Energy Efficient End-use Equipment
International Energy Agency

Achievements of appliance energy efficiency standards and labelling programs

A GLOBAL ASSESSMENT IN 2016

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The IEA Technology Collaboration Programme on Energy Efficient End-Use Equipment (4E) is an International Energy Agency (IEA) Implementing Agreement established in 2008 to support governments to formulate effective policies that increase production and trade in efficient end-use equipment. Twelve countries have joined together to form 4E as a forum to co-operate on a mixture of technical and policy issues focused on increasing the efficiency of appliances and equipment. However 4E is more than a forum for sharing information – it initiates projects designed to meet the policy needs of participating governments. Participants find that pooling of resources is not only an efficient use of available funds, but results in outcomes which are far more comprehensive and authoritative.

Current members of 4E are: Australia, Austria, Canada, Denmark, France, Japan, Korea, Netherlands, Switzerland, Sweden, UK and USA.

Further information on the 4E Technology Collaboration Programme is available from: **www.iea-4e.org**

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Executive Summary

National energy efficiency standards and labelling (EESL) programs have been in existence since the 1970s and now operate in more than 80 countries around the world, covering more than 50 different types of appliances and equipment in the commercial, industrial and residential sectors. While the design and coverage of EESL programs vary according to national circumstances, they provide the cornerstone of most national energy efficiency and climate change mitigation programs.

As governments consider how best to take advantage of further energy efficiency resources to meet future demands for cleaner energy, this 2016 update of a major report in 2015 identifies identifies additional examples of achievements of EESL programs, which have been among the most broadly adopted and longest running energy efficiency policies.

Based on evidence from a wide cross-section of countries with EESL programs, the energy efficiency of major appliances in these countries have increased at more than three times the underlying rate of technology improvement.

One-off improvements of more than 30% have been observed when new EESL programs have been first introduced to a market where few energy efficiency programs had existed previously.

These substantial efficiency improvements for individual appliances and equipment have translated to national energy savings and reductions in CO_2 emissions. The most mature national EESL programs covering a broad range of products are estimated to save between 10% and 25% of national or relevant sectoral energy consumption.

In all of the EESL programs reviewed, the national benefits outweighed the additional costs by a ratio of at least 3 to 1, i.e. EESL programs deliver energy and CO_2 reductions while also reducing total costs. This compares extremely favourably with the cost of other clean energy options and supports the conclusion from the International Energy Agency that end-use efficiency measures offer the least cost pathway to energy and CO_2 emission reductions.

The energy efficiency of major appliances in these countries have increased at more than three times the underlying rate of technology improvement

Appliances and equipment covered by EESL programs have not only dramatically improved in efficiency over the past 20 years, but are also cheaper to purchase. While EESL programs may have caused small changes in prices close to the implementation of new energy efficiency measures, they appear to have had little long-term impact on appliance price trends.

This is mainly due to the ability of appliance manufacturers to find new and cheaper ways to improve efficiency and to production volume-related cost reductions. EESL programs have been very successful in fostering innovation, expanding existing markets and opening up new market opportunities. This has led to enhanced employment outcomes, with 900,000 direct jobs created by EESL programs in the EU and 340,000 jobs in the USA.

A range of other benefits, including improvements in air-quality and the reduction of public expenditure on health, have been found to flow from EESL programs, and provide additional justification for investment in these types of programs. In jurisdictions where these types of policy objectives are of high national importance, the contribution made by such co-benefits can be sufficiently large in their own right to justify EESL programs.

In some very specific cases, the reduced energy costs resulting from EESL programs may be used by householders and companies to purchase additional energy services (the rebound effect). In developed countries, this is likely to be limited to the use of heating, cooling, water heating and to a lesser extent lighting, mainly in low-income households. In many cases, these increased comfort levels may be an intended outcome of EESL programs, for example when targeted at low-income households. Even when a rebound effect has been found to occur, EESL programs have still demonstrated a net energy saving, and overall cost-effectiveness.

1 Introduction

This report is an update of the first 4E report published in 2015 that recorded achievements of government energy efficiency standards and labelling (EESL) programs, which are amongst the longest running and most widely adopted type of national energy efficiency program.

National EESL programs have been in existence since the 1970s and have grown since this date, so that now EESL programs operate in more than 80 countries around the world and apply to more than 50 different types of appliances and equipment in the commercial, industrial and residential sectors [1]. While the design and coverage of EESL programs vary according to national circumstances, they provide the cornerstone of most national energy and climate change mitigation programs.

Typically, EESL programs use one or more of the following complementary tools to improve the energy efficiency performance of appliances and equipment[1]:

- Energy labels enable consumers to make an informed choice at the point of purchase, either by showing the comparative performance of all appliances (rating labels) or by identifying the best-in-class products (endorsement labels).
- Minimum energy performance standards (MEPS) provide a level playing field in competitive markets by removing the worst performing products without diminishing consumer choice [2].

Following the UNFCCC Paris Agreement in 2015[2], as governments consider how best to take advantage of further energy efficiency resources to meet future demands for cleaner energy, this report provides a catalogue of the achievements to date of one of the largest and longest running energy efficiency programs.

This record is drawn from over 150 publications that detail the evidence of the impacts of EESL programs in more than 20 countries[3], and covers more than 30 different product types (see Attachment A for more information on the methodology).

The recorded impacts from EESL programs summarised in this report include:

- Increases in the energy efficiency of appliances, equipment and lighting technologies, over and above autonomous rates of change.
- Reductions in national energy consumption and associated greenhouse gas emissions savings.
- Changes in the consumer purchase price of appliances and equipment.
- Delivery of co-benefits, such as employment, health and energy security.
- The effects on manufacturing innovation and market transformation.
- The additional energy services purchased by beneficiaries of energy efficiency fuel bill reductions – the 'rebound' effect.

[1] Both types of programs are underpinned by test procedures and compliance strategies.
[2] Adopted on 12 December 2015 at the 21st Conference of the Parties of the United Nations Framework Convention on Climate Change.
[3] Including the EU and its 28 Member States.

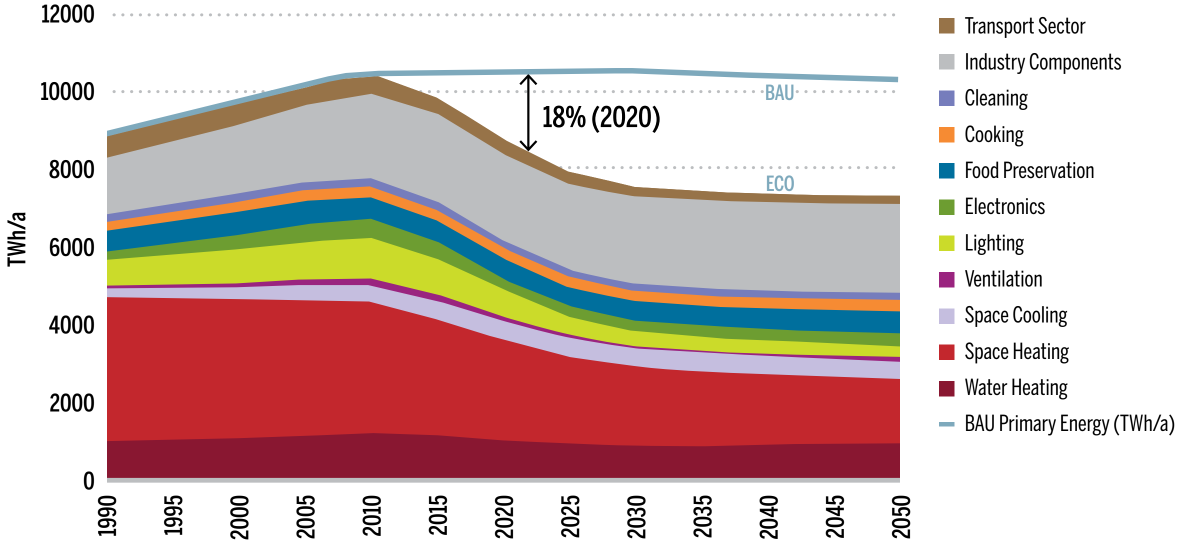
2 Impact on rates of energy efficiency improvement

The evidence from a wide cross-section of countries with EESL programs indicates that the energy efficiency of major appliances has improved at an average rate around 3% to 4% per annum over a long period (see below and Attachment B). This compares favourably to the underlying rate of technology improvement of between 0.5%-1% per annum.

2.1 2016 Update

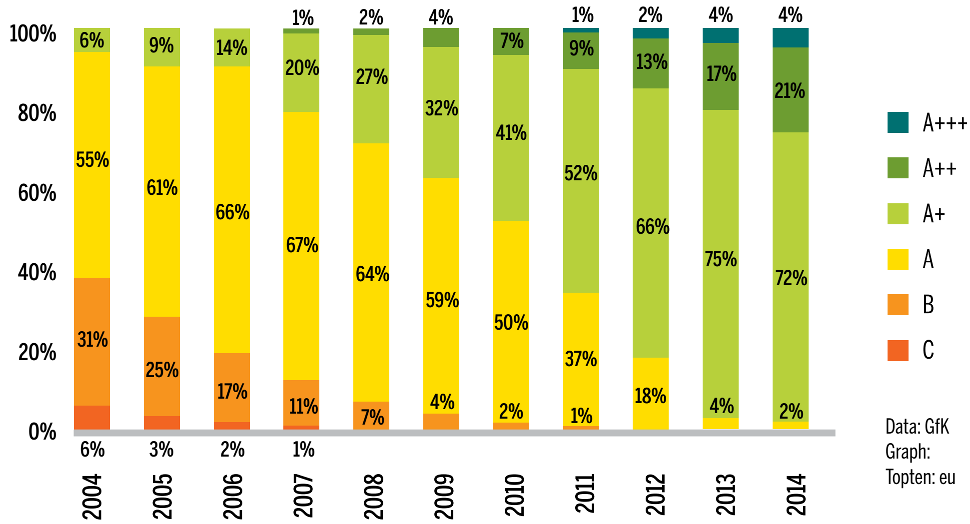
Updated impact analysis of the EU Ecodesign program indicates that the current program will cut primary energy consumption due to these products by 18% (890 TWh) in 2020 (Figure 1); equivalent to a reduction of 9% of the total 2010 EU energy consumption [3].

Figure 1: Primary energy consumption of products included in the eco-design impact accounting, May 2015 [3]



Between 2004-2014, the average sales weighted efficiency of new refrigerators in the EU has improved by 3.4% per annum, as indicated by the market share of labelled products shown in Figure 2. This resulted in a 25% reduction in energy consumption over this period [4].

Figure 2: Efficiency class distribution of new refrigerators sold in the EU-28 [4]

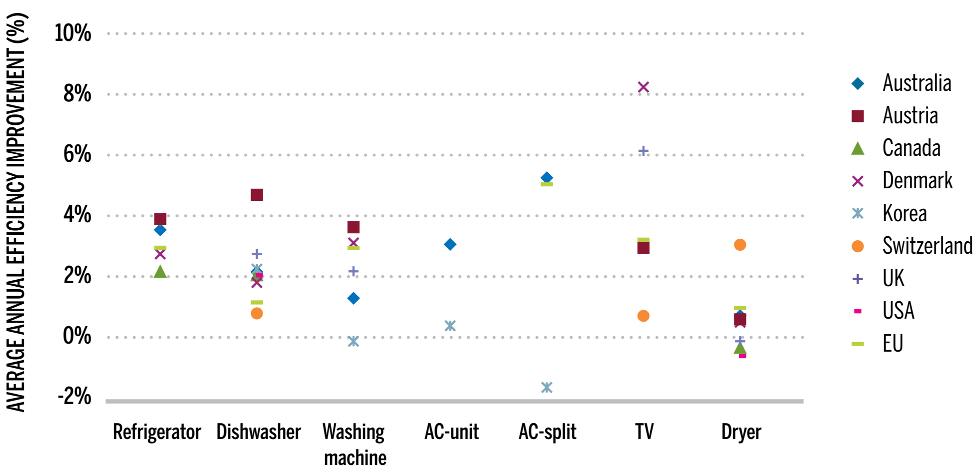


In Australia, the sales-weighted average energy efficiency of refrigerators increased at 2.7% per annum[4] between 1993 and 2014 (taking account of changes in volume over the period), while separate freezers improved at 2.2% over the same period [5].

In the 2-3 years following the introduction of refrigerator MEPS in Mexico in 2003, the average efficiency of manual defrost refrigerators improved by 17% while auto-defrost refrigerators improved by 27% [6].

A summary of improvement rates for major appliances by country up to 2014 shown in Figure 3, based on evidence collected in this report, although it should be noted that these rates have been calculated over differing time periods [7-13]. Given that improvement rates are highly influenced by national performance requirements, which are updated periodically and independently, the data presented in these snapshots can also vary from year to year.

Figure 3: Annual efficiency improvement rates for major appliances [7-13]



Similar improvements in efficiency of new energy-using products have been observed in Japan, primarily as a result of their Top Runner Program. The information in Table 1 from 2015 updates previous results presented in Table 8 in Attachment B.

Table 1: Improvements in Japanese product efficiency under the Top Runner Program [14]

PRODUCT CATEGORY	START YEAR (FY)	END YEAR (FY)	ACTUAL IMPROVEMENT (%/YR)
AC - non-ducted/wall-mounted, 4kW or less	2005	2010	3.1%
AC - non-ducted/wall-mounted, over 4kW	2006	2010	3.7%
AC - other than non-ducted/wall-mounted	2001	2012	1.4%
Electric refrigerators (residential)	2005	2010	7.4%
Electric freezers (residential)	2005	2010	4.5%
Electric rice cookers	2003	2008	3.1%
Lighting equipment for fluorescent lamps	2006	2012	2.3%
Self-ballasted fluorescent lamps	2006	2012	1.1%
Electric toilet seats	2006	2012	2.9%
TV (liquid crystal/plasma)	2008	2012	12.6%
Computers	2007	2011	16.6%
Magnetic disk units	2007	2011	15.2%
Vending machines	2005	2012	5.8%
DVD recorders	2006	2010	9.8%
Routers	2006	2010	9.0%
Switching units	2006	2010	11.4%

[4] Taking account of changes in volume.

2.2 Previous analysis

In the years prior to efficiency regulations in 2004, the average efficiency of Australian air conditioning units improved at approximately 0.5% per annum. This grew to around 3% per annum after 2004 and to around 4% per annum after updated requirements in 2006/07 [15]. In Korea, a 59% increase in energy efficiency across all products covered by its EESL program was observed between 1996 to 2010 [16], equivalent to an annual improvement of 3.4% per annum.

Larger improvements have been observed, for example when new EESL programs have been first introduced to market where few energy efficiency programs had existed previously. A 32% efficiency improvement was achieved in one year (1994-1995) when Mexico first implemented MEPS for refrigerators [17]. A 7% improvement in the efficiency of refrigerators in the EU was recorded in the first year following the introduction of mandatory energy labelling in 1995 [18], [19], [20].

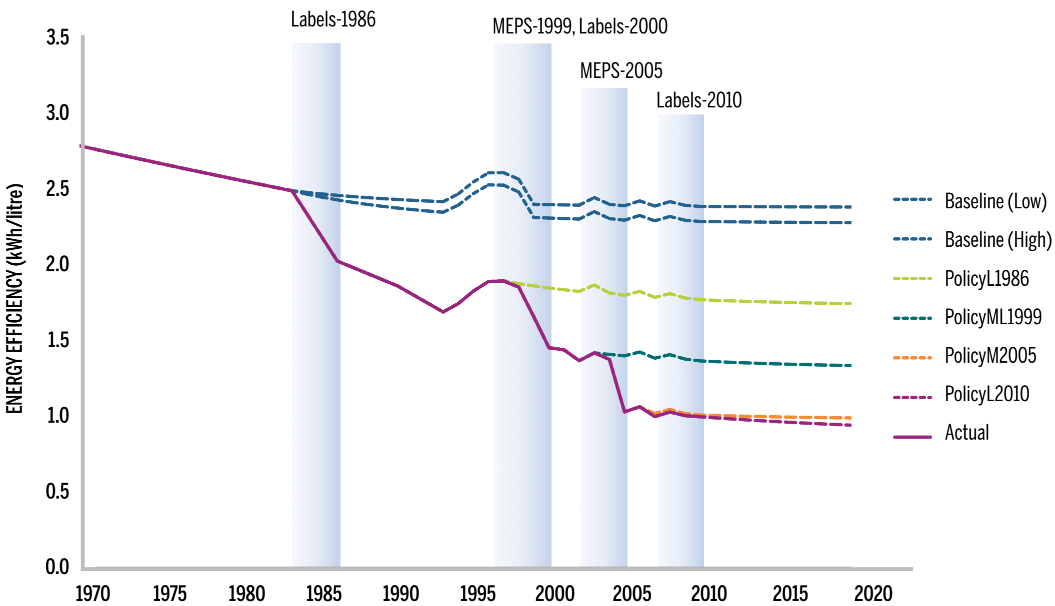
The rate of improvement in the efficiency of televisions and some other consumer electronics products has also been above average since the introduction of EESL programs by several economies from 2008. In most of these cases, the underlying rate of technology change has also exceeded 1% per annum [21] [22].

For the larger EESL programs in the USA, China and Europe total savings are estimated to range between 10-20% of national or sectoral energy consumption

Where lower long-term rates of efficiency improvements have been observed, this appears to be the result of a failure to review and upgrade performance requirements to keep pace with the rate of improvement in new products entering a market. There is strong evidence to show that significant and sustained improvements in energy efficiency occur where policies are subject to on-going revision and updating.

For example, Figure 4 illustrates the impact of successive policy measures on the performance of refrigerators in Australia, leading to an annual 3.6% decline in the average energy consumption between 1986 and 2010. The USA has also seen a 4% per annum improvement in the energy efficiency of its refrigerators over the period 1989 to 2010, driven by continued updating of policy measures in 1990, 1993, 2001 and 2014 [23].

Figure 4: Change in efficiency of Australian refrigerators [24]



These substantial efficiency improvements for individual appliances and equipment have translated to national energy savings and reductions in CO_2 emissions. The scale of these savings depend upon the scope and maturity of national EESL programs, but for the larger programs in the USA, China, Europe and Australia total savings are estimated to range between 10% and 25% of national or relevant sectorial energy consumption, as applicable (see Attachment C).

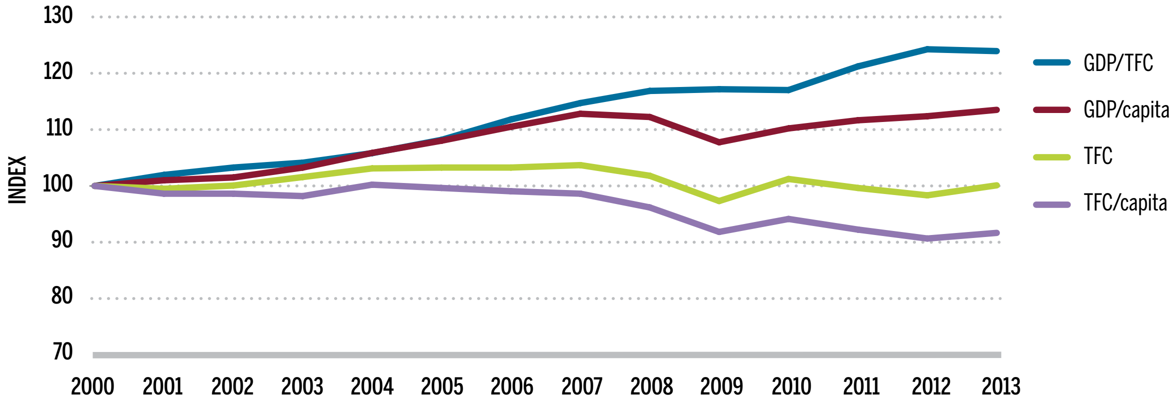
3 The cost-benefit of energy efficiency

The costs of efficiency improvements include the EESL program administrative and compliance/enforcement costs, together with the incremental cost to consumers of more efficient technologies. However, the net cost of efficiency improvement must also account for the reduced operating costs experienced by users of more efficient equipment.

3.1 2016 Update

Analysis by the International Energy Agency (IEA) reveals that energy efficiency has led to a decoupling of economic and energy growth [25]. In 2013, OECD energy consumption was equivalent to 2000 levels, while GDP expanded by 26% (see Figure 5).

Figure 5: Changes in OECD Gross Domestic Product (GDP) and Total Final Energy Consumption (TFC)



Although often hidden, the overall impacts of energy efficiency investment since 1990 across all IEA countries are very concrete. In 2014 alone these benefits included [26]:

- 22 EJ in avoided fuel consumption (=32 EJ primary energy).
- USD 550 billion in saved costs to consumers.
- 190 Mtoe replaced energy imports by locally supplied efficiency.
- 820 MtCO_2 in greenhouse gas emissions reductions.

Taking a longer investment timeframe[5], the quantity of energy avoided by on-going energy efficiency activities in 11 IEA countries[6] during 2010 was larger than actual demand met by any other single supply-side resource, including oil, gas, coal and electricity, thus making energy efficiency the largest or "first" fuel [27].

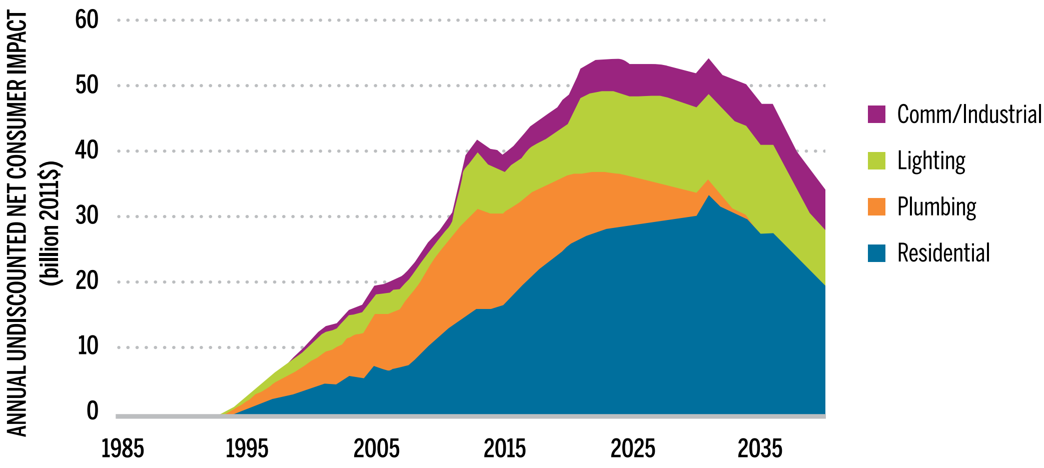
As identified elsewhere in this report, energy efficiency programs for appliances and equipment have made a significant contribution to these achievements.

[5] i.e. the result of cumulative investment in energy efficiency since 1974.
[6] Australia, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Sweden, the United Kingdom and the United States

3.2 Previous analysis

As shown in Figure 6 for the USA, the net financial benefits to consumers from EESL programs already implemented are considerable.

Figure 6: Annual undiscounted net consumer benefit for all MEPS by sector, USA [28]



In all of the EESL programs reviewed the national benefits outweighed the additional costs by at least 3 to 1[7], i.e. the net cost of energy savings was negative from a societal viewpoint.

For example, in the United States, MEPS for all products has had an estimated average benefit to cost (B/C) ratio of about 3:1 [29]. In the UK, product policy (mainly European EESL legislation) in 2012 had a B/C ratio of 3.8:1 [30]. Similarly, the EESL program for refrigerators and freezers in Fiji showed a B/C ratio of 3.5:1 [31].

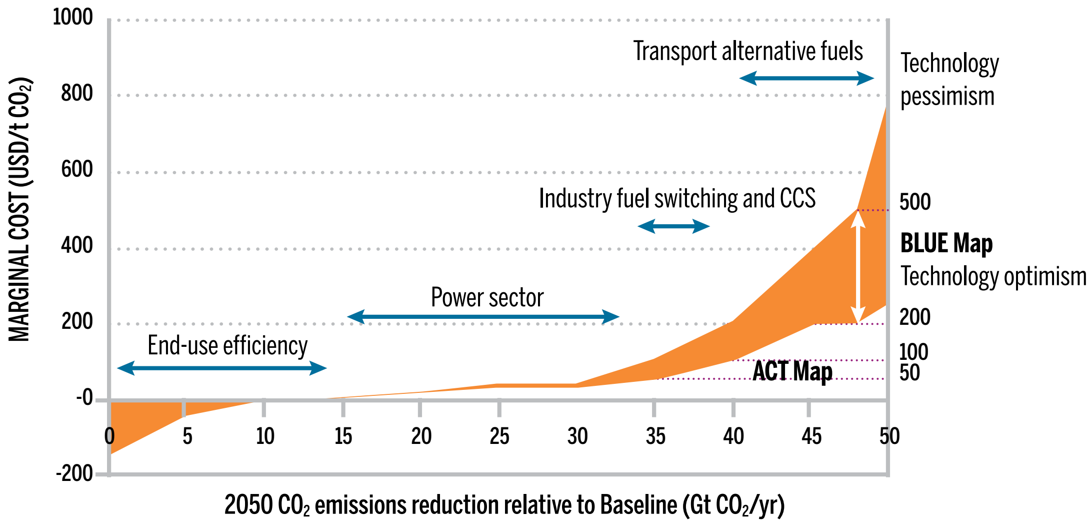
Voluntary programs can also deliver cost-effective outcomes, with the extensive USA based "ENERGY STAR" program reporting that for every incremental dollar Americans invested in energy efficiency through ENERGY STAR, they saved, on average, $4.50 [32].

These findings support the conclusion from the International Energy Agency that end-use efficiency measures offer the least cost pathway to CO_2 emissions reductions (see Figure 7) [33].

For every metric tonne of greenhouse gas emissions reduced through ENERGY STAR, Americans saved more than $125 on their energy bills

[7] As part of the regulation process in many jurisdictions, ex-ante impact assessments are undertaken of any proposed program measures; and measures are usually only pursued if the there is a Benefit/Cost ratio (B/C) that exceeds 1.0 and/or if the sum of Net Present Value of costs and benefits from the measure is greater than zero.

Figure 7: Marginal emission reduction costs for the global energy system, 2050 (IEA) [33]



It should be noted that cost-effectiveness of EESL measures are usually ensured by setting performance requirements at a level where the life cycle costs are minimised[8].

Since a large proportion of the costs associated with EESL programs relate to the expected changes in product purchase price, understanding the incremental cost of energy efficiency improvement is key to accurately predicting the benefit to cost ratio and setting performance requirements. This is discussed further in the following section.

[8] This is typically a core part of the standard setting methodology, e.g. in the USA and the EU.

4 Impact on appliance and equipment purchase prices

While it is commonly assumed that raising energy efficiency levels will push up purchase prices for equipment, the reviewed evidence shows that long-term appliance purchase prices are generally declining in real terms while products are also becoming more efficient.

4.1 2016 Update

Across the EU average real prices for refrigerators decreased by 12.5% between 2004 and 2014, or 1.3% per annum. As a result, lifetime costs[9] fell by 21% over this period, or 2.3% per annum [4][10]. In France and Portugal over the same period, refrigerator real prices have decreased by 19% and 22% respectively; while lifetime costs in these countries have fallen by 24% (2.7% per annum) and 28% (3.2% per annum) [4].

Average real washing machine prices across the EU-21 have also declined by 25% from 2004 to 2014, (2.8% per annum), despite higher efficiency and larger capacities. In France, the reduction in real prices was 33% (3.9% per annum) [4].

In Australia the real price decline in new refrigerators, washing machines and dishwashers sold between 1993 and 2014 is shown in Table 2, alongside the corresponding reduction in the average energy consumption over the same period [5]. Further details are provided in Attachment D.

Table 2: Long term trends in average energy consumption and real purchase price in Australia for new whitegoods [5]

PRODUCT	CHANGE IN ENERGY CONSUMPTION 1993-2014	ANNUAL RATE OF CHANGE IN ENERGY CONSUMPTION	CHANGE IN REAL PURCHASE PRICE 1993-2014	ANNUAL RATE OF CHANGE IN REAL PURCHASE PRICE
Refrigerators	-41.3%	-2.5%	-33.2%	-1.9%
Freezers	-43.1%	-2.6%	-37.5%	-2.2%
Washing Machines	-19.9%	-1.0%	-45.9%	-2.9%
Dishwashers	-44.1%	-2.7%	-48.7%	-3.1%

Note: Annual rate of change is the overall change to the power of 1 over (n-1) for n years of data (n-1 data intervals). Recent large increases in rated capacity for clothes washers has slowed energy reductions but improvements in overall efficiency have continued.

USA analysis comparing actual product price changes with those expected as a result of MEPS confirms the data previously provided in this report. A retrospective review of most of the 60+ U.S. studies used to assess regulatory impacts have found that ex ante costs have generally over-estimated the actual costs of future regulation, resulting in the sub-optimal uptake of significant societal benefits. It suggests that regulatory analyses approaches currently used do not accurately project future technical change in industries subject to regulation [34].

4.2 Previous analysis

Australian refrigerator prices declined by between 2.5%-5%[11] per annum in real terms between 1993 to 2008, and this trend did not change around the introduction of MEPS in 2005, which resulted in a 25%-35% reduction in energy consumption [24].

A recent study in Sweden also shows an upward trend in efficiency whilst product prices were falling [35]. Similar long-term declines in real product prices have been observed in reliable studies from the UK, Australia [36] and the EU [23].

Long-term appliance purchase prices are generally declining in real terms while products are also becoming more efficient

[9] Lifetime costs are calculated based on real purchase price and real electricity costs over the average lifetime of the product.

[10] Real costs have been calculated from the nominal values provided in this reference. For the calculation of all real prices and real lifetime costs, the following assumptions have been used: 2004 to 2014 inflation index for Europe = 1.22, for France = 1.19 and for Portugal = 1.21 from www.inflation.eu. Assumed energy tariffs for late 2014 are from Eurostat and are: Europe EUR 0.20/kWh, France = EUR 0.175/kWh and Portugal = EUR 0.22/kWh and that energy prices have stayed constant over the period 2004 to 2014.

[11] The range in the declining rate of prices and energy consumption reflect different categories of refrigerators.[12]

In this context of falling appliance prices, a comparison of expected purchase price increases with the actual price changes observed two years after the MEPS implementation in the USA found that the marginal price increase had been overestimated on average by a factor of 10 (see Table 3) [37][12].

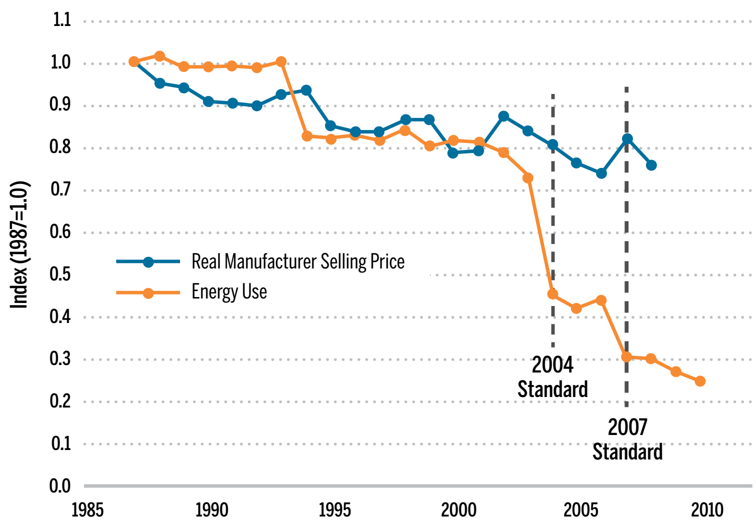
Table 3: Comparison of predicted and actual price increases from USA MEPS [37]

PRODUCT	DOE ESTIMATE OF INCREMENTAL PRICE OF STANDARD (NOMINAL $)	DOE ESTIMATE (2011$)	COST FROM CENSUS (2011%)	DIFFERENCE (2011$)
Refrigerators	32	56	37	-18
Clothes Washers	34	54	-35	-89
Clothes Washers	126	199	10	-188
Electric Water Heaters	67	108	28	-80
Non-Electric Water Heaters	75	121	34	-88
Central AC – 3 tons	167	267	207	-59
Room AC	7.50	13	-162	-175
Commercial AC – 15 tons	334	512	-224	-736
Ballasts	4.27	6.73	-1.74	-8.47
Average		148	-12	-158
Median		108	10	-88

In Europe, product prices were anticipated to rise on average by 14% following the introduction of EU Ecodesign regulations. However, evidence suggests that these increases did not happen or were smaller than anticipated [38].

More detailed analysis indicates that there may be a small change in the decreasing price trend close to the implementation of significant new energy efficiency measures but the downward trend re-appears soon after. This is illustrated by the example of clothes washer in the USA in Figure 8 and in Attachment D.

Figure 8: Price and energy trends for clothes washers in the USA [37]



The reason why energy efficiency regulations have had little long-term impact on purchase prices appears mainly due to changes in retail mark-ups, economies of scale in production and innovation by manufacturers [39], [40].

These findings indicate that it will be cost-effective for EESL programs to be more ambitious than under the previously assumed static or increasing price assumptions, by using the concept of "learning rates" to predict future appliance price trends (as proposed for the USA) [41]. Reducing appliance purchase costs and increasing energy costs push the cost effectiveness threshold for energy efficiency to higher levels.

[12] Excluding AC, since their price fell dramatically. The late 1990s saw a dramatic increase in the production of air conditioners in China, together with dramatically increased world trade, and this had major impacts on the price of these appliances in most countries.

5 Innovation and industry leveraging

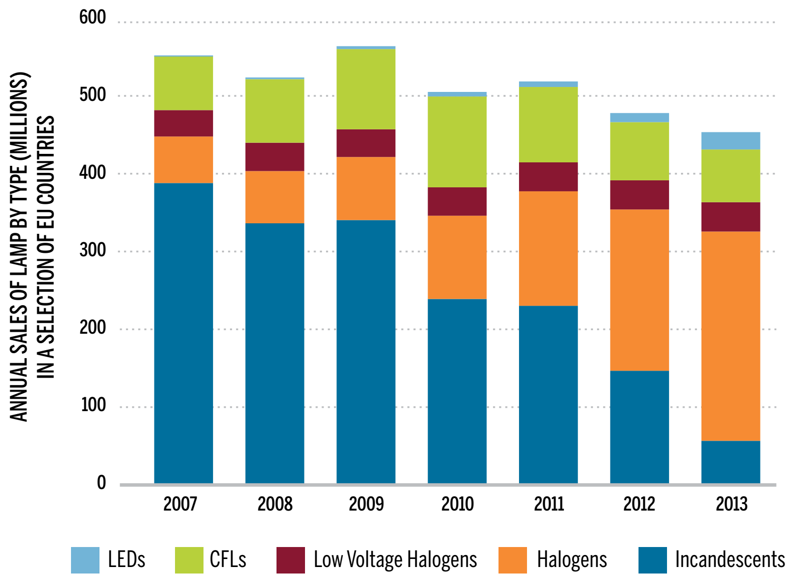
EESL programs foster innovative solutions within competitive markets where the manufacturing sector strives to deliver improved product performance at least cost. As noted in the previous section, the ability of appliance manufacturers to find new and cheaper ways to improve efficiency in part explains how products prices have not increased despite dramatic increases in efficiency.

5.1 2016 Update

EESL programs have enabled product designers to deliver new and cheaper ways to improve efficiency, while also offering consumers more features than ever before without impact on service quality or reliability.

Comparing the range of televisions or lighting products available in stores now with the range 10 years ago, it is clear that the market has dramatically transformed, giving consumers more choice in all respects except perhaps the choice to select products that are less energy efficient.

Figure 9: Annual lamp sales in selected EU Countries, 2007-2013 [42]



A retrospective review of USA regulations noted that: "(the) *better-than-expected price and efficiency outcomes did not (impact on)… the availability of products with high quality performance attributes other than energy use. Instead, in most cases the statistically significant changes that occurred in third-party quality variables across MEPS events represented improvements in product quality. Similarly, the rate of significant repairs over five years of product ownership declined across our study period, according to third-party surveys"* [34].

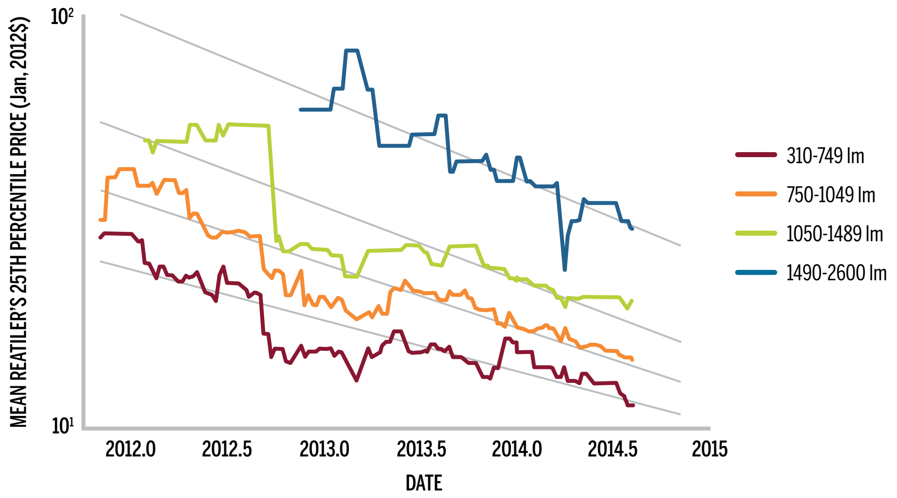
When MEPS apply to all the market and are performance based, rather than prescribing one particular design or technology over another, they help drive innovation [43]. The fact that the regulatory process has been unsuccessful in predicting future efficiency costs is further evidence of innovation [1001]. As a result, the American Society of Mechanical Engineers (ASME) ranked the promulgation of standards among the top-10 engineering accomplishments of the last century — right up there with the automobile and airplane [44].

In Europe, the first energy label for dryers in 1995[13] set the highest performance level, the "A" tier, at a level products then sold on the market could not achieve. This aspirational tier, along with financial incentives, motivated manufacturers to introduce new heat pump drying technology into the European market, so that sixteen years later heat pump dryers account for 40% of the market share[14] [45]. Switzerland has now set a MEPS level that effectively mandates heat pump dryers for new sales [3] [46].

[13] Note regulation date is 1995, effective date is 1996.
[14] The role of regulations to 'pull' technology markets has been further explored by 4E in its report: *'Technology-Forcing Standards for Energy Efficiency'*, June 2013

Regulations designed to 'phase-out' inefficient lighting products have had a considerable impact on the market, causing the entry of many new lighting technologies into market (see Figure 9) [42]. In view of the efficiency benefits and other features of Light Emitting Diodes (LED), governments have introduced quality assurance measures to reduce barriers[15] to the rapid uptake of high quality LED products [47]. As a result, the market share of LEDS is growing, providing economies of scale in manufacturing. This, together with falling component costs, competitive pressure, and policy support for research and development, has led to LED prices falling by 28% to 44% per year (see Figure 10) [48].

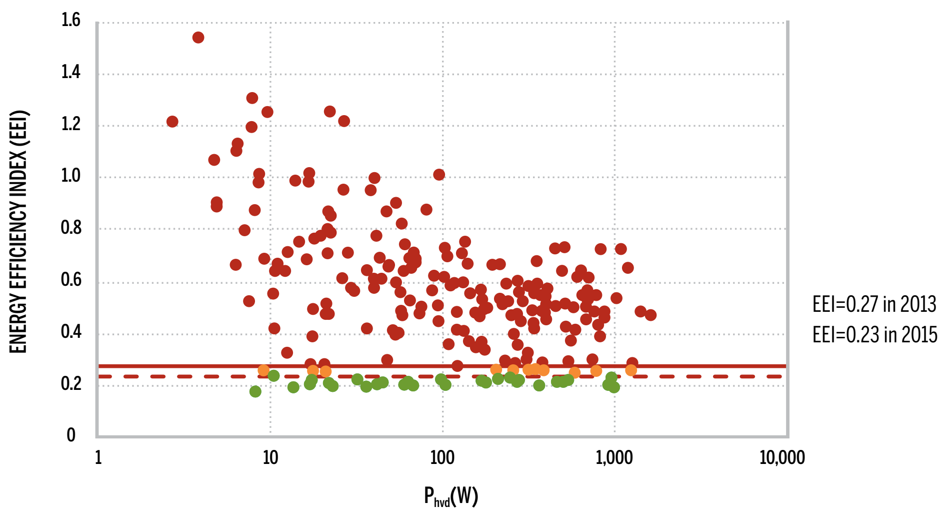
Figure 10: Trends in price of LED A lamps by lumen bin



Note: Trends in the mean retailer's 25th percentile price for LED A lamps, by lumen bin. Trends are shown on a semilog plot, so that exponential curves describe straight lines with slope equal to the exponential decline rate a.

In some cases, the industry itself can drive innovation, and seek regulatory support to assist the uptake of the new technologies. Recent innovation has seen the efficiency of circulation pumps[16] increase dramatically through the use of high efficiency motors coupled with integrated variable speed drives. EU regulation, supported by industry, has helped to underpin the transformation of the market, with the latest round of MEPS requiring all pumps sold to reach high efficiency performance levels (Figure 11).

Figure 11: Circulators (from 2009 market) compared to requirements in EC/641/2009 [49]



Notes: EEI is Energy Efficiency Index which is the ratio of the actual energy to a reference energy figure (lower is more efficient). Power on X axis is a logarithmic scale.

[15] Such as a consumer backlash to poor quality products, as experienced with CFLs.
[16] Used in hydroponic heating systems to move hot water around radiators either as standalone pumps in a system or integrated into the boiler itself. There are around 140 million circulator pumps in use across the EU.

5.2 Previous analysis

Successful innovation in response to EESL programs typically leads to the expansion of existing markets and/or new markets for those local industries that take up the innovation challenge, leading to enhanced employment outcomes.

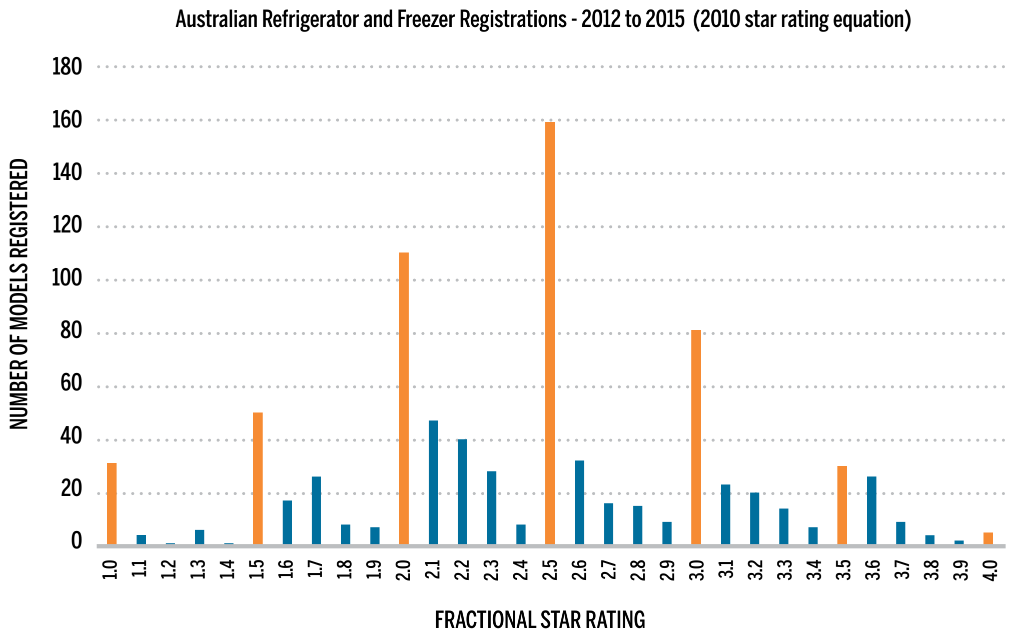
In the EU it has been estimated that by 2014, 0.8 million direct jobs had been created by EESL programs together with a further 3 to 5 times as many indirect jobs [38]. It is estimated that MEPS in the USA were responsible for the creation of 340,000 full-time equivalent jobs by 2010 [50].

On-going innovation appears strongest in the deployment, commercialisation and diffusion of innovative energy efficiency technologies [51], which is shown clearly by the market entry of more efficient products following announcements of new EESL regulatory requirements, but in advance of the due dates [36], [24], [15].

Similarly, in the case of comparative labelling schemes, industry has been found to respond to the program by striving for higher and higher ratings to differentiate their products from competitors, particularly for products that use a significant amount of energy[17].

For example, in Australia it is evident that manufacturers of refrigerators strive to achieve the 'next' highest half star on the energy rating label, as shown in Figure 12. Analysis of European data for refrigerators has also shown a prevalence of models just reaching the labelling efficiency thresholds [52].

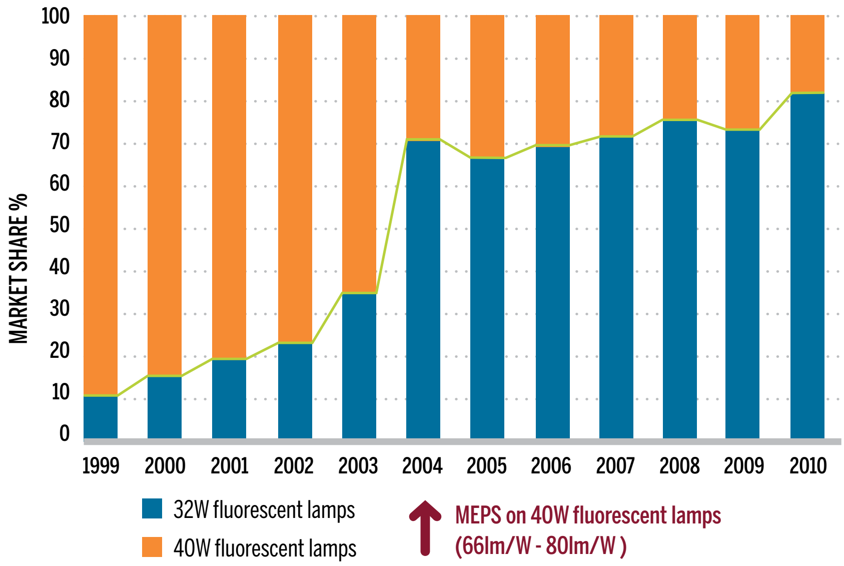
Figure 12: Distribution of Australia refrigerators according to star rating [53]



Further examples of innovative responses to energy efficiency policies are numerous. The Korean lighting market has been transformed through a program designed to replace 40W fluorescent lamps with higher efficiency 32W fluorescent lamps that increased their market share to around 70% by 2004 (see Figure 13) [16].

[17] E.g. refrigerators and ACs

Figure 13: Market share of fluorescent lamps in Korea 1999 – 2010 [16]



6 Co-Benefits

A range of co-benefits, in addition to efficiency improvements and energy savings, have been found to flow from EESL programs and often provide further justification for investment in these types of programs.

6.1 Employment

Successful innovation in response to EESL programs typically leads to the expansion of existing markets and/or new markets for those local industries that take up the innovation challenge, leading to enhanced employment outcomes.

6.1.1 2016 Update

Investment in energy efficiency measures tends to create up to twice as many jobs compared to new energy generation as a result of their relatively high levels of labour intensity [54]. While estimates of employment factors vary considerably, one study found that in the appliances and electronics sectors 1.02 jobs are created per GWh saved [54].

In 2010, the provision of energy efficiency goods and services sold in the EU directly led to the employment of approximately 900,000 people. Between 100,000 and 300,000 additional jobs would be generated if all the estimated energy savings potential was realised [54].

Other opportunities for job creation may arise through the export of services developed domestically. For example, in Denmark the growth potential of energy efficiency equipment and advice is around 27bn Danish krone (USD 0.5bn) by 2020, supporting 9,000 new jobs. Two-thirds of these new jobs would be due to the export of energy efficient equipment and advisory services to other European and International markets [54].

6.1.2 Previous analysis

In the EU it has been estimated that by 2014, 0.8 million direct jobs had been created by EESL programs together with a further 3 to 5 times as many indirect jobs [38]. It is estimated that MEPS in the USA were responsible for the creation of 340,000 full-time equivalent jobs by 2010 [50].

EESL programs are estimated to have created 800,000 *direct* jobs in Europe and 340,000 jobs in the USA

6.2 Other Co-benefits

The comfort, health, financial, and risk-abatement consequences of energy efficiency's multiple benefits contribute to the betterment of regional economies. This outcome underscores the need for energy policy and resource planners to recognise and account for these values [55].

6.2.1 2016 Update

The value of energy efficiency to utilities depends to a large extent upon the regulatory environment and cost structure. In the USA, a survey of the average value given to energy savings identified $48.37 per kilowatt-year (kW-year) for distribution and $20.21 (kW-year) for transmission across 36 utility energy efficiency programs. The values of further utility benefits are shown in Table 4.

Table 4: Utility-specific multiple benefits of energy efficiency programs [55]

BENEFIT	DESCRIPTION	RANGE OF VALUES
Utility nonenergy benefits	Value of cost savings to a utility stemming directly from energy efficiency programs	$3.68 to $63.87 per participant per year*
Avoided cost of transmission and distribution capacity	Value of avoiding or deferring the construction of additional transmission and distribution assets	$0 to $200.01 per kilowatt-year (kW-year)
Avoided cost of energy	Avoided marginal cost of energy produced	$0.024 to $0.19 per kilowatt-hour (kWh)
Avoided cost of generating capacity	Avoided cost of constructing or purchasing new generating capacity	$22.25 to $433.90 per kW-year
Demand reduction induced price efforts (DRIPE)	Value of energy or capacity market price mitigation or suppression resulting from reduced customer demand	Energy: $0 to $0.024 per kWh Capacity: $0.62 to $34.07 per kW-year
Avoided cost of renewable portfolio standards	Value of a reduced cost of compliance with renewable portfolio standards as electricity sales decrease	$0.50 to $9.82 per megawatt-hour

Values are in nominal terms. *Participants are low-income residential customers. *Source:* Baatz 2015

The following benefits from improved energy efficiency within the **business sector** have been identified:

- Cost reduction (reduced electricity demand and power factor charges, water use, other fuel consumption, maintenance, labour, compliance costs, taxes).
- Business efficiency (reduced cycle times, improved productivity and reliability, stoppage reductions, equipment reconfiguration, better process control technology, improved cost accounting).
- Quality improvements (improved product, process, or service quality; faster cycle times; reduced defects; customer and employee comfort).
- Risk abatement (reduction in energy market supply disruptions and price volatility, fewer lapses in emissions and safety compliance, fewer industrial process bottlenecks, less spending to offset equipment and real property degradation).
- Revenue enhancements (demand response incentives, market appeal of green products, new product lines, quick turnaround times, product customization and high margins).
- Ancillary benefits (enhanced corporate image, upgraded workforce skills).

Although sometimes difficult to quantify, the value of these additional benefits may exceed the direct reduction in energy costs [55].

The reduction of **air pollution** is a significant driver for energy efficiency in China, since emissions from coal plants has contributed to an estimated quarter of a million premature deaths in 2011 [56].

Traditional stoves cause at least 4.3 million premature deaths annually and 110 million disability-adjusted life years – primarily among women and children. A program to deploy improved cook stoves[18] aims to reduce both indoor and outdoor pollution and provide better energy access. Reduced fuel consumption frees up time by women and children for other activities such as school attendance, and prevents deforestation with a positive impact on biodiversity, soil quality and water resource management [56].

The continued product and system development of low cost high efficiency lighting has led other benefits to be observed. For example, the results of a clinical study demonstrated that a new well-designed lighting system, when compared to medication, resulted in more sleep, more regular sleep-wake-cycles, reduced depression and reduced dementia. This example of improved quality of life for resident dementia patients was based on designing better illuminance, light colour and dynamic changes that more closely mirrored changes in daylight throughout the day, which helped put patient circadian rhythms back into a normal sequence [57, 58]. These types of health and well-being benefits are clearly of very high value, but are difficult to cost in monetary terms alone.

[18] Almost all homes in China now have an improved cook stoves, with each estimated to save emissions by 1 to 3 tonnes of CO_2e per year.

6.2.2 Previous analysis

In the EU, 336 million m^3 of drinking water (equivalent to 1.2% of the EU residential total) will be saved by 2020 as a result of the EESL program for washing machines and dishwashers [38].

In China the EESL program will remove the need for 28 gigawatts of generating capacity by 2020, improving air quality by annually avoiding 6.8 million tonnes of sulphur dioxide emissions, 4.8 million tonnes of NOX and 29 million tonnes of particulates [59].

The IEA has noted that a broad spectrum of significant co-benefits are routinely associated with the introduction of EESL programs (see Figure 14) [60].

For example, improved indoor temperatures associated with space heating energy efficiency improvements in New Zealand were found to generate savings in health costs that were around 10 times the energy related savings [61].

In general, these co-benefits will improve the cost-benefit case for EESL programs. In jurisdictions where policy objectives such as improving air-quality or reducing public expenditure on health are of great national importance, the contribution made by increased energy efficiency in these areas may be sufficiently large in their own right to justify EESL programs.

In China the EESL program will remove the need for 28 gigawatts of generating capacity by 2020

> *"Policy–makers may well consider other co-benefits (alone) to be satisfactory outcomes of these investments in light of broader national priorities ... particularly for emerging economies looking to improve the quality of life of its citizenry" [60].*

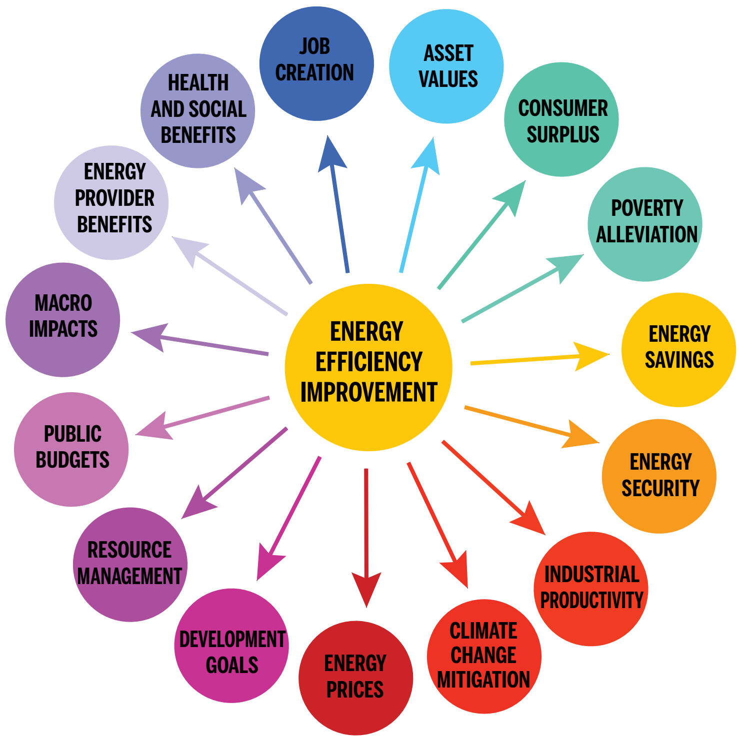
Figure 14: Range of co-benefits associated with EES&L programs [60]

Individual level Co-benefits (individuals, households, enterprises)
- Health and well-being impacts;
- Poverty alleviation: Energy affordability and access;
- Increased disposable income.

Sectoral level Co-benefits (industrial, transport, residential, commercial)
- Industrial productivity and competitiveness;
- Energy provider and infrastructure benefits;
- Increased asset values.

National level Co-benefits
- Job creation;
- Reduced energy-related public expenditures;
- Energy security;
- Macroeconomic effects.

International level Co-benefits
- Moderating energy prices;
- Natural resource management;
- Achievement of Development goals.



7 Rebound effect[19]

A key impact of increased energy efficiency is that the delivery of energy services, such as heating, cooling or lighting, is made cheaper for consumers. Where consumers choose to use some of this cost saving to pay for increased use of energy services, thereby reducing the projected energy savings, this is commonly known as the rebound, substitution or take-back effect [62][20].

In recent years there has been concern expressed that the scale of the rebound effect may significantly reduce the impacts of energy efficiency programs in terms of energy and cost savings to households and companies [64-66] [67, 68]. While there is not a large body of empirical evidence, it is possible to provide clarification on the likely impact of the rebound effect in relation to EESL programs.

While the direct rebound effect may be significant, it is likely to be limited to some very specific cases, where increased comfort levels may be a desirable outcome of the EESL programs

Firstly, it should be noted that the rebound effect can be an intended consequence of the EESL program. In programs targeted at low income households in the northern hemisphere, factoring-in a 30% increase in heating is typical [69]. Similarly, in the New Zealand example in section 6 a key objective from the policy to improve heater efficiency was to enable householders to heat their dwellings to a higher standard.

Secondly, the main rebound effect in households will occur when users of appliances and equipment constrain their usage due to excessive running costs prior to the energy efficiency improvement i.e. they limit their use of individual appliances to what they can afford to spend on energy bills[21]. This suggests that the rebound effect will mainly apply where the demand for energy services is not satiated and this will predominantly apply to low-income consumers. It also suggests that it will be most evident for those types of appliances with the greatest potential for significant savings in running costs, as understood by consumers and where they feel they have some discretion in usage.

In developed countries, the numbers of households where the rebound effect is relevant will be limited. Just over 10% of households are classified as fuel poor[22] in England, and this proportion is likely to be equivalent or less in most other developed countries[23] [70]. The proportion of relevant households in developing countries is likely to be greater, although this will depend upon national circumstances, including demographics and climate.

Thirdly, the rebound effect is also limited to appliances that individually consume considerable quantities of energy and that are under the control of the householder. This explains why there is little evidence for any significant rebound effect in refrigeration, clothes or dishwashing, home entertainment and other uses of consumer electronics[24]. The effect in lighting may be in the region of a 5-12% reduction in energy savings. Any rebound effect may be most apparent in space heating, cooling and in water heating. Estimates, largely from the USA, indicate a direct rebound effect for heating, cooling and water heating of 10-30%, 0-50% and 10-40%, respectively (see Attachment E) [71, 72]. These large variations are largely due to the extent that the demand for energy services is satiated in households targeted by the EESL program.

[19] Indirect rebound effects can also occur but these are difficult to identify within an economy where various behaviours by consumers and producers may offset each other. These include the use of savings to purchase other goods and services that also require energy to provide, and where new technology creates new production possibilities and increases economic growth [36].

[20] Indirect rebound effects can also occur but these are difficult to identify within an economy where various behaviours by consumers and producers may offset each other. These include the use of savings to purchase other goods and services that also require energy to provide, and where new technology creates new production possibilities and increases economic growth [63. Sorrell, S., *The Rebound Effect: an assessment of the evidence for economy-wide energy savings from improved energy efficiency*, 2007.

[21] A similar effect to rebound can also occur where there are physical (not cost) constraints on energy service supply, For example where energy supplies are limited or where appliance capacity is inadequate (heating or hot water system unable to meet the desired user demand (e.g. in rental properties). In these cases, a switch to a more efficiency appliances effectively provides the consumer with increased capacity, which may be used to access a greater level of energy services.

[22] Fuel poor households are those that spend more than 10% of their income on heating bills.

[23] Note that data on fuel poverty in England has been collected over many years and understanding of this issue is highly advanced.

[24] The observed increased in the size of such appliances may indicate that some energy costs savings have been used to purchase increased capacity, although this might better be explained by the reduced capital cost of appliances (see Section 4).

Within the commercial and industrial sector, the reduction of input energy costs should be reflected in cheaper products and services, and stimulate increased demand for outputs. Since energy is typically a small component of input costs (<10%), a doubling of energy productivity[25] might be expected to increase fuel use by not more than 2.5% [72].

Finally it should be noted that, while the direct rebound effect may be significant, it is likely to be limited to some very specific cases, where increased comfort levels may be a desirable outcome of the EESL programs. Any such effect should be accounted for within the cost-benefit analysis conducted by EESL programs. Where this has been done, programs have still demonstrated a net benefit.

8 Conclusions

This thorough review of the achievements of EESL programs provides overwhelming evidence that these programs have made a very significant contribution to the reduction of energy use and CO_2 emissions, and at a very much lower cost than could have been achieved by other clean energy supply options.

This conclusion takes into account any likely rebound effect if end-users purchase more energy services with the savings generated by increased efficiency. Furthermore, the additional flow-on benefits from EESL programs in terms of improved health from higher thermal comfort and/or avoided air pollution; job creation and energy security provide added justification for these programs.

Governments should take account of these findings when they consider their investment options and priorities for meeting energy demand, noting that all EESL programs have the potential to expand in scope and ambition to deliver more energy and CO_2 savings, as well as beneficial additional policy outcomes. A better understanding of the range of potential co-benefits that may arise from energy efficiency programs will facilitate the collection of data by policy makers to provide more quantitative assessments of these impacts in the future.

This 2016 update of the original 2015 report provides further evidence to substantiate these conclusions.

[25] With other inputs constant.

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Abbreviations

4E	Energy Efficient End-use Equipment, IEA Implementing Agreement
AC	Air-conditioner
B/C	Benefit to Cost ratio
CLASP	Collaborative Labelling and Appliance Standards Program
COP	Coefficient of Performance (output energy / input energy)
EE	Energy efficiency
EESL	Energy Efficiency Standards and Labelling programs
EU	European Union
Ex-ante	Before an event; term used in policy appraisals to indicate that savings estimates are undertaken before the measure has been implemented
Ex-post	After an event; term used in retrospective policy evaluation to indicate that savings estimates were done after the measure has been implemented
TWh	Terawatt hour
IEA	International Energy Agency
kWh	kilowatt hour
MEPS	Minimum Energy Performance Standards
$MtCO_2e$	Mega-tonnes of carbon dioxide equivalent
USA	United States of America
USD	US dollars, currency

Attachment A: Methodology outline

The project methodology involved an extensive international review of the published reports and conference papers, including over 150 reports and papers from more than 20 countries[26] covering more than 30 product types, which deal with the impact evaluation of energy efficiency programs. Many leading energy efficiency experts from around the world were consulted (see acknowledgements) regarding suitable studies that could be utilised as part of the evidence base for this study. Wherever possible, multiple sources have been identified to support and corroborate the findings and to confirm the wide spread benefits of energy efficiency programs.

In selecting published data to include, comprehensive ex-post studies were given the highest weighting, as these tend to provide the most reliable evidence base of savings achieved in practice. This is particularly true where such studies effectively address key aspects that may have had an impact on savings (capacity changes, ownership trends, sales, actual efficiency, etc.) using a decomposition approach in the analysis. However, formal ex-post evaluation studies, where energy savings are estimated from a review of historical data after program implementation, are not common in the published literature.

MEPS impacts are generally easier to estimate, and many ex-ante estimates of energy savings have been found to be accurate through ex-post evaluation studies. This is because MEPS defines an efficiency benchmark that all products must reach, providing some certainty regarding the likely future program impact. In contrast, it can be more challenging to estimate the likely future impact of labelling programs before they are introduced, particularly voluntary labelling programs, as the savings achieved rely on consumer and manufacturer market responses, which in turn are dependent upon communication, marketing and stakeholder understanding. In the case of labelling impacts, ex-post studies were generally considered more robust and accurate in terms of estimating energy savings achieved.

A final aspect of note is that few reports examined document in any detail the issue of attribution of claimed energy savings. Attribution[27] can be quite important where there are several programs that overlap and/or where there is rapid technology change that is driven by issues that may not be directly related to energy efficiency.

26 Including the EU and its 28 Member States.

27 Attribution of saving requires the development of a credible counter-factual scenario of what may have happened if the program was not implemented in the past. Savings are then calculated as the difference between the counter-factual and what actually happened. This can be relatively simple for a single program measure where there is good data. Counter-factual cases where programs have been in place for many years (e.g. a no labelling counter-factual for a country that has had energy labelling for over 30 years) is potentially very uncertain. Attribution requires good data, knowledge and understanding and to some extent is subjective. The methodologies deployed in the development of counter-factual scenarios are often poorly documented. Estimating future scenarios of program impacts and savings requires the same approach in terms of attribution.

Attachment B: Efficiency Improvements

Through the use of MEPS and labels, governments have measured an increase in the rate of efficiency improvement of new appliances and equipment being sold in their markets. Typically, annual rates of improvement across many major jurisdictions were found to be in the range of 3% to 4% per annum for large whitegoods over a long period, compared to an underlying autonomous rate of improvement of around 1% per annum[28].

For example, in China between 1999 and 2007 the average rate of efficiency improvement for labelled mid-sized refrigerators was 3.8% per annum under their EES&L program and for air-conditioners between 2005 and 2009 the average annual rate of efficiency improvement was estimated to exceed 5% per annum based on a combination of ex-ante and ex-post estimates [59].

Similar annual improvement rates have been found by IEA 4E Mapping and Benchmarking studies on refrigerators, washing machines, dishwashers and air conditioners across a range of countries, all of which have policy measures in place over at least part of the period where data is available [7-10][29]. A summary of the annual 'efficiency' improvements in the IEA 4E benchmarking studies are shown in Table 5 below. It should be noted that some of the data used to estimate these averages are model-weighted (rather than sales weighted, which tends to be more accurate). In addition, the time series available varies by country and these do not always fully span EES&L policies of interest. As such, they are likely to be underestimates of the impact of EES&L policy measures.

Table 5: Average annual efficiency improvements from 4E benchmarking studies (% per annum) [7-10].

PRODUCT ->	REFRIGERATOR	DISHWASHER	WASHING MACHINES FRONT LOADERS	AC-UNITARY	AC-SPLIT
Underlying units ->	(Normalised kWh/Litre) [1]	(Normalised EEI) [1]	(Normalised EEI) [1]	(EER)	(EER)
Australia	-3.6%	-2.3%	-1.4%	3.1%	5.3%
Austria	-4.0%	-4.8%	-3.7%	-	-
Canada	-2.3%	-2.1% *	-10.4% *	0.2% *	-
Denmark	-2.6%	-1.9%	-	-	-
Korea	-	-2.3%	0.0% [2]	0.5%	1.5%
Switzerland	-	-0.9%	-	-	-
UK	-3.9%	-2.8%	-2.3%	-	-
USA	-11.9%	-2.1% *	-	-	-
EU	-3.0%	-1.3%	-3.0%	-	5.1%
Average (including EU overlap)	**-3.2%**	**-2.3%**	**-2.1%**	**1.8%**	**3.0%**

Note 1: the underlying units for the first three products are 'energy intensity', so a negative figure implies an increase in energy efficiency.
Note 2: The underlying data are varying in quality and extent, so some of these figures should be treated with caution, for example, front loader washing machine values for Korea are based on just 3 years of data, whilst reference [24] reports a 14% decrease in energy intensity from 2006 to 2010, equivalent to a decrease of -2.1% per annum.

'*' indicates where the values are model-weighted, rather than sales-weighted.

[28] See IEA publications: Tracking Clean Energy Progress 2015, Energy Technology Perspectives. Also Manne and Richels 1992, Global 2100 model which estimates the rate of autonomous energy efficiency improvement at 0.23% to 1.2 % p.a.

[29] The 4E Mapping and Benchmarking studies provide a useful basis for comparing data across different countries, which was the primary purpose of this work. For almost all products examined, data show that energy efficiency rates have improved significantly, often over very long periods. However, these comparisons have some limitations in that some of the data sets provided by individual countries do not have sales data attached to individual model data and the time periods where data are available is not always comparable. For example, the refrigerator data included in Table 2 cover a period of 16 years for Denmark and Canada, 15 years for Japan, 12 years for the UK, 10 years for Australia, 8 years for the EU and 7 years for Austria. Also, the start and end years vary and the timing of different policy measures varied in each country.

A major international review of major appliance energy and price trends was published in the journal Energy Policy in 2010 [39]. That paper documents a large number of studies that cover many countries and appliance types around the world. That paper also assesses the long-term historical reductions in energy consumption and price for refrigerators, freezers, washing machines, clothes dryers and dishwashers. The rate of energy efficiency improvement ranged from 1% per annum to as much as 6% per annum in some cases. The data also showed long term reductions in appliance purchase prices. The key results are summarised in Table 6.

Table 6 Yearly changes in price and specific energy consumption of large appliances [39]

APPLIANCE	SOURCE	COUNTRY	TIME PERIOD	YEARLY CHANGE IN %	
				PRICE	SEC[A]
Washing machines	Weiss et al. (2010)	NL	1965-2008	-2.4	-2.5
	Bertoldi and Atanasiu (2007)	EU-15	1996-2004	-	-3.3
	CECED (2003)[b]	EU	1994-2002	-	-4.5
	Dale et al. (2002)	USA	1983-2001	-2.4	-0.9
	EES (2006)	AUS	1993-2005	-2.6	-1.3
	Laitner et al. (2004)	USA	1980-1998	-3.4	-
	Waide (2001)[c]	EU-15	1996-1998	-	-2.5
Laundry dryers	Weiss et al. (2010)	NL	1969-2003	-2.1	-1.5
	Bass (1980)[d]	USA	1950-1961	-2.3	-
	Bass (1980)[d]	USA	1950-1974	-2.2	-
	EES (2006)	AUS	1993-2005	-1.1	-0.7
	Laitner et al. (2004)[d]	USA	1980-1998	-3.2	-
	Laitner et al. (2004)[e]	USA	1980-1998	-2.9	-
Dishwashers	Weiss et al. (2010)	NL	1968-2007	-3.8	-2.3
	Bass (1980)	USA	1947-1968	-2.0	-
	Bass (1980)	USA	1947-1974	-2.0	-
	Ennen (2006)[b,f]	EU	1998-2994	-	-5.1
	Ennen (2006)[b,g]	EU	1998-2004	-	-6.0
Refrigerators	Weiss et al. (2010)	NL	1964-2008	-1.2	-2.4
	Bass (1980)	USA	1922-1940	-2.6	-
	Bertoldi and Atanasiu (2007)[f]	EU-15	1993-2005	-	-4.3
	Bertoldi and Atanasiu (2007)[b]	EU	1993-2004	-	-4.5
	CECED (2004)[b,h]	EU	1999-2003	-	-3.5
	Dahlman (2007)	AUS	1993-2005	-	-3.9
	Dale et al. (2002)	USA	1980-2001	-2.5	-4.6
	EES (2006)	AUS	1993-2005	-1.7	-4.6
	ECCJ (2006)	JPN	2001-2005	-15.1	-5.1
	Laitner et al. (2004)	USA	1980-1998	-3.2	-
	Schiellerup (2002)	UK	1992-1999	-6.3	-3.9
	Schiellerup (2002)[i]	UK	1992-2000	-	-3.4
	Waide (2001)[c,j]	EU-15	1994-1998	-	-2.3
Freezers	Weiss et al. (2010)[k]	NL	1970-2003	-1.5	-1.9
	Weiss et al. (2010)[l]	NL	1970-2003	-1.1	-
	EES (2006)	AUS	1993-2005	-2.5	-3.3
	Laitner et al. (2004)	USA	1980-1998	-5.3	-
	Schiellerup (2002)[k]	UK	1992-1999	-5.1	-3.1
	Schiellerup (2002)[l]	UK	1992-1999	-5.0	-5.6

(See notes overleaf...)

Table reproduced from Weiss et al. in Energy Policy 38(2) 2010 [24].
Abbreviations: AUS-Australia, EU-Europe, EU-15-15 member countries of the European Union; JPN-Japan; NL-The Netherlands; UK-United Kingdom; USA-United States of America.
a SEC-specific energy consumption.
b Including member countries of CECED (European Committee for Domestic Equipment Manufacturers).
c Sales weighted averages.
d Electric laundry dryers.
e Gas laundry dryers.
f Referring to dishwashers with a capacity of 12 standard place settings.
g Referring to dishwashers with a capacity of 9 standard place settings.
h Total of cold appliances.
i Refrigerator-freezer combinations.
j Covering the total of cold appliances.
k Upright freezers.
l Chest freezers.

Table 7 below provides an update of the values shown in Table 6 for selected countries, based on more recent data. Australia's data are for the period 1993 to 2014 inclusive, whilst Korea's data for refrigerators are for 1996 to 2010. Korea data for clothes washers for top loaders are from 2005 to 2010 [73], [36], [74].

Table 7: Updated rates of annual efficiency improvement for selected appliances in Australia and Korea

COUNTRY	REFRIGERATORS	FREEZERS	DISHWASHERS	CLOTHES WASHERS
Australia	-3.3%	-2.3%	-2.7%	-2.5%
Korea	-5.8%			-3.4%

Note: Values quotes are rates of change in specific energy consumption, which can be taken as the inverse of energy efficiency. All Australian data are 1993 to 2014 inclusive, Korean refrigerators are 1996 to 2010 and Korean clothes washers are 2005 to 2010.

In Japan, the Top Runner Program has delivered consistent efficiency improvements of between 0.3-9% per annum since the late 1990s across a broad range of product types [73] (see Table 8).

Table 8: Average annual product efficiency improvements – Japan Top Runner Program 1998 – 2008 [73]

PRODUCT TYPES	AVERAGE EFFICIENCY IMPROVEMENT PER ANNUM
Air Conditioners - Room	7.6%
Refrigerators	7.6%
Freezers	4.4%
Lighting	4.1%
Computers	9.0%
Copiers	6.3%
Water heaters	0.9%
Heaters - Space	0.3%
Televisions - Flat	6.7%
VCRs or DVD	9.0%
Microwaves	2.5%

Note: Efficiency improvements are sales-weighted values. The figures in this table may be different from other studies due to different time periods and the type of data processing undertaken (e.g. models or sales weighted averages)

The Top Runner approach used in Japan is different from MEPS used in other countries in that sales weighted average efficiency of shipments for each supplier is required to meet the Top Runner target (compared to traditional MEPS where all products from all suppliers must exceed the minimum efficiency level specified). However, it has been argued that the policy objectives and impacts are very similar [75].

2016 Update

Table 9 shows updated results of the Top Runner Program (Table 8).

Table 9: Improvements in Japanese product efficiency under the Top Runner Program [14]

PRODUCT CATEGORY	START YEAR (FY)	END YEAR (FY)	PREDICTED ENERGY EFFICIENCY IMPROVEMENT (%)	ACTUAL ENERGY EFFICIENCY IMPROVEMENT (%)	ACTUAL/ EXPECTED RATIO	ACTUAL IMPROVEMENT (%/YR)
AC - non-ducted/wall-mounted, 4kW or less	2005	2010	22.4%	16.3%	0.73	3.1%
AC - non-ducted/wall-mounted, over 4kW	2006	2010	17.8%	15.6%	0.88	3.7%
AC - other than non-ducted/wall-mounted	2001	2012	13.6%	15.9%	1.17	1.4%
Electric refrigerators (residential)	2005	2010	21.0%	43.0%	2.05	7.4%
Electric freezers (residential)	2005	2010	12.7%	24.9%	1.96	4.5%
Microwave ovens	2004	2008	8.5%	10.5%	1.24	2.5%
Electric rice cookers	2003	2008	11.1%	16.7%	1.50	3.1%
Lighting equipment for fluorescent lamps	2006	2012	7.7%	14.5%	1.88	2.3%
Self-ballasted fluorescent lamps	2006	2012	3.2%	6.6%	2.06	1.1%
Electric toilet seats	2006	2012	9.7%	18.8%	1.94	2.9%
TV (liquid crystal/plasma)	2008	2012	37.0%	60.6%	1.64	12.6%
VCRs	1997	2003	58.7%	73.6%	1.25	9.6%
Computers	2007	2011	77.9%	85.0%	1.09	16.6%
Magnetic disk units	2007	2011	75.8%	75.9%	1.00	15.2%
Copying machines	1997	2006	30.9%	72.5%	2.35	6.2%
Space heaters (oil)	2000	2006	3.8%	5.3%	1.39	0.9%
Gas cooking appliances (oven area)	2002	2008	20.3%	25.8%	1.27	3.9%
Gas water heaters	2002	2008	1.1%	7.9%	7.18	1.3%
Oil water heaters	2000	2006	3.5%	4.0%	1.14	0.7%
Vending machines	2005	2012	33.9%	48.8%	1.44	5.8%
DVD recorders	2006	2010	20.5%	45.2%	2.20	9.8%
Routers	2006	2010	16.3%	40.9%	2.51	9.0%
Switching units	2006	2010	37.7%	53.8%	1.43	11.4%
Transformers	1999	2006/2007	30.3%	13.1%	0.43	1.7%

Attachment C: Energy & CO_2 Savings

Information on total programmatic energy, greenhouse gas and financial savings are taken from both ex-ante studies that provide national impact assessments, as well as a number of ex-post studies. Savings reported in a selection of studies are summarised in Table 10. It should be noted that the scale of these savings depend upon the scope and maturity of national EESL programs.

The two studies from Australia are notable, as these were very detailed long-term ex-post studies that estimated the energy impacts actually realised from a range of previous programs [15, 24]. These studies were found to validate the pre-regulatory ex-ante impact estimates. In fact, both of these studies showed that the actual savings were higher than predicted by the impact assessment undertaken prior to implementation of the last major program measure. This type of outcome has been found to be true in many cases[30], as the ex-ante estimates are often based on conservative estimates, which underplay the potential savings from the program measure and over-estimate likely program and product costs (see section 4).

Table 10: Examples of savings within different jurisdictions

JURISDICTION	PRODUCT TYPES	SAVINGS ACCRUAL PERIOD	SAVINGS (TWH)	SAVINGS (USD)	SAVINGS ($MTCO_{2-E}$)
European Union [38]	Ecodesign / Labelling directives	1990-2010	213	N/A	N/A
European Union [38]	Ecodesign / Labelling directives	2010-2020	1719 [1]	120bn [2]	320 [3]
USA [28]	Federal energy and water conservation standards [4]	1987 - 2013	10,753	N/A	2,113
USA [28]	Federal energy and water conservation standards [4]	In 2013	1,187 [5]	56bn [6]	218 [7]
USA [32]	Energy Star – Voluntary Program	1992 - 2013	2,700	295bn	2,198
USA [32]	Energy Star – Voluntary Program	In 2013	380	32bn [8]	294
China [59]	All programs	To 2020	1,143 [9]	N/A	N/A
Australia [15] [10]	Air-conditioner program	2003-2020	6.5	0.8bn	N/A
Australia [24]	Refrigerators/Freezers	1986 - 2009	5.9 [11]	N/A	6
Fiji [31]	Refrigerators and Freezers	2012 - 2014	0.005	0.85m	0.002
India [76]	All programs	2012 - 2030	70	N/A	N/A

Notes:

1. On average the energy saving is 19% for the products included in the accounting.
2. This represents the net benefit from a €170 bn. gross saving on running costs (87% energy) compared with €60 bn. in extra acquisition costs associated with the more efficient products.
3. This is 18% of the included products and 6.7% of the EU total (4721 $MtCO_{2e}$).
4. Includes the impacts of energy and water conservation standards that have been adopted from 1987 through 2013 covering a total of 43 product categories.
5. This is equivalent to 4% of total USA energy consumption and 4% of national CO2e emissions. The implied carbon/cost conversion factors for the "USA - All Federal programs" is significantly different to that reported for the "USA Energy Star Program" because Federal Programs report primary energy savings whereas the Energy Star program reports delivered energy savings. There will also be some other differences relating to aspects such as coverage, fuels, time periods and evaluation methodologies.
6. This represents an average household saving of USA $361 in operating costs in 2013.
7. This is equivalent to 4% of national CO_{2e} emissions.
8. In addition to direct reductions in energy costs the study estimates that more than $11billion in benefits to society due to reducing damage from climate change were also realised in 2013.
9. By 2020, annual savings are expected to be equivalent to 11% of residential electricity use.
10. This analysis included an accurate ex-post analysis of data between 2003 and 2008.
11. Most of the savings (around 4.1 TWh/year) is attributed to energy labels introduced from 1986, thus policies from the late 1990s onwards will have realised an estimated energy savings of around 1.8 TWh/year per annum by 2009.

[30] One exception was in the case of some of the EU preparatory measures. A study by the Wuppertal Institute made corrections for some factors: accounting for rebound/take back and double counting of some aggregate savings (e.g. refrigerator and motors) [44].

Information presented in the main report also includes the following:

- In the USA, it is estimated that in 2014, standards and labelling programs saved 12% of electricity consumption and 4% of USA end-use natural gas demand [77]. In addition, the voluntary Energy Star program saved a further 5% of electricity consumption in 2014. Together these programs are estimated to have saved 17% of total electricity and 4% gas consumption in the USA.
- The Australian and New Zealand Equipment Energy Efficiency committee [78] has estimated that in 2012, standards and labelling programs saved 6.2 TWh within the residential sector. This equates to 10% of the residential sector electrical energy consumption in that year (ABARE).
- The EU Eco-design program is estimated to deliver an annual saving in primary energy of 19% by 2020 and savings in the residential sector amounting to 25% of residential energy consumption [38].
- Also by 2020, annual savings from residential energy efficiency programs in China are expected to be equivalent to 11% of residential electricity use [59].

Attachment D: Impact on appliance and equipment purchase prices

Most countries that conduct ex-ante assessments of the future impact of MEPS regulations assume that the average purchase price of equipment is static and will rise after program implementation due to increased costs of energy efficiency. However, the reviewed evidence showed that appliance purchase prices are generally declining in real terms and have been for many years.

For example, across all the EU Ecodesign regulations, the average product price rise was anticipated to be 14% [38]. However, much of the ex-post evidence suggests that these increases in purchase prices tend not to happen or are much smaller than anticipated. This is partly due to the long term decline in product prices (as observed in reliable longitudinal sales data based studies from the UK, Australia [36] the USA and the EU [23]), so any relative increase is usually small and not necessarily seen by the consumer as a price rise in the context on ongoing price reductions.

This phenomenon has been identified by various studies, for example, an international study by Ellis et al. suggests that more efficient appliances do not necessarily cost more to buy [79]. Similarly, a recent study in Sweden shows efficiency improving whilst product prices were falling [35]. While regulatory interventions may still have an impact on the price trends (i.e. to reduce the rate of real price decline), the ongoing trend towards lower capital costs of appliances and equipment means that greater levels of efficiency can be justified within a total life cycle analysis.

Recently, a few detailed long term studies in the EU and the USA have been undertaken to explain these falling purchase prices, both as a function of time and total cumulative production [39], [40]. The outcome of such research is sufficient for analysts to now recommend that these so called "learning rates" on appliance price trends be taken into account in ex-ante studies, thereby allowing the setting of MEPS requirement levels at slightly more stringent levels (e.g. as proposed for the USA) [41].

Despite these longitudinal analyses, there are few current studies that compare the ex-ante estimates of expected price increases against the ex-post evidence. An analysis of Australian refrigerator prices changes for each major type for each year from 1993 to 2008 using actual prices paid by consumers (corrected for inflation) show that real prices for most types have declined rapidly in real terms over the 15 year period (2.5% to 5% per annum depending on the type) [24]. Importantly, that study found that MEPS in 2005 resulted in a 25% to 35% reduction in energy consumption (which varied by type) over three years with no discernible change in the long-term real price trend before and after implementation.

A USA study took the ex-ante DOE estimates of expected purchase price increases and compared them to the actual price changes two years after the MEPS were implemented as set out in Table 11. This study concluded that the ex-ante study, on average, overestimated the marginal increase in purchase price by a factor of 10 [37][31]. However, it should be noted that the early DOE studies tended to assume purchase prices were flat whereas there is sufficient evidence to strongly suggest that they were in fact falling, so this USA study's findings in relation to the degree of overestimate in purchase price should be somewhat tempered[32].

An earlier LBNL paper reached a similar conclusion on overestimating the expected rise in purchase price from MEPS [80]. This paper listed four conclusions about appliance trends and retail price setting:

1. For the past several decades, the retail price of appliances has been steadily falling while efficiency has been increasing.
2. Past retail price predictions made by DOE analyses of efficiency standards, assuming constant prices over time have tended to overestimate retail prices.
3. The average incremental price to increase appliance efficiency has declined over time. DOE technical support documents have typically overestimated this incremental price and retail prices.
4. Changes in retail mark-ups and economies of scale in production of more efficient appliances may have contributed to declines in prices of efficient appliances.

[31] Excluding AC, since their price fell dramatically. The late 1990s saw a dramatic increase in the production of air conditioners in China, together with dramatically increased world trade, and this had major impacts on the price of these appliances in most countries.

[32] The DOE estimated purchase price increases may be reasonable when superimposed on the underlying price trend, but not the implied absolute purchase price.

Table 11: Comparison of predicted and actual price increases from USA MEPS [37]

JURISDICTION	STANDARD EFFECTIVE DATE	DOE ESTIMATE OF INCREMENTAL PRICE OF STANDARD (NOMINAL $)	PRIMARY CASE (CUSTOM 2-YEAR PERIOD)				
			BEFORE	AFTER	DOE ESTIMATE (2011$)	COST FROM CENSUS (2011%)	DIFFERENCE (2011$)
Refrigerators	7/1/2001	32	2000	2002	56	37	-18
Clothes Washers	1/1/2004	34	2002	2004	54	-35	-89
Clothes Washers	1/1/2007	126	2006	2008	199	10	-188
Electric Water Heaters	1/20/2004	67	2003	2005	108	28	-80
Non-Electric Water Heaters	1/20/2004	75	2003	2005	121	34	-88
Central AC – 3 tons	1/23/2006	167	2005	2007	267	207	-59
Room AC	10/1/2000	7.50	1998	2000	13	-162	-175
Commercial AC – 15 tons	1/1/2010	334	2009	2010	512	-224	-736
Ballasts	1/1/2005	4.27		2006	6.73	-1.74	-8.47
Average					**148**	**-12**	**-158**

A deeper, more recent, analysis of several federal MEPS regulations by the USA over time explored whether purchase prices continue to fall, and whether further efficiency opportunities exist following the introduction of MEPS. This USA analysis clearly shows that the decline in both the purchase price and the LCC continues after the implementation of successive measures, and in most cases at a higher rate of decrease (Figure 15) [23]. This data suggests that MEPS has little impact on purchase price, while cumulative shipments are a far more important determinant in the estimate of long-term price trends.

This is more clearly illustrated in a long-term analysis of clothes washer energy and price in the USA. Figure 16 shows that clothes washer prices have been declining for more than two decades. Small increases (or pauses) in the decreasing price trend are evident close to each MEPS level, suggesting that some small price impacts may have occurred[33] but the downwards trend re-appears soon after.

[33] **Note:** Care is required in the interpretation of this type of data, as the mix and capacity of products may change slightly from year to year, as well as the features that may impact on price but not efficiency. It is therefore important to disaggregate the data and take account of features and services at a model level. An example is the recent popularity of stainless steel refrigerators – these are considerably more expensive but the outer material has no impact on energy efficiency. If an analysis of price trends did not take the prevalence of this non-energy feature into account from year to year, it could be wrongly interpreted that price increases are due to energy related factors if shifts in the share of such features happen to coincide with the implementation of energy program measures. The analysis presented in Figure 8 and Figure 9 use a "quality adjusted price" to account for changes in features.

Figure 15: Purchase price (orange) and LCC (blue) trends for appliances pre-standards and post-USA Federal MEPS [23]

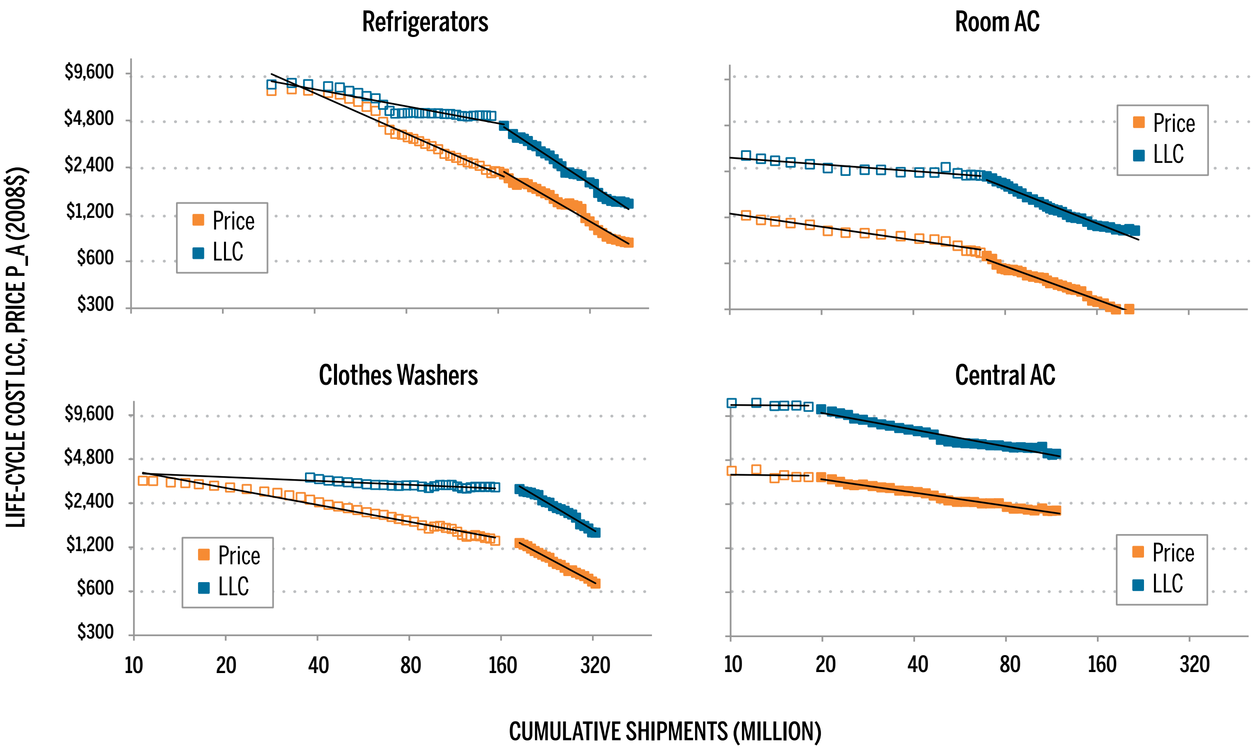
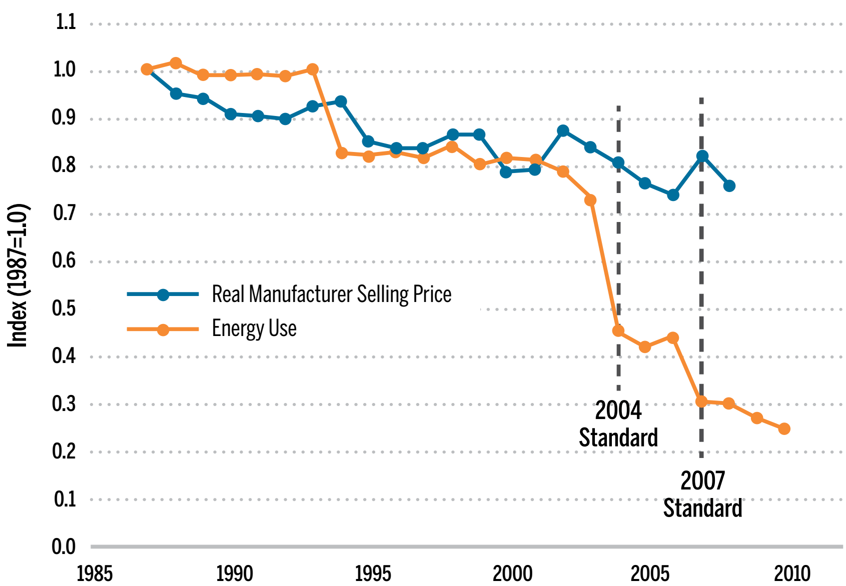


Figure 16: Price and energy trends for clothes washers in the USA [37]



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Updated analysis for Australia shown in Figure 17 to Figure 19 illustrate the real price decline in new refrigerators, washing machines and dishwashers in Australia sold between 1993 and 2014 alongside the corresponding reduction in the average energy consumption over the same period [5].

Figure 17: Average purchase price and energy consumption of new refrigerators, Australia

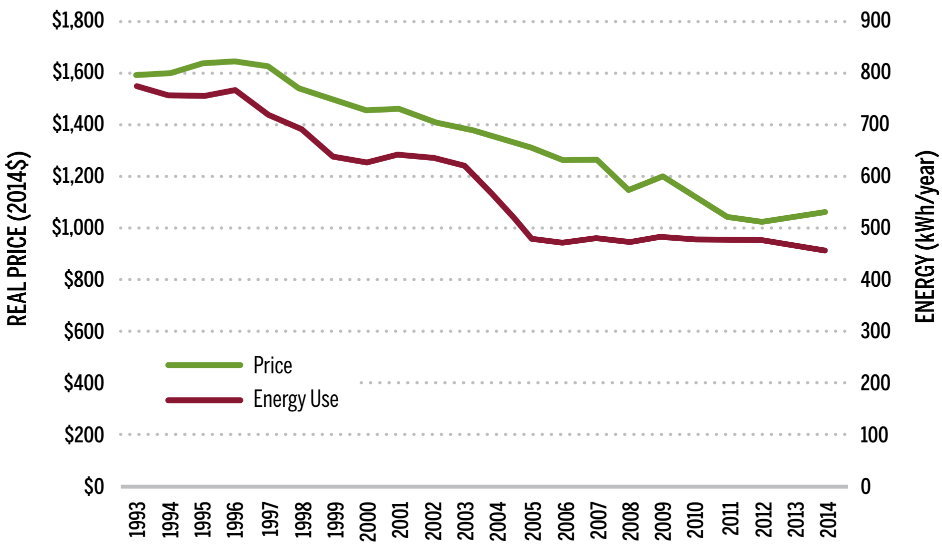
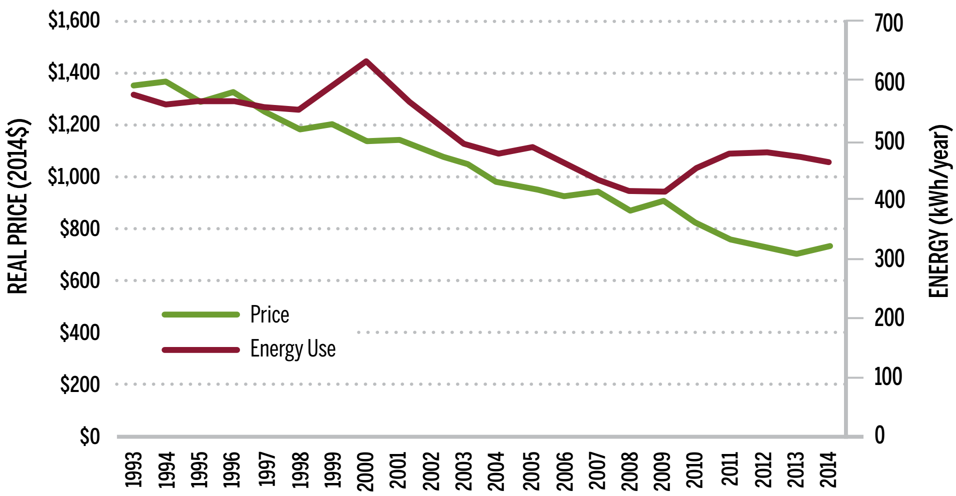
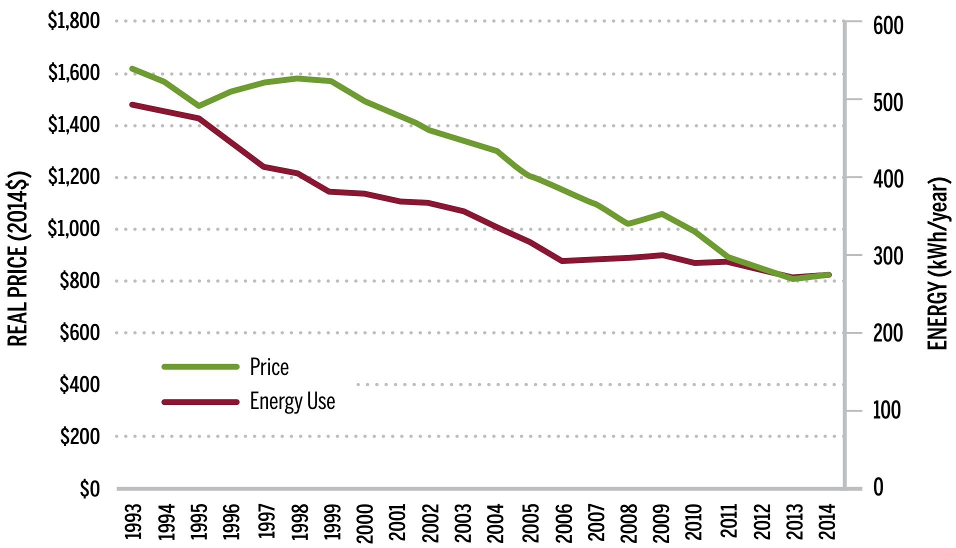


Figure 18: Average purchase price and energy consumption of new clothes washers, Australia[34]



[34] Washer energy has been going up for both types due to increases in capacity

Figure 19: Average purchase price and energy consumption of new dishwashers, Australia



Attachment E: Estimates of the rebound effect

From the available literature, it appears that for many residential appliances the direct rebound is relatively small, and could be close to zero for whitegoods because their use is rarely constrained by energy cost issues alone. In a 2010 review of the impact of EU Ecodesign, Irrek et al found from the available evidence that the range of estimates for direct rebound effect for lighting were relatively low (5%-12%), while the reported values for heating and air conditioners may be higher (10%-30% and 0-50% respectively) [71]. The overall estimate of direct rebound was however relatively low, at approximately 10%. Much of the evidence cited is from a meta-analysis published in 2000 and summarised in Table 12 [72].

In most studies cited in this report any rebound (in the form of changes in the level of energy service provided) is taken into account when estimating the overall energy and program benefits. Furthermore, where direct rebound does occur, it should not necessarily be considered a negative outcome.

Where consumers choose to take some of the potential energy savings from an energy efficiency program in the form of increased service levels, this means that the consumer is valuing the increased energy service more than the potential energy cost reductions that they might have otherwise realised if the energy service level had remained the same. In some cases, such as programs for low income households, this so called 'take back', in the form of higher standards of heating or cooling, is in fact an intentional policy outcome which may have other benefits such as improved health and well-being (e.g. 30% increase in heating was intended in one low-income program [69]). Such potential "co-benefits" associated with this type of rebound are discussed further in Section 6.

Finally, it should also be noted that with energy service saturation, and increasing income effects, the direct rebound is expected to be lower in the future.

Table 12: Estimates of direct rebound by application [71]

SECTOR	APPLICATION	DIRECT REBOUND EFFECT	AVERAGE
Private households	Space Heating	10-30%	20%
Private households	Space Cooling	0-50%	25%
Private households	Hot water	<10-40%	25%
Private households	Lighting	5-12%	8.5%
Private households	White goods	0%	0%
Industry and commerce	Lighting	0-2%	1%
Industry and commerce	Process technology	0-20%	10%

Attachment F: New Danish efficiency indicators

A recent report commissioned by the Danish Energy Agency shows improvements ranging from 2.8 to 8.3% per annum in the efficiency of new products sold in Denmark between 2005 and 2014 [13] (see Table 13).

Table 13: Average efficiency (EEI) of products sold in Denmark, 2005-2014 [13]

PRODUCT	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	ANNUAL REDUCTION
Refrigerator/freezer	0.483	0.471	0.459	0.469	0.460	0.451	0.419	0.388	0.367	0.360	2.84%
Washing machine	0.649	0.655	0.649	0.638	0.643	0.637	0.595	0.520	0.466	0.462	3.20%
Television	0.944	1.016	0.990	1.002	0.926	0.844	0.670	0.471	0.269	0.242	8.26%

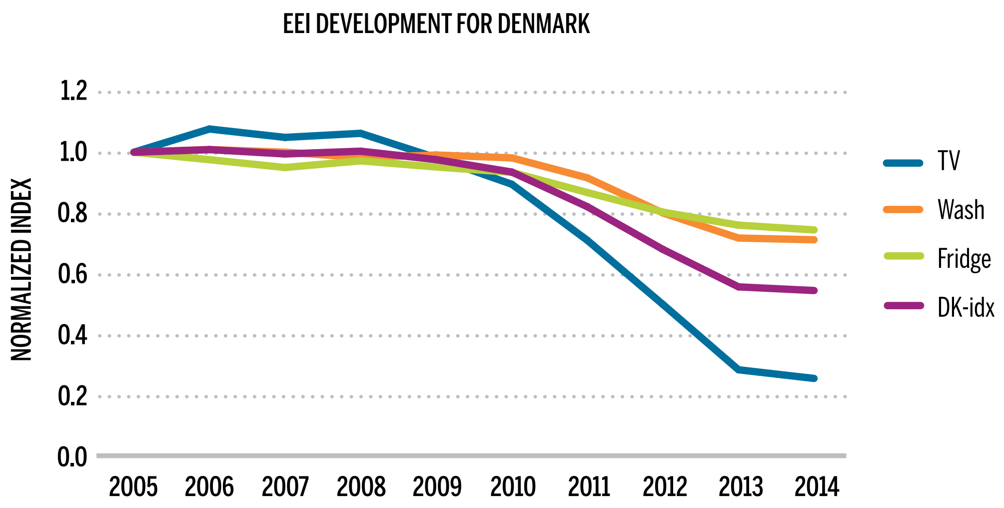
Using these average efficiency values, a national weighted annual average energy efficiency index (DK-idx) of 5.1% has also been calculated, based on indices developed using 2005 as the base year.

As shown in Figure 20, the substantial improvement in energy performance of these products begins around the time of the introduction of Ecodesign and labelling requirements within the European market in 2009 and 2010 (Table 14). This indicates that these regulations have provided a strong driver for these efficiency improvements.

Table 14: Date of EU energy efficiency regulations

PRODUCT	REGULATION	DATE IN FORCE
Television	Ecodesign and labelling	2010 Latest requirements 2012
Washing machine	Ecodesign and labelling	2010
Refrigerator/freezer	Ecodesign and labelling	2009

Figure 20: Annual efficiency indexed development for appliances in Denmark, 2005-2014 [13]



Further analysis using the average consumption of the same new appliances sold in Denmark (see Table 15) results in slightly lower efficiency improvements due to the impact of larger equipment and more features; however, the reductions observed are still significant, ranging from 1.7 to 8 per cent per annum (Figure 21).

Table 15: Average energy consumption (kWh/year) of products sold in Denmark, 2005-2014 [13]

PRODUCT	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	ANNUAL REDUCTION
Refrigerator/freezer	256	251	244	250	245	241	237	232	221	218	1.66%
Washing machine	201	206	208	207	212	213	201	178	162	163	2.12%
Television	347	386	380	390	365	336	273	194	111	98	7.96%

Figure 21: Indexed annual average new consumption (base year 2005) for appliances sold in Denmark, 2005-2014 [13]