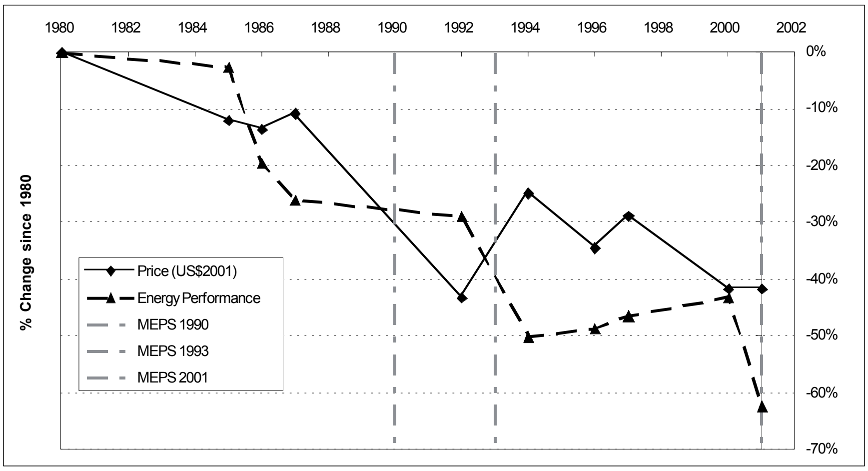

Figure 3: Relative average energy consumption and real prices, US refrigerators (Dale et al, 2002)

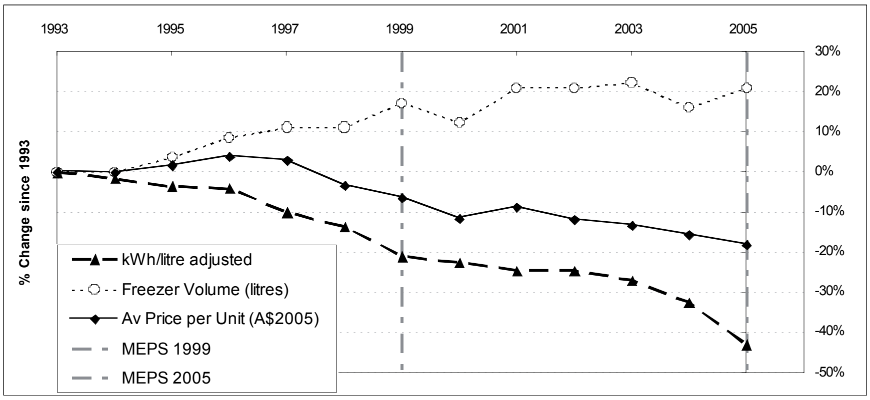

Figure 4: Relative average energy consumption and real prices, Australian refrigerators (EES, 2006a)

and the United Kingdom. It should be noted that impacts of regulations are often evident beforehand, as the market introduces more efficient products in time to meet the requirements. After the enforcement date, some further reduction in the average energy consumption may be seen as new efficient models continue to enter the market.

In the **United States**, the average energy consumption of refrigerators and freezers decreased by 60 % between 1980 and 2001, while at the same time real consumer prices have fallen by 40 % (Figure 3) (Dale *et al*, 2002).

Minimum energy performance standards (MEPS) for residential refrigerators and freezers in the United States were first introduced in 1990, and subsequently updated in 1993 and 2001. Figure 3 shows that around the time when the 1993 and 2001 MEPS requirements were introduced, the average energy consumption dropped by approximately 20 % on each occasion. This strongly suggests that the majority of efficiency gains have been driven by the introduction of regulatory policies.

In **Australia**, tracking of the refrigerator market since 1993 indicates that energy consumption in the average refrigerator has decreased by over 40 %, while real prices paid by consumers has actually fallen by nearly 20 %. At the same time the average size of freezer compartments in Australian refrigerators has increase by 20 %.

MEPS was introduced in Australia 1999 for refrigerators and freezers, and updated in 2005. While there is a noticeable reduction in energy consumption immediately prior to these dates (see Figure 4), it is less noticeable than in the United States, and there is no apparent correlation with changes in prices.

This may be due to the effect of comparative energy labelling, which was introduced for refrigerators and refrigerator-freezers in 1986, and updated in 2000. This programme has gained significant presence in the marketplace amongst consumers, and the trend prior to 1999 suggests it has provided a sustained incentive for manufacturers to introduce more of efficient equipment. Labelling may therefore have helped to prepare the market prior to the introduction of MEPS and resulted in fewer energy and price fluctuations than seen in the United States.

In the **United Kingdom**, the energy consumption of refrigerators and freezers declined by 20 %-25 % between 1989 and 2000, while the real average prices of these types of equipment also fell by between 24 % and 29 % (Schiellerup, 2001).

The UK introduced an energy label for refrigerators and freezers in 1995, and the energy consumption of both chest freezers and fridge-freezers dropped immediately prior to this date (no price information is available prior to 1995).

In the 3rd quarter of 1999 MEPS were introduced in the UK. As shown in Figure 5, the energy consumption of both refrigerators and freezers fell markedly around this date. The real average price of these types of equipment also declined substantially, apparently unaffected by the introduction of MEPS.

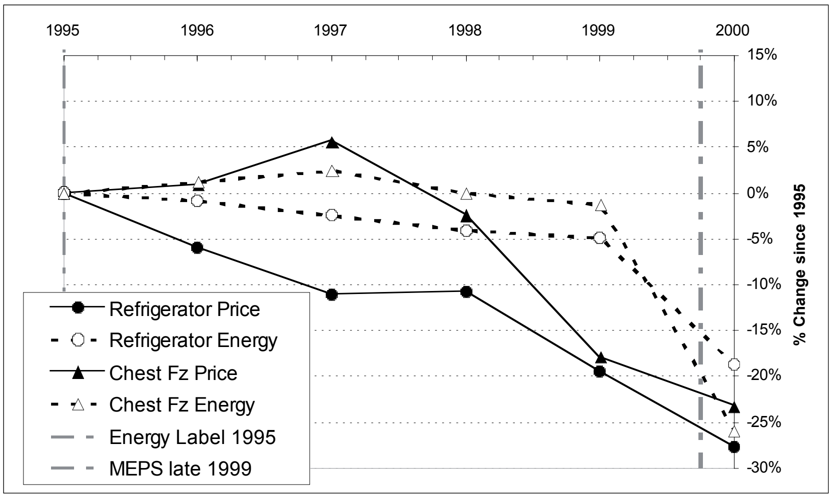

Figure 5: Relative average energy consumption and price, UK refrigerators and chest freezers (Schiellerup, 2001)

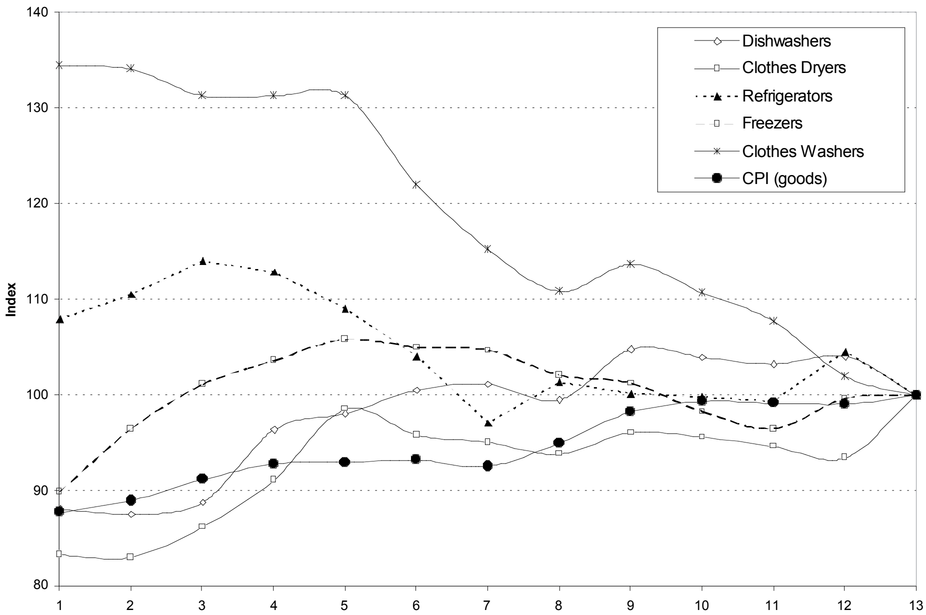

Figure 6: Nominal electrical equipment prices (adjusted for capacity, volume, etc.) compared to prices for household goods and services, Australia

Correlation tests between national electricity prices and the energy performance of electrical equipment showed very varied results indicating no statistically significant relationship. To the extent that some examples of a correlation were found, these appear to be largely circumstantial.

COMPARISON WITH PRICE MOVEMENTS IN OTHER CONSUMER GOODS

The consumer price index (CPI) in countries with MEPS and labelling programmes has risen by 2 % to 3 % per annum over the equivalent periods, except in Japan where the rise has been 0.5 % per annum. Since the appliances studied in this paper have not experienced price rises exceeding these levels, this suggests that the introduction of regulations has not adversely affected the price of equipment compared to the general basket of goods and service. This point is illustrated in Figure 6 which shows the nominal prices of Australian electrical equipment have generally risen less than the other household goods and services in this economy.

It is likely that the price of other goods and services will have risen more that indicated by the CPI in Figure 6, since the latter includes the data for electrical equipment.

The general conclusion is that the imposition of regulations has not caused any sustained impact on long term price trends. For some products, the introduction of MEPS or similar programs has coincided with temporary price rises, but this may be due to other factors (such as changes in non-energy attributes) and in all cases the downward trend is rapidly restored.

All the appliances studied have experienced a decline in real prices of between 10 % to 45 %, while energy efficiency increased by 10 % to 60 %. These gains have been made without sacrificing levels of service, since in all but one case the size or

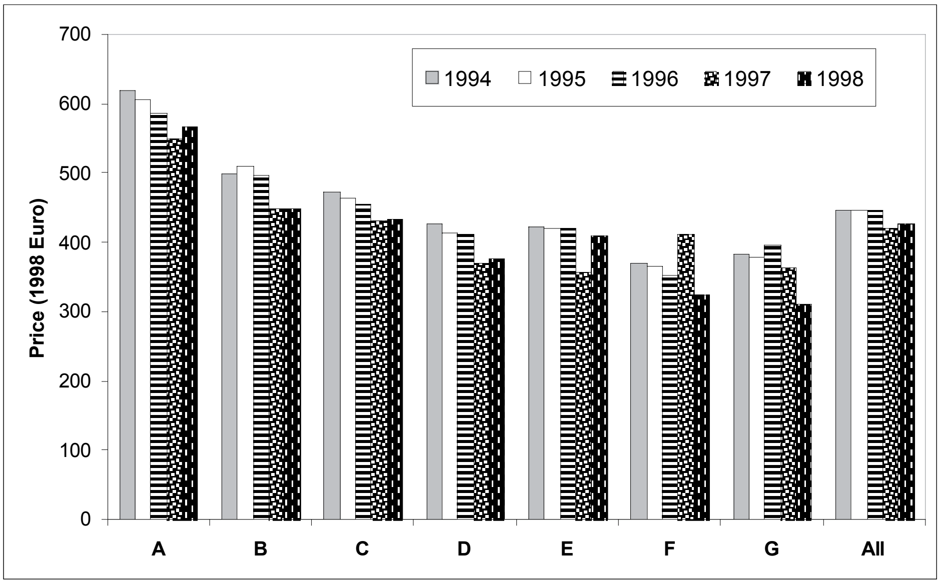

Figure 7: Price of European cold appliances, 1994-1998 (Waide, 2001)

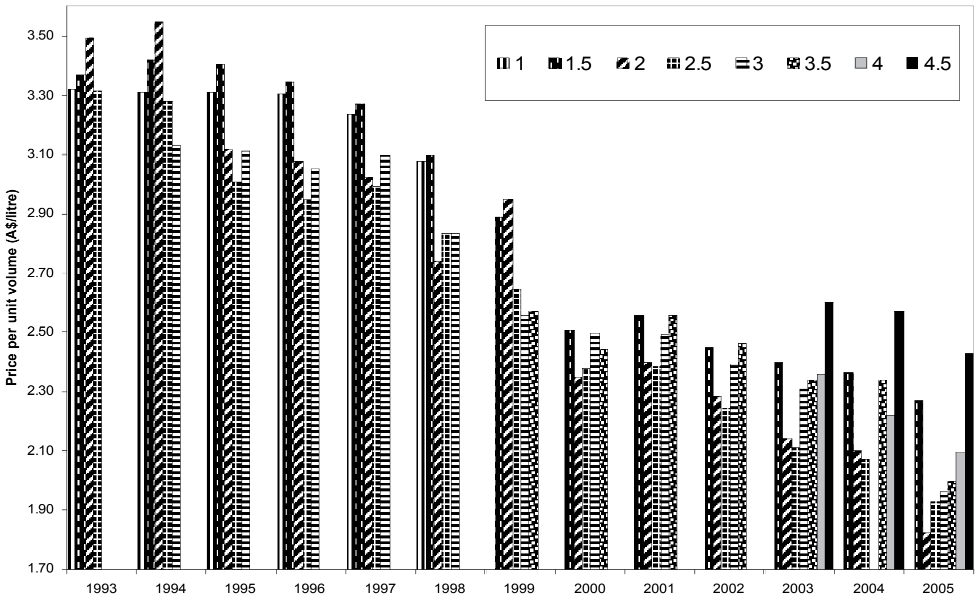

Figure 8: Real price per unit volume by star rating, Australian class 5 refrigerators, 1993-2005 (EES, 2006b). Class 5 refrigerators represent over 50 % of the Australian market.

capacity of the appliances monitored have either remained the same or increased.

Further, there is some evidence to suggest that where energy performance labels have already been introduced, the short-term impact of minimum energy performance standards MEPS on prices is reduced. This may be due to the fact that the market is already prepared to some extent (at the very least, manufacturers already know the relative performance of their models).

It should be noted that in all countries which implement MEPS there are considerable lead times built-in to the regulatory processes to enable the market to adjust to the specified requirements. Typically, formal notice is given some 2-5 years in advance of implementation, which may be extended by longer periods of industry consultation or other informal processes. Feedback from industry indicates that these lead times enable the market to minimise any cost implications from increased efficiency regulations by integrate design and manufacturing changes into normal industrial cycles.

If this data shows that **average** prices have fallen, generally unabated by regulations for efficiency, what has happened to the price of the highest efficiency products in relation to the price of similar products?

Figure 7 shows the real price of European cold appliances by category of energy label between 1994 and 1998. It is evident that almost all prices reduced between 1994 and 1998; however

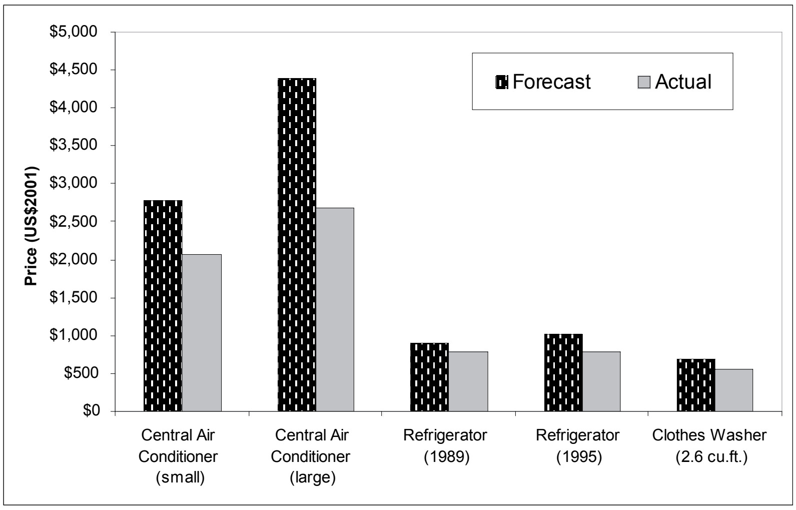

Figure 9: Comparison of predicted and actual prices (Dale et al, 2002)

appliances labelled A (the most efficient) continue to be more expensive than the other categories. It is noticeable that the price differential between categories B to G is small and not apparently explained by the large span of energy performances.

Similarly, there appears no correlation between price and energy efficiency in the Australian refrigerator market, except for the very highest efficiency models when they enter the market. As seen in Figure 8 the 3 star products are often cheaper than the less efficient 1 or 2 star products, and the 4 star products are less expensive than the 1 star models.

Although there appears no correlation between price and energy efficiency and the average price of appliances has been falling consistently, there is evidence that the most efficient products in some categories are more expensive than products which are less efficient.

Discussions with industry suggest that this reflects the additional cost of features other than energy efficiency. More expensive appliances tend to differentiate themselves by appearance, quality of materials and higher levels of controls; all of which add to their price. Typically they brand themselves as high quality products, and low energy consumption may be used as a further indicator of quality.

Comparison with forecasted costs/prices

Not only have prices of energy efficient appliances fallen in real terms, but where ex-ante studies have made predictions about future costs, actual prices are considerably lower than those forecasted.

For example, Figure 9 shows a comparison of predicted and actual prices for three appliance types, used in technical analysis for the US Department of Energy to assess the impact of MEPS at different stages (ie. they span only one round of regulations). In each case the forecasted prices exceed those observed in practice after implementation of regulations, and clearly this effect is likely to be cumulative over several rounds of MEPS. Similar results are found in other studies in the US, Europe and Australia.

These findings raise a series of questions about the methods that are used to forecast the future cost of energy efficiency improvements, and the accuracy of these methods. Improving our understanding of these issues is vitally important in order to determine which policies will achieve effective energy and greenhouse savings at least cost.

What's going on?

This paper shows that prices of appliances have been falling consistently over the past few years and have at the same time become very much more energy efficient. Furthermore, while the most expensive appliances appear to also be more energy efficient, in general there appears little correlation between price and efficiency. This is contrary to conventional forecasts which tend to assume that improvements in appliance efficiency will cause prices to increase. In order to explain these findings, we have highlighted issues relevant to the appliance industry in more detail.

DESIGNING FOR ENERGY EFFICIENCY

Appliances are going through a continual design process, either at the 'platform' or model level. For whitegoods the platform will typically be redesigned every 3-5 years while changes to models will occur more frequently. At the platform level, major technical changes are made but cosmetic alterations can be incorporated in model upgrades.

The design of a new platform incorporates all major requirements including any relevant energy performance levels. Therefore energy performance is only one of many design criteria which must be met. It is the task of the designers to find a solution which meets these criteria at least cost.

Discussions with several of the leading whitegoods manufacturers confirm that in past years it has been feasible to meet energy performance requirements at little or no additional cost. This is due to the following reasons:

- There has been sufficient advanced notice to meet the requirements through normal re-design processes.
- Manufacturers have been innovative in the ways in which energy performance has been improved.

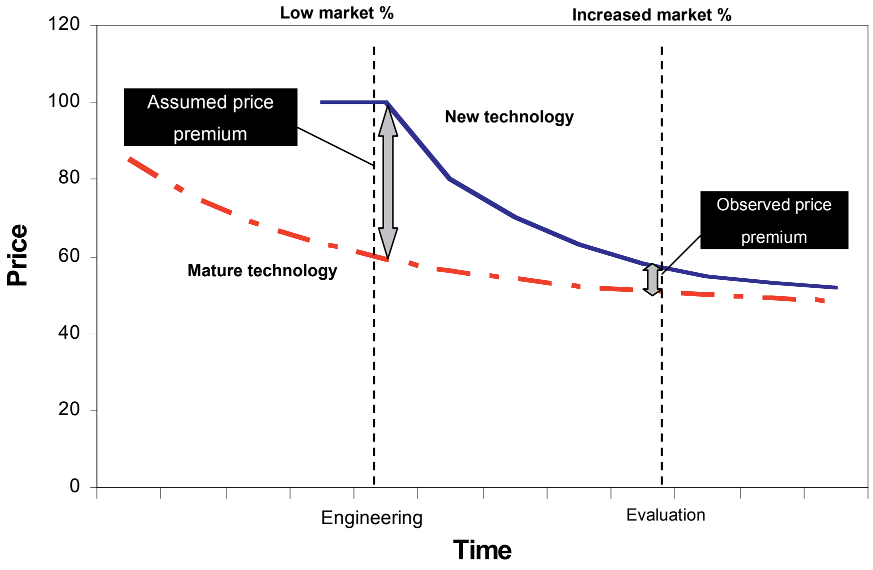

Figure 10: Price impact of market growth for energy efficient technology

- The costs of some components have fallen considerably. For example, electronic timeclocks and controls have become very much more available and cheaper.

It is clear that changes in the market for components is one factor which could not have been predicted by engineering type analysis, yet has greatly reduced the cost of efficiency improvements.

This example also shows the ability of design processes to provide innovative solutions to overall performance targets, taking into account current market conditions. Where more prescriptive type requirements are used, there is a danger impeding innovation and losing some of the cost benefits.

INDUSTRY COST STRUCTURE

In most markets, the price of most electrical and electronic appliances has fallen considerably over the past several years. While there are many factors which contribute to this, a major reason is that the manufacturing costs have been reduced. This has been achieved by a combination of switching to lower cost manufacturing centres, increased automation and competitive sourcing of components. Consequently, any small increases in cost due to improved energy performance have been lost amongst the larger cost savings which have been achieved.

PRICING POLICIES

Although price is the major issue for consumers, it does not necessarily reflect changes in the cost of producing and distributing an appliance. This is because suppliers may apply different margins to appliances in their range, they may change these amounts over time and one manufacture may apply a different pricing structure to a competitor.

In the particular case of energy efficient products, which often enter as a niche-market product, the low volume of sales may require a higher than average mark-up for the company to make a profit. As an efficient product gains market share, the margin may be reduced in order to become more competitive. Alternatively, a company that is aggressively seeking to enter a new market, or to establish energy efficient brand recognition, may choose consistently lower margins for a period of time, (see Hinnells, 2005 for further discussion).

The commercially sensitive nature of pricing policies, together with the complexity of separating out purely efficiency costs from other appliance features, makes it difficult for an outside observer to understand how prices relate to the costs of manufacture.

In a typical engineering analysis however, some assumptions must be made about margins in order to determine the effect on consumer prices. These are generally based on industry-wide mark-ups. The results yielded by this type of analysis can therefore only reflect average impacts and will not capture the shorter-term impacts of various pricing strategies pursued by manufacturers in the marketplace.

SUMMARY

Based on this analysis, it appears that the observed fall in prices of energy efficient appliances over the past years is mainly due to:

- Increased volumes of production;
- Innovative design solutions; and
- Decreased cost of production.

Government regulations for energy efficiency have been successful in moving energy efficient products out of niche markets and into the mainstream. As volumes of manufacture have increased, the cost per unit of manufacture has fallen and this has generally been reflected in the price of products to consumers.

In addition, there have been further production efficiencies which come from familiarity with new processes and technology, and the development of innovation.

The most likely explanation for the difference between the predicted and observed prices is depicted in Figure 10. At the time of an engineering analysis, energy efficient products have a low market share and command a high price premium compared to the conventional technology. By the time that further evaluation is undertaken, often after five or more years, the market for energy efficient products has grown considerably and the price reduced, converging with that of the conventional technology.

At the same time, equipment prices generally have fallen, but this has not been as pronounced; so that the price differential between a 'conventional' and 'energy efficient' product has decreased.

Improved methods of predicting costs

In practice a number of methods, and combination of methods, are used to estimate the relationship between cost and efficiency for appliances. Each have their benefits and short-comings, as described below.

ENGINEERING ANALYSIS

One method is to identify the technological changes required to make improvements to energy performance, and to cost these items. This *engineering analysis* approach includes identifying design options or new technologies and their resultant energy savings. The cost of these options is often estimated based on input from manufacturers, taking into account assumptions about volume and implementation dates. (McMahon, 2004) Manufacturers may also provide information on the relationship between costs and prices, used to model the impact on consumers.

This process has the advantage of being able to isolate the cost of energy improvements from other types of design changes, however as shown in Figure 9 there has been a tendency to over-estimate the cost of energy efficiency. There are a number of potential explanations for this, including:

- Insufficient cost benefits attributed to economies of scale and learning-by-doing;
- Incorrect assumptions regarding the margins for appliances;
- Existing manufacturers may provide high estimates in order to deter Governments from undertaking intervention activities;
- Modellers may themselves be conservative in order to present the worst case scenario and prevent any future shocks.

PRICE/MARKET COMPARISONS

In some cases, projected prices are estimated from an examination of the current market, based on the price of the most efficient models (in the target or other countries), or a statistical analysis of the spread of products. In this instance the distribution of price and efficiency for the range of current models available in a market are analysed to determine a correlation. Alternatively the cost of the most efficient models may be used as a proxy for future costs.

This type of analysis uses the market price and, where necessary, makes assumptions regarding the mark-ups in the supply chain to estimate costs of production. However the range of appliances in a market may have many varying characteristics in addition to energy performance. For example, models may also differ in size, design, level of control or materials, and all of these characteristics will have an influence on the cost/price of the product. It is therefore difficult to find products which are comparable in every respect except energy performance, in order to make reasonable assumptions regarding the relationship between price and performance.

In addition pricing policies are usually complex, commercially sensitive and change over time. Thus the forecasting of future prices based on current prices introduces many potential inaccuracies. Further, basing future prices on the price of high efficiency products with low market share in today's market can ignore the economies of scale which occur when their market share expands.

TIME SEQUENCE ANALYSIS

A final method is to study the relationship between efficiency and price over time, and use this to determine a price/efficiency path. Where information is available, the tracking of prices and efficiency of appliances can provide a good indication of how prices change as the market share of more efficient appliances grows. However, this type of retrospective analysis can only be undertaken where products have been in the marketplace for a number of years and the data is comprehensive.

Where products change frequently, a new technology is introduced, or where other product features change (volume, style, etc), it is difficult to use this method effectively.

LEARNING BY DOING

The observations regarding the prices of energy efficient appliances shown in this paper are not dissimilar to effects found in other industries, where the combination of these economies is often termed '*learning by doing*'. Importantly, learning by doing relates the cost of a technology to sales volume through the 'progress ratio' – which is the ratio of costs for every doubling of sales. Although the price of a commodity may not necessarily reflect the cost, Figure 11 illustrates a typical cost and price path for many technologies; showing a reduction in both costs and prices with cumulative sales.

Although the data on energy efficient appliances used previously includes many elements not specifically relating to energy efficiency it is difficult to use this to calculate historical progress ratios, however examination of some examples of new energy efficiency technologies is included below:

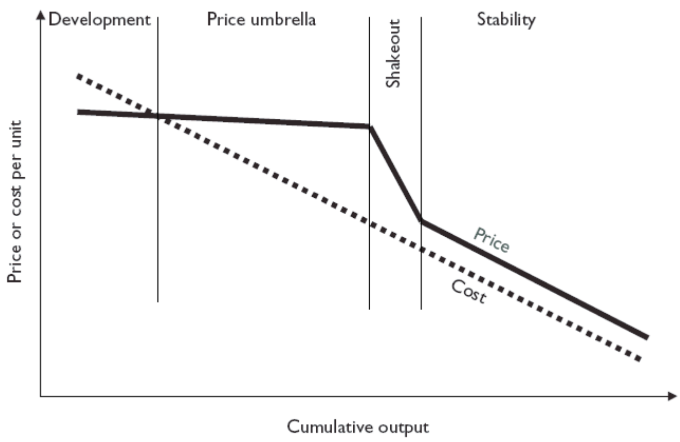

Figure 11: Learning by doing (OECD/IEA, 2000)

Table 1: Estimated progress ratios for energy supply technologies (McDonald and Schrattenholzer, 2001)

Product	Progress ratio
Nuclear Power plants	5.8%
Hydropower plants	1.4%
Coal Power plants	7.6%
Wind Power plants	17%
Solar PV Modules	20%

Table 2: Progress ration for end-use technologies (McDonald and Schrattenholzer, 2003)

Product	Progress ratio
Japanese air conditioners	10%-17%
Laser diodes	23%
Ac/Dc Converters	37%

US electronic ballasts

In 1991, the US Government launched the Green Light program to encourage the uptake of electronic ballasts by commercial building owners, and by 1997 these products had 35 % of all new ballast sales in the US. As a consequence, prices dropped from US$ 40 to US$ 12 (Duke and Kammen, 1999). The progress ratio for electronic ballasts in the US shows a progress ratio of 91 %, or a 9 % price reduction for every doubling of output.

Compact fluorescent lamps

Also in lighting, there has been considerable growth in the market for compact fluorescent lamps as a more efficient replacement for incandescent lamps. In this case the international market has grown from approximately 80 million lamps to 1,400 million between 1990 and 2004, led by over 20 national labelling and MEPS programs (AGO, 2006). At the same time, prices have dropped dramatically, from approximately $ 30 per lamp to $ 5 or less (Calwell *et al,* 2002, EcoNorthwest, 2002, 2004). This data suggests a progress ratio of approximately 10 %. This contrasts with a value of 20.1 % found in a 2000 study, but which was based on higher estimates of global CFL sales (Iwafune, 2000).

Other examples

Although there has been a number of studies of into 'learning by doing' rates for energy systems including renewable energy technologies (see Table 1), little analysis has been undertaken to date on progress ratios for end-use energy efficiency technology.

Recently, McDonald and Schrattenholzer have cited values for some end-use technologies, presented in Table 2. Although diodes and ac/dc converters are not in themselves energy efficient technologies, they are significant components in many modern electronic appliances, and it is reasonable to assume that their progress ratios are indicative cost reductions in electronic components.

FURTHER WORK

'Learning by doing' provides a good explanation for the general reduction in energy efficient appliance prices that have been observed over the past few years in most markets. As expected, some anomalies will exist as a result of the pricing policies pursued by individual companies, which mean that prices do not always track the underlying cost structure. Nevertheless, the limited number of examples cited show that progress ratios for end-use technologies are not dissimilar from emerging energy supply technologies.

Applied to engineering type analysis, 'leaning by doing' techniques could provide a more accurate method of predicting the future costs of energy efficient appliances. However, further data collection and analysis will be required in order to determine progress ratios that can be used with confidence in this way.

Conclusions

Understanding the future cost of energy savings from equipment is an important input for the type of energy and economic impact modelling used to inform policy makers. Without accurate forecasts of demand side costs some of the lowest cost options for greenhouse mitigation may be overlooked.

Results spanning a range of equipment in the US, European countries, Japan and Australia demonstrate that these are much more energy efficient and less expensive now than 10 years ago, and their price continues to fall each year.

Most of the types of equipment tracked are included in government programmes designed to promote energy efficiency, such as MEPS or labelling schemes. Despite the fact that there are differences in the penetration and types of equipment, and in the requirements of government programmes, this study demonstrates that the implementation of regulatory policies has not increased the price of regulated products in any of the countries studied. In addition, the price of these products appears to have risen less than the general trend for products and services over the same period. Interviews with representatives of the appliance industry confirm that 3-5 years advanced notice has allowed them to integrate energy performance requirements within their conventional design processes and minimise costs.

It is also apparent that actual market prices for energy efficient equipment are considerably less than had been predicted prior to the implementations of measures to stimulate growth in the market for efficient technologies. The most likely explanation is that costs have reduced as the market share has grown, and companies have found innovative means to reduced energy consumption.

Since most appliance features are continually improving it is difficult to isolate the impact of energy efficiency improvements by observing prices only. Engineering analysis provides the most effective means to predict future manufacturing costs, but the results should be used with care as they are likely to under-estimate future changes in the underlying cost-structure and the role of innovation in the design process.

'Learning by doing' provides a good explanation for the general reduction in energy efficient appliance prices that have been observed over the past few years, and the limited number of examples cited show that progress ratios for end-use technologies are not dissimilar from emerging energy supply technologies. Applied to engineering type analysis, 'leaning by doing' techniques could therefore provide a more accurate method of predicting the future costs of energy efficient equipment.

Rather than increasing appliance prices, this study shows that the government policies designed to increase the market share of energy efficient equipment have not increased consumer prices, while at the same time cutting greenhouse gas emissions.

Residential electrical equipment household appliances contribute 30 % of all electricity consumed in OECD countries and produce 21 % of all energy-related CO_2 emissions. In this context it is extremely important that the relationship between the price and efficiency of equipment is better understood. This will require considerably more resources than is commonly allocated for the collection of data on costs, prices and efficiency; engineering type analyses and the development of predictive tools such as 'learning by doing' curves.

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