# PROJECTING THE IMPACTS OF ENERGY PROGRAMS: HOW GOOD WERE THE ESTIMATES?

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## ABSTRACT

When programs such as energy labelling and minimum energy performance standards are considered by governments, estimates are usually made of the reduction in energy consumption that the programs will bring about. It is rare for these estimates to be revisited after the programs are implemented, often because no new data are available.

Estimates were made in 1991 about the energy impact of introducing energy labelling in 1986. At that time, since there was not full monitoring of appliance efficiency levels in the market, a number of estimation techniques had to be used. In 1993, projections were made of the energy impact of the proposal to implement minimum energy performance standards in 1996 for a number of appliances. The standards were actually implemented in 1999.

Between 1993 and 1999 there was continuous monitoring of the energy characteristics of all appliances sold. Although data have not yet been analysed for the period after the implementation of standards, the data already available give insights into market trends, and inot the validity of the original projections.

This paper reviews the trends in appliance efficiency and compares them with the previous estimates and projections. Of the seven appliance categories reviewed, the projections of energy reduction trends made in the early 1990s appear fairy accurate for three products, underestimated for two and overestimated for two. The conclusion is that the original estimates gave an indication of the energy value of the proposed MEPS policy that is reasonably consistent with information collected since.

## 1. BACKGROUND

The energy labelling and standards program in Australia originated in 1982, when the Government of the State of New South Wales first carried out a study of the projected energy savings, and announced the "Government's decision to implement an energy efficiency labelling scheme to cover appliances such as refrigerators and freezers" (EANSW 1982).

At that stage there was no Australian standard for measuring the energy consumption of refrigerators, and the best source of data on comparative running costs was the product reports in the Australian Consumers' Association (ACA) magazine, *Choice*. Energy consumption was recorded when products were tested for their ability to perform under the range of ambient temperatures specified in Australian Standard (AS) 1430 *Household Refrigerators and Freezers*. The results were not easily reproducible, since the internal settings were not standardised, but the data still allowed reasonable comparison of energy consumption and efficiency between models.

From about 1984, refrigerator manufacturers and the ACA began using the test which was to be incorporated in the labelling regulations in 1986, and which was eventually published as AS2575.2-1989 *Energy Labelling of Appliances Part 2*: *Determination of energy consumption and efficiency rating*.

In order to fully track "sales-weighted energy efficiency" movements in the market, it is important to have two basic types of data: the efficiency level of every model; and the sales of every model.

From 1986 the energy consumption and efficiency ("star rating") of every refrigerator, freezer, dishwasher and airconditioner model on the Australian market was on the public record, because the information had to be registered for energy labelling purposes. Efficiency data for clothes washers and dryers became available in 1990. However, information about the sales of every model did not become available until 1993, when Australian governments commissioned a commercial monitoring agency to track model sales (AGO 2001). airconditioner model sales are still not available to the government, so analysis to the same level of detail as for other products is not possible.

Between 1986 and 1993 the following methods were used to estimate trends in product energy efficiency:

- Model-weighted analysis: this consists of tracking the reported energy efficiency and consumption of all models on the market. This method gives a gross indication of market shifts over time: for example, the number of one-star models (the least efficient) declined rapidly after 1986, and the highest refrigerator star ratings on the market rapidly went from 3 to 5.
- Partial sales-weighted analysis: the total market share of each brand was available from commercial sources, and the number of models of each brand was known from the energy label register. An assumption that every model of a brand had equal sales was clearly incorrect, but nevertheless gave a better indication of the market average than model-weighted analysis alone.
- Model succession: most refrigerator manufacturers target their models to popular market niches – for example, they will always have a 450 to 500 litre frost free refrigerator-freezer model in their product range. Whenever these models reach the end of their production lives they are replaced with other models, and the reduction in energy consumption of these successor model gives an indication of trends in energy efficiency.

These techniques were used by the author to assess the effects of labelling on product energy efficiency between 1980 and 1990 (GWA 1991). The study found that there had been a background trend of efficiency improvements in the market in any case, and this had accelerated from 1985 – the year *before* labelling became mandatory – as suppliers redesigned their least efficient products and, in some cases, withdrew them from the market before labelling commenced.

In 1993 the author completed a study of the benefits and costs of implementing minimum energy performance standards (MEPS) for the electrical appliances which were already labelled, and for electric storage water heaters, which were not labelled (GWA et al 1993). The projections were based on the assumption that the MEPS levels recommended in the study would take effect in 1996, following a notice period of up to three years to allow suppliers to prepare. The authorities adopted the recommendations in part but for various reasons implementation of MEPS was delayed about three years, to October 1999 (see Table 1).

On the following graphs, the estimated impact of energy labelling is indicated by the difference between two trend lines: "no-intervention baseline" and "with labelling only (historical)". Both of these trends are the author's best estimates, based on the techniques and the studies mentioned above.

The projected energy saving from MEPS is also indicated by the difference between two trends: the "with labelling only (projected)" and "with MEPS" where in addition to the effect of labelling the least efficient products are excluded. This must increase the sale-weighted average, since sales of sub-MEPS models are substituted by sales of models which meet MEPS. The energy impact is sensitive to the year that MEPS take effect. Because the average energy efficiency of the models on the market is increasing anyway, the more delayed the implementation of a particular MEPS level, the fewer the number of models likely to be affected and the less the energy impact.

Table 1 Appliance MEPS recommendation and outcomes, Australia

| Product | Recommendation (GWA et al 1993) | Outcome |
|---|---|---|
| Refrigerators, refrigerator-freezers, freezers | MEPS formulae recommended for 8 product classes; MEPS recommended to start in 1996 | MEPS commenced in October 1999; recommended formulae modified |
| Clothes dryers | MEPS formula recommended | No MEPS adopted |
| Clothes washers | No MEPS recommended – product does not meet criteria for MEPS | No MEPS adopted |
| Dishwashers | No MEPS recommended for time being, pending review of energy tests and basis for efficiency calculations | No MEPS adopted; energy tests have been revised, but MEPS issue not yet reconsidered |
| Airconditioners (household) | No MEPS recommended for time being, pending review of energy tests and basis for efficiency calculations | No MEPS adopted; energy tests have been revised, but MEPS issue not yet reconsidered |
| Electric storage water heaters >= 80 litres | MEPS recommended: 55% of current standing heat loss, to commence in 1996 | MEPS commenced in October 1999; MEPS level 70% of then standard heat loss |
| Electric storage water heaters < 80 litres | MEPS recommended: 70% of current standing heat loss, to commence in 1996 | MEPS commenced in October 1999; MEPS level 100% of then standard heat loss (a) |

(a) This still had an effect, since before MEPS heat loss of most models was 110-150% of the standard.

## 2. VERIFYING PROJECTIONS AFTER THE FACT

The only trend that can ever be verified after an energy program commences is the *actual* sales-weighted energy consumption and energy efficiency of appliances. The accuracy of the "no-program" projections can never be directly verified, because once a program is implemented the no-program scenario disappears. Nevertheless, it is possible to make inferences regarding the "no-program" scenario by examining efficiency trends after the program is implemented (the "with program" scenario).

If energy efficiency with the program increases more slowly than the no-program projection (let alone the with-program projection), both projections were clearly wrong, and some major change in the market had been overlooked.

If energy efficiency with the program increases more rapidly than the with-program projection, then either (a) the program has a higher impact than expected, or (b) the no-program projection was wrong, and some major change in the market had been overlooked.

Even where there is no new intervention in the market (eg MEPS were not implemented for clothes dryers, clothes washers and dishwashers), the actual energy efficiency trend provides a test of the accuracy of the modeller's assumptions and projections.

Increasing energy efficiency does not necessarily result in decreasing energy consumption. Both energy efficiency and energy consumption can increase at the same time: eg if the increase in average adjusted volume of refrigerators (fresh food compartment volume plus temperature-weighted freezer volume) is more rapid than the efficiency increase (reduction in average kWh/litre).

The energy service provided by appliances can change in quality as well as quantity. Not only can the size of refrigerators (adjusted volume) increase – giving more quantity of cold storage space – but there may be a rising proportion of sales of automatic defrost (called "frost free" in Australia) rather than cyclic defrost. This would represent a higher *quality* of service and would imply higher energy consumption. Quality, or utility, can increase in other ways as well. The transition from ozone-depleting chlorofluorocarbons (CFCs) to other refrigerants and foam blowing agents represents an increase in utility through a reduction in negative environmental impacts; it can be achieved with constant energy consumption if the energy efficiency of the product is increased.

Therefore the following questions need to be asked when interpreting reported trends in product energy consumption:

- What was the change in average quantity and quality of the service provided by the appliances?
- What would the likely trends have been in the absence of any market interventions, such as labelling or MEPS?

In most cases, the main indicator of interest is the annual energy consumption per unit sold. This makes up a large part of the continuing monetary cost of operating appliances, and determines the ultimate load on the electricity supply systems and the environmental impacts, including greenhouse gas emissions. If these are growing rapidly, then it is of little comfort to energy policy-makers that householders are getting more services for each kWh of electricity and each kg of $CO_2$.

The diagrams in this paper illustrate trends in average energy consumption for the product groups for which sales-weighted monitoring data are available (data are not available for airconditioners or water heaters). The trends for the period 1980-2007 are indexed to 1993, the year the projections were made and – coincidentally – the first year of full market monitoring. The period is divided into sub-periods as follows (indicated by the corresponding letters on the diagrams):

A. Between 1980 and the introduction of energy labelling (1986 for refrigerators, freezers and dishwashers, 1990 for clothes washers and clothes dryers)
B. Between the introduction of labelling and 1993, when the projections were made
C. Between 1993 and 1996, the intended introduction date for MEPS
D. Between the intended introduction of MEPS in 1996 and the actual introduction in late 1999 (the most recent market monitoring data are for the year ended 1999, so post-MEPS effects are not yet evident)
E. After the introduction of MEPS (where applicable)
F. For products where no MEPS have been introduced, the period after the projections were done.

For each product, the "no-intervention baseline" indicates the likely trend in energy efficiency that would have occurred without either energy labelling or MEPS. The impact of labelling can be see in the "with labelling only (historical)" and "with labelling only (projected)" estimates, which were made in the period 1991 to 1993. In 1993 also, the impact of introducing MEPS for selected products in 1996 was estimated (the trend "with MEPS projected"). All of these trends were developed using the methods described earlier (model-weighted, partial sales-weighted and model succession analyses). (GWA 1991, GWA et al 1991, GWA et al 1993). The actual energy trends monitored between 1993 and 1999 are also shown (NAEEEC 2001).

## 2.1 REFRIGERATORS

Figure 1 illustrates trends for single-door refrigerators with icemaking compartments, which accounted for about 16% of refrigerator sales in 1993 and 14% in 1999. It was projected that the rate of efficiency improvement would stall in the mid 1990s, as manufacturers phased out CFCs, and would then accelerate as the MEPS implementation date approached in 1996. This scenario appears to have been largely borne out, except that the late acceleration in efficiency was delayed by the deferral of implementation to 1999.

Figure 2 illustrates trends for cyclic defrost refrigerator-freezers, which accounted for about 31% of refrigerator sales in 1993 and 12% in 1999. Here again, the projected trend appears to have been borne out, matched to the delayed implementation date of 1999.

Figure 3 illustrates trends for frost free (automatic defrost) refrigerator-freezers, which accounted for about 39% of refrigerator sales in 1993 and 63% in 1999. The rate of reduction in energy consumption per unit in the pre-MEPS period was far higher than expected. It was 0.70 of the 1993 level in 1999. The average adjusted volume of frost free refrigerators also declined over the period, so the fall in energy per litre of adjusted volume was not quite as great: to 0.77 of the 1993 level in 1999. There was

a more rapid market shift from cyclic to frost free units than expected when the projections were made. As the focus of the market shifted, the import of energy-efficient frost free models increased and the technical development efforts of local manufacturers focussed on frost free.

Figure 4 indicates the trend in average consumption for the three types combined, weighted by their actual share of refrigerator sales (together they made up 86% of refrigerator sales in 1993 and 90% in 1999). It appears that the actual weighted reduction in refrigerator unit energy consumption was even higher than predicted with MEPS, and took place even though MEPS implementation was deferred. If the market shift to frost free had occurred with unit energy consumption falling only at the baseline rate, the average consumption per unit would have *increased* at about 0.4% per annum ("with labelling only (projected)"). The projected reduction with MEPS, adjusted for market shift ("with-MEPS (projected)") would have been about 1.4% per annum. However, because of the rapid reduction in the average consumption of frost–free units, the weighted reduction trend ("actual pre-MEPS") was almost double - about 3.0% per annum - even though MEPS had been delayed so that it did not take effect within the period.

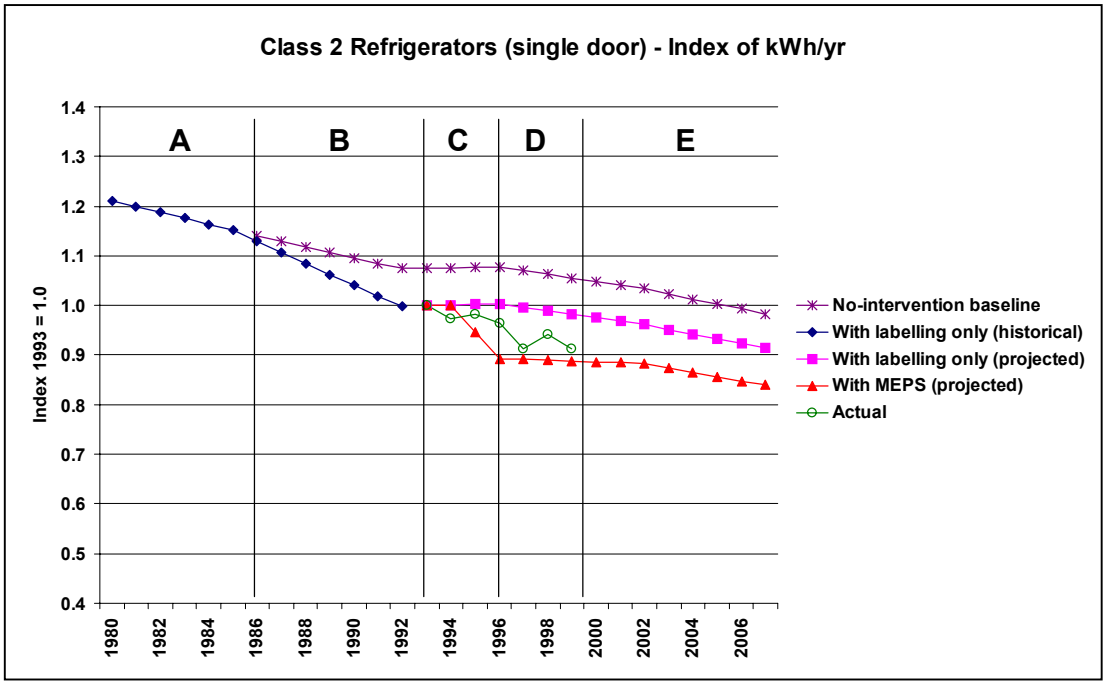


Figure 1 Energy consumption trends and projections – single door refrigerators

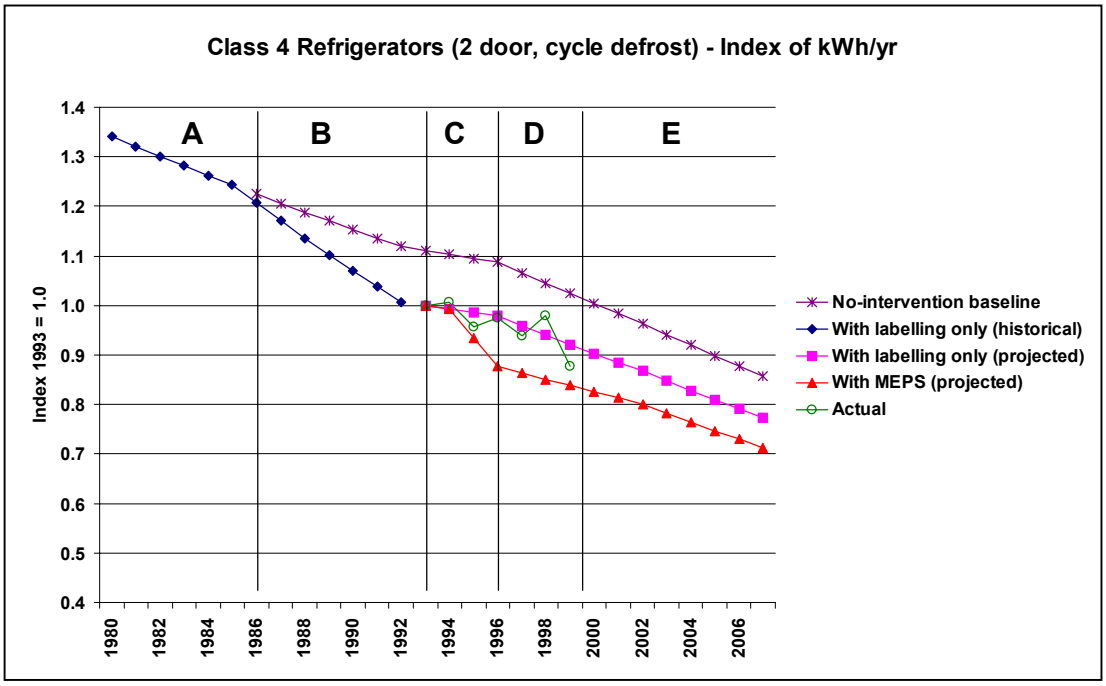


Figure 2 Energy consumption trends and projections – refrigerator-freezers (cyclic)

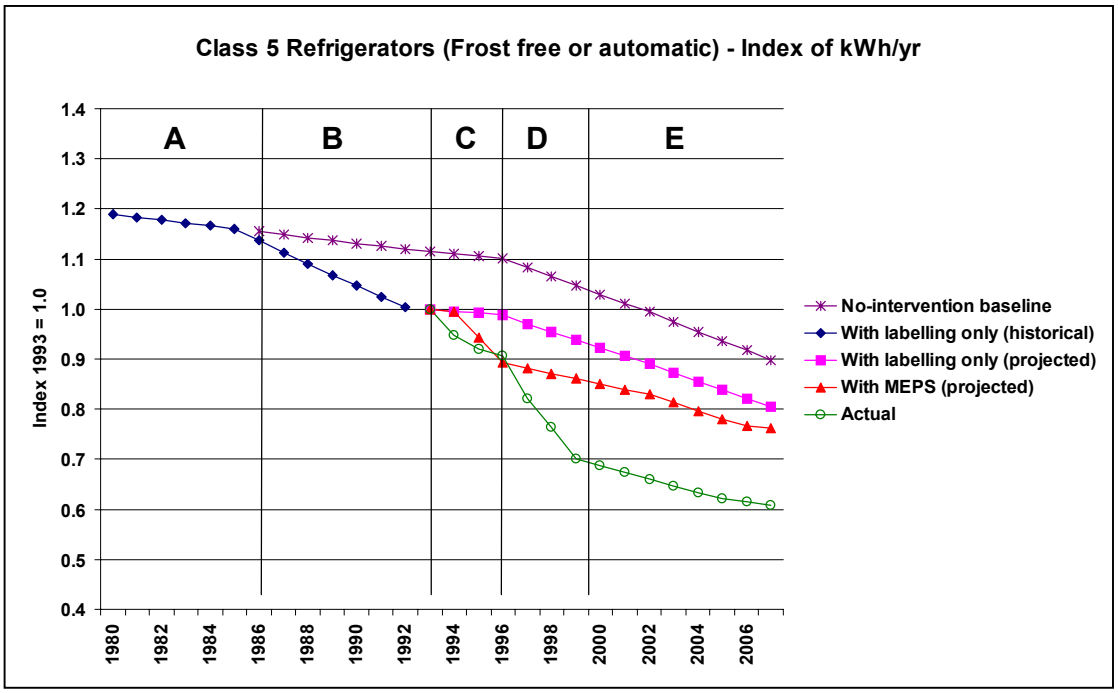


Figure 3 Energy consumption trends and projections – refrigerator-freezers (frost free)

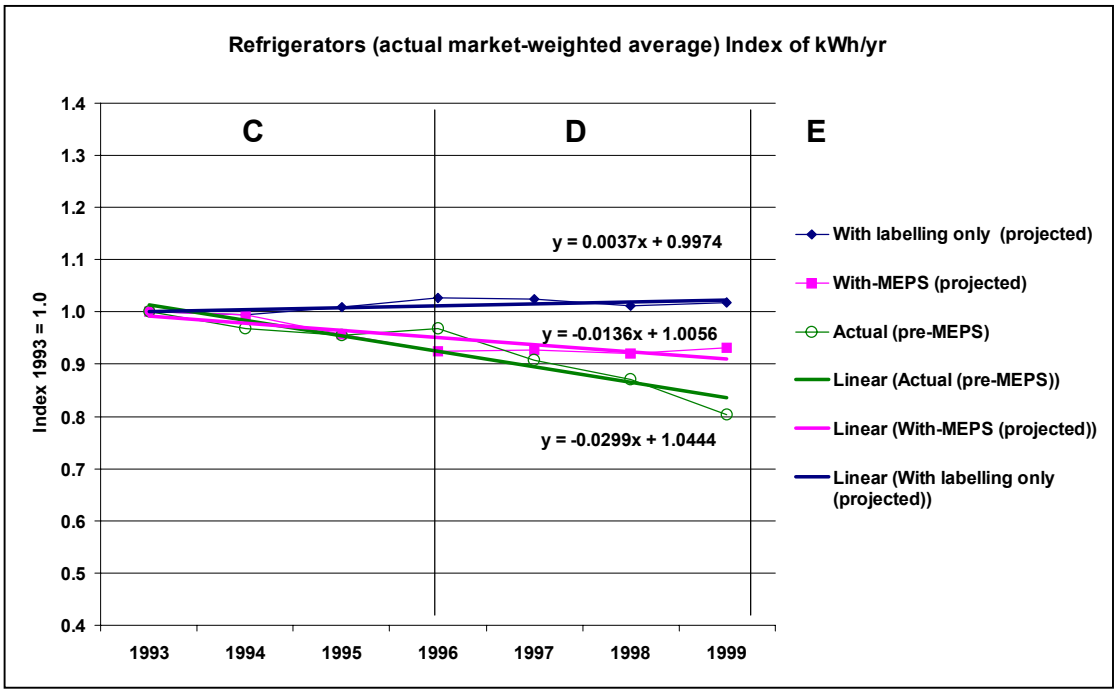


Figure 4 Weighted energy consumption trends and projections – three refrigerator classes

## 2.2 FREEZERS

The energy consumption trend for all freezers is indicated in Figure 5; energy per unit fell at a rate of 0.5% per annum over the period, although the rate was by no means even. The energy services supplied by freezers increased both quantitatively (average volume increased at a rate of 0.6% per annum) and qualitatively (the market share of fan assisted frost-free vertical freezers increased from 17% to 31%).

It appears that there was some lag in the freezer market's adjustment to MEPS: in 1999, nearly 8% of freezers sold failed to meet the MEPS levels that became mandatory in October 1999, compared with less than 2% of refrigerators (NAEEEC 2001). This suggests that a last-minute adjustment in the freezer market was still to take place. The sales data for 2000 will indicate whether this assumption is correct.

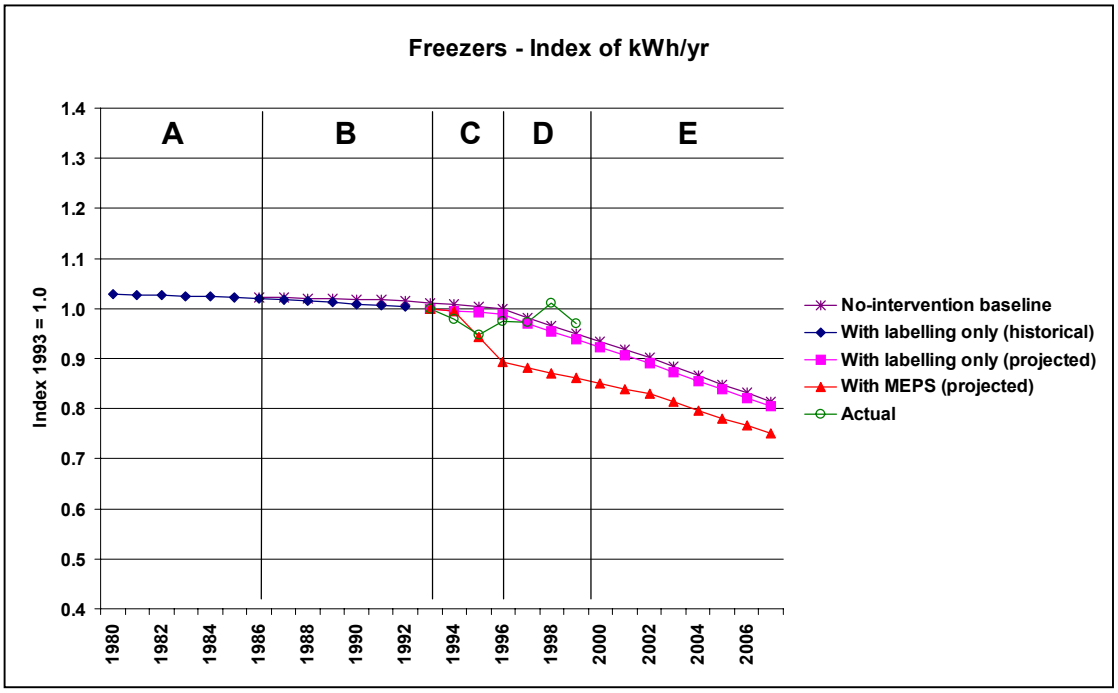


Figure 5 Energy consumption trends and projections – all freezers

## 2.3 CLOTHES WASHERS AND DRYERS

Figure 6 indicates the historical, projected and actual trend in average kWh/kg load for clothes washers. As MEPS were not implemented for clothes washers, there is no with-MEPS projection. The "with labelling only" projection was for a rapid reduction in energy consumption, partly on the expectation that the share of front-loaders sold would increase significantly. Front-loaders (horizontal axis models) did increase market share from 7.5% to 12.4% between 1993 and 1999, but the rate of shift to front loaders slowed and top-loaders still retained over 85% of the market.

In retrospect, the rate of energy reduction was over-estimated. However, the energy consumption on the energy label is for a warm wash, whereas more than 64% of loads are now washed in cold water, up from 61% in 1994 (ABS 1999). As 80% to 90% of the apparent energy consumption currently shown on the label comes from heating water, the increase in cold washing in actual use means that the real reduction in energy per kg load was more rapid than suggested by Figure 6. Incidentally, the trend to cold water washing is the main reason why MEPS cannot be recommended for clothes washers: once water heating energy is excluded, the remaining energy difference between the most and least energy-efficient models and between top loaders and front loaders becomes too small to justify MEPS.

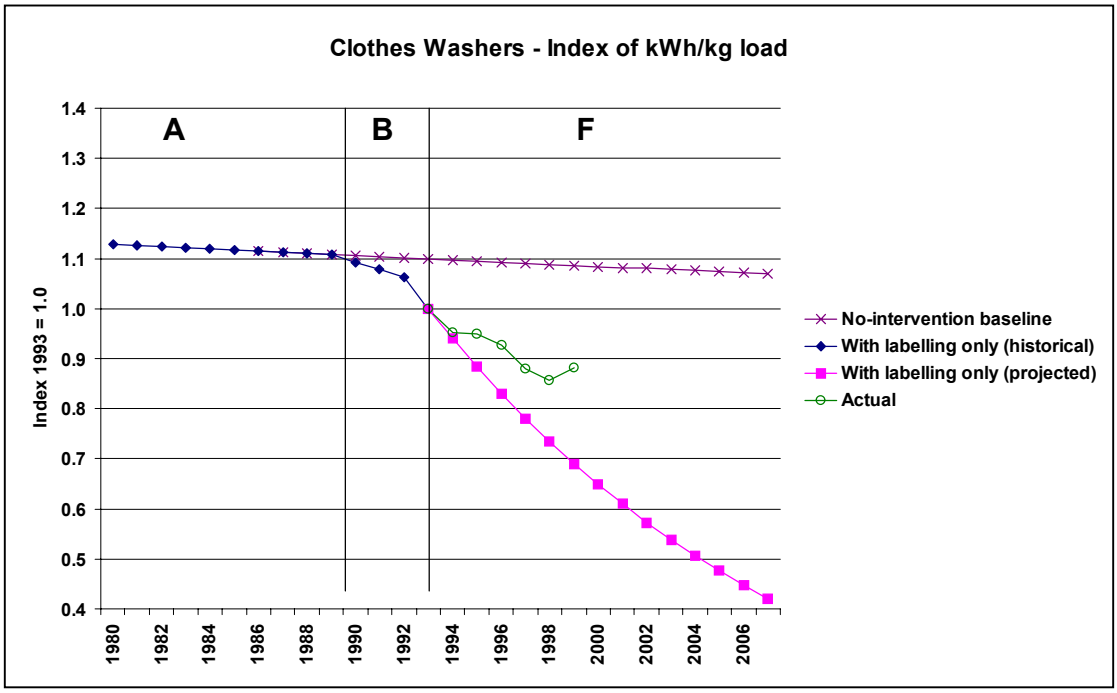


Figure 6 Energy consumption trends and projections – clothes washers

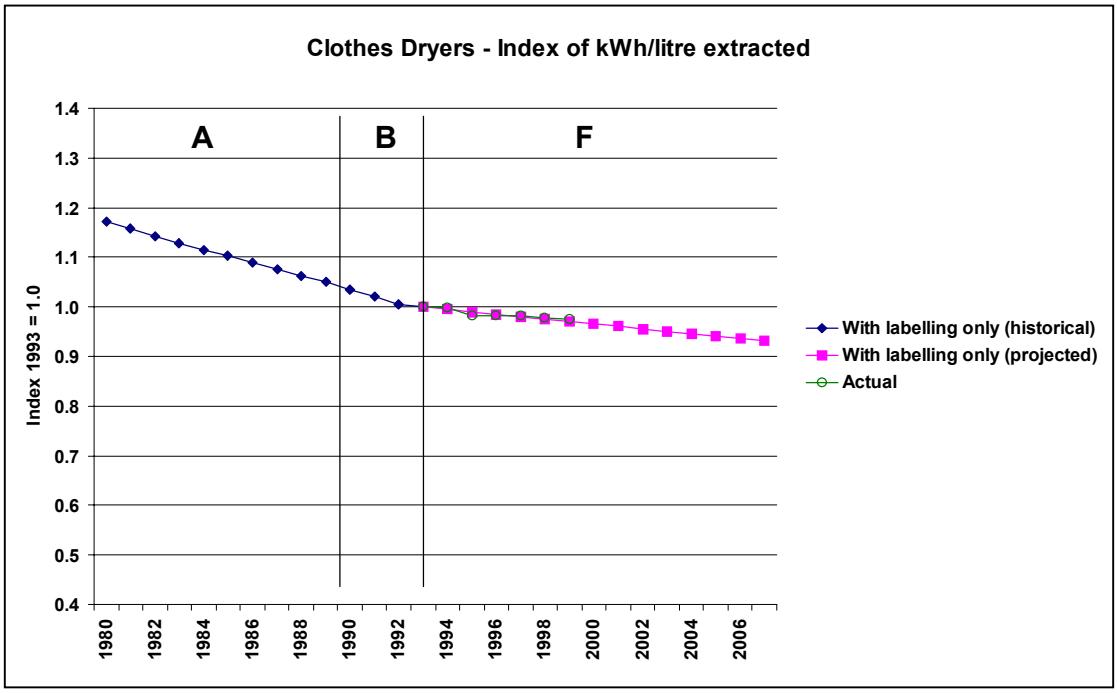


Figure 7 Energy consumption trends and projections – clothes dryers

Figure 7 indicates the historical, projected and actual trend in average kWh/litre water extracted for clothes dryers (excluding any field adjustment factors for dryers that stop automatically when they sense the load is dry: these increased their market share from 10% in 1993 to 27% in 1999). Labelling has had little effect on underlying water removal efficiency. The 1993 projection of slow improvement in energy performance was borne out.

2.4 DISHWASHERS

Figure 8 indicates the historical, projected and actual trend in average kWh/yr for dishwashers (excluding the effects of changes in average place setting capacity). As MEPS were not implemented for dishwashers, there is no with-MEPS projection. The introduction of labelling in 1986 brought about a major reduction in energy consumption per unit for dishwashers, as it did for refrigerators. Between 1982 and 1990, the average water use on the "normal" cycle fell by about 55%, and this rate of reduction was not expected to be sustained (GWA et al 1993). Despite this, the weighted average label-cycle water use (a slightly different measure) declined by a further 25% between 1993 and 1999.

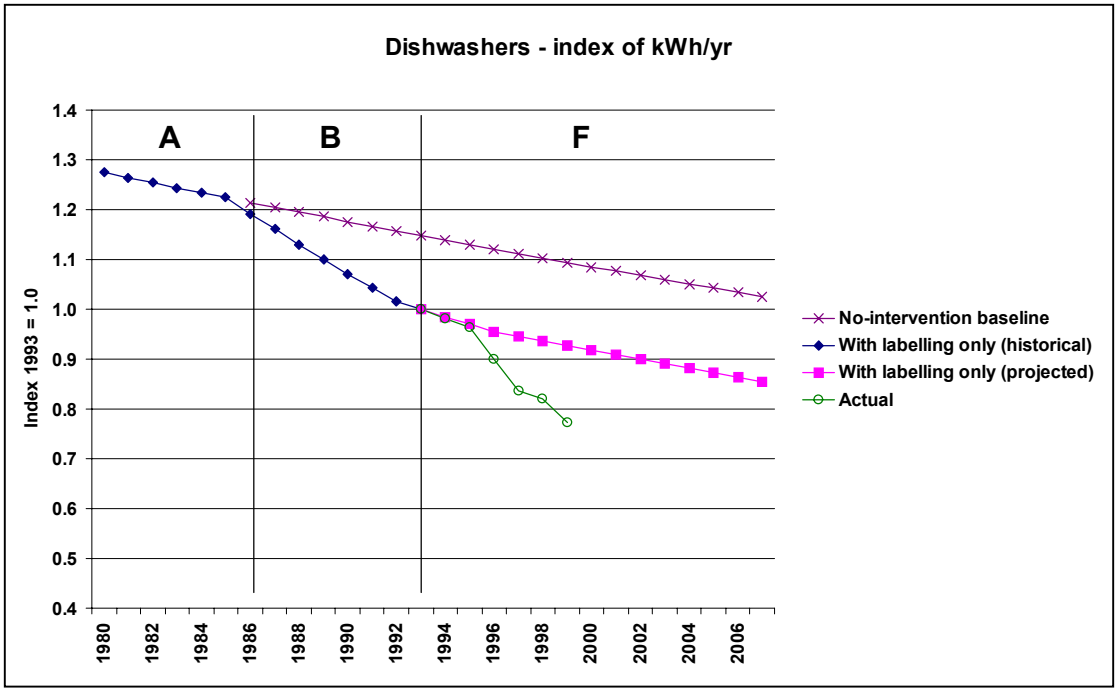


Figure 8 Energy consumption trends – dishwashers

## 3. CONCLUSIONS

The conclusions on the accuracy of the appliance energy consumption projections made in 1993 are summarised in Table 2. Of the seven appliance categories reviewed, the projections of energy reduction trends appear fairy accurate for three products, underestimated for two products and overestimated for two.

For the four products where MEPS was implemented, this raises the question of whether previous projections of what would have happened without MEPS (ie "with labelling only (projected)") should now be revised, using the actual data that has since become available. If so, the estimated impact of MEPS should also be revised. The changes in the frost free refrigerators market would have affected both estimates more or less equally, so the difference between them - the indicator of MEPS impact - remains about the same. Similarly, the changes in the freezers market suggest that the projection of energy reductions without MEPS was over-estimated to about the same extent as the with-MEPS projection, so the estimated impact of MEPS remains about the same.

To answer the question raised in the title of this paper: the original 1993 estimates were not perfect, but probably good enough, in that they gave an indication of the energy value of the proposed MEPS policy that is reasonably consistent with information collected since. Of course, the actual energy

impact of the recommended MEPS levels was significantly diminished by the "business-as-usual" improvements that took place during the three year implementation delay. Those refrigerator and freezer product classes where energy consumption in 1999 was still above the with-MEPS projection appeared to be reducing consumption sharply –this will produce energy savings, but less than if the same reductions had taken place three years earlier, as originally envisaged.

Table 2 Summary of changes in energy indices, 1980-99

| | Assessment of with-MEPS or BAU projection (a) | Assessment of no-MEPS projection (a) |
|---|---|---|
| Refrigerators – single door | Fairly accurate | Fairly accurate |
| Refrigerators – cyclic defrost | Fairly accurate | Fairly accurate |
| Refrigerators – frost free | Reduction underestimated | Reduction underestimated |
| Freezers | Reduction overestimated | Reduction overestimated |
| Clothes washers | Reduction overestimated | NA |
| Clothes dryers | Fairly accurate | NA |
| Dishwashers | Reduction underestimated | NA |

(a) in GWA et al (1993)

Table 3 summarises the reductions in historical energy indices illustrated in the diagrams. For the period 1980-92, the trends were estimated using a range of methods (model-weighted, partial sales-weighted and model succession analyses). For 1993-99, the trends were derived from direct market monitoring. The greatest rates of energy improvement, for dishwashers, cycle defrost and frost free refrigerator-freezers, were in the range 2.3% to 2.9% per annum. Single door refrigerators, clothes washers and clothes dryers had energy improvement rates in the range 1.0% to 1.6% per annum. The slowest improvement rate. 0.3% per annum, was for freezers.

Finally, Table 3 indicates the estimated impact in 1999 of both energy labelling and MEPS (to the extent that MEPS affected efficency trends in the lead up to its formal implementation in 1999). It is estimated that frost free refrigerators sold in 1999 consumed 33% less energy per unit than if there had been no programs intervening in the market. The impact for dishwashers was almost as great (29.4%). The only products for which market intervention appears to have been largely ineffective are freezers (where sales are declining in any case) and clothes dryers (although the possible energy savings from shifts to auto-sensing products has not been factored in).

Table 3 Summary of changes in energy indices, 1980-99

| | 1980 (Estimate) | 1999 (Actual) | Estimated Reduction | Annual rate of reduction | 1999 no-intervention baseline | 1999 Actual compared with baseline |
|---|---|---|---|---|---|---|
| Refrigerators – single door | 1.212 | 0.911 | -25% | -1.6% | 1.055 | -14% |
| Refrigerators – cyclic defrost | 1.341 | 0.878 | -35% | -2.3% | 1.024 | -14% |
| Refrigerators – frost free | 1.190 | 0.701 | -41% | -2.9% | 1.047 | -33% |
| Freezers | 1.028 | 0.970 | -6% | -0.3% | 0.949 | 2% |
| Clothes washers | 1.129 | 0.881 | -22% | -1.4% | 1.086 | -19% |
| Clothes dryers | 1.171 | 0.976 | -17% | -1.0% | 0.931 | 5% |
| Dishwashers | 1.274 | 0.773 | -39% | -2.7% | 1.094 | -29% |

All values index of kWh/yr, with 1993 = 1.0

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